

Evaluating Automated Anti-Icing Technology to Reduce Traffic Collisions

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Abstract

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Reducing fatalities, injuries, and property damage related to traffic collisions is a priority for road safety agencies. Traffic collisions result in more than 2,200 fatalities and 173,000 injuries each year on Canadian roads. Inclement weather is a contributing factor in traffic crashes for approximately 21 percent of the injuries and 25 percent of property damage [1]. Costs related to traffic collision damage are relatively high especially if fatalities occur, and the closure of lanes and the resultant traffic delays substantially add to these costs. Efficient tools are available to road agencies to reduce traffic collisions related to inclement weather.

This paper explores the relationship between road collisions and surface conditions and illustrates the successful implementation of automated anti-icing technology to reduce vehicle collisions due to weather and surface factors. Fixed Automated Spray Technology (FAST) deployments in Ontario, Utah, and Pennsylvania are specifically examined in this paper.

Road surface condition sensors, automatic notification alerts, and automated anti-icing spray systems are also examined in this paper. Automated anti-icing systems minimize the amount of chemical needed for de-icing by spraying the road in advance of icing and only when required. These technologies help maintenance managers to reduce traffic collisions and fatalities and make more timely and efficient decisions.

Introduction

Nearly 24% of weather related crashes are directly related to adverse winter weather [See Table 1]. In addition, weather related crashes make-up 21% of all injuries and 25% of all property damage, including 2,200 [1] and 7,400 [2] fatalities annually across Canada and the U.S., respectively. This problem not only affects those parties directly involved, but creates significant impacts to all users and maintenance agencies as well as sizeable economic impacts. One direct economic impact is Commercial Vehicle Hour loss that is estimated at \$2.2 to \$3.5 billion dollars, annually in the U.S due to weather related traffic incidents [3]. In recent history, transportation agencies across North America have begun to develop and implement means and methods to battle weather related crashes, especially in adverse winter weather conditions, by exploring concepts and preventative measures such as Anti-Icing. Anti-icing is a shift in methodology from traditional De-Icing. De-icing is a reactive process that uses chemical means to break the bond of snow or ice with pavement once formed. In other words, De-icing requires and implies that ice is already present by definition, which makes the bond more difficult to remove.

The Insurance Corporation of British Columbia defines Anti-icing as: a proactive practice of applying chemicals early enough to prevent snow or ice from bonding to the road surface. [4] The Federal Highway Administration (FHWA) defines Anti-Icing as: 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. [5] It is evident that Anti-Icing is an accepted practice across North America. According to the Kentucky Transportation Cabinet, “Preventing the bond is three times more efficient than breaking the bond between frozen precipitation and the pavement.” [6] Anti-Icing can be accomplished by many different methods, including fixed asset and mobile asset technologies. Fixed asset technology is the primary focus of this paper; however similarities with mobile asset technology will be discussed.

Mobile Anti-Icing technology is becoming a primary focus of agencies that adopt Anti-Icing strategies. It is a widely accepted and effective practice used by many agencies to combat the effects of adverse weather, and provide a primary line of defense for winter maintenance. Mobile Anti-Icing is typically accomplished by decision makers analyzing forecast data to determine when an adverse weather event will begin affecting roads, then dispatching mobile assets to apply Anti-Icing chemical prior to the event. Mobile assets generally are tanker-equipped trucks with specialized spray equipment to deliver a liquid agent to the roadway.

Fixed Automated Spray Technology, or FAST, is a specific method of performing Anti-Icing operations. FAST systems combine atmospheric and pavement data from a Road Weather Information System (RWIS) or Environmental Sensor Station (ESS) with an electro-mechanical means of delivering Anti-Icing chemical to the pavement surface in a timely manner to prevent the bond of snow and/or ice with the pavement surface. FAST systems are activated based on the analysis of real-time data including active measurements of the pavement surface and freezing point temperatures of any liquid that may be present. These systems are designed for and target specific areas. According to the Kentucky Transportation Center, these factors are: (1) crash prone areas;

(2) isolated structures that require the de-icing truck to travel an unreasonable distance to treat; (3) remote areas that are difficult to reach in bad weather; or (4) bridges over water which may be more susceptible to freezing moisture (3). [6] In addition to these, other agencies also consider: high traffic areas; local micro-climates (low-lying, high-humidity); Roadway/Bridge geometry (grade, superelevation); empirical evidence of persistent icing conditions; and constant shading.

This paper evaluates the impact of weather related traffic crashes, the history of FAST systems, current available technology, and experience to demonstrate the overall effectiveness of FAST to reduce weather related traffic crashes.

Impacts of Weather Related Traffic Crashes

Agencies generally perform and report crash statistics and the economic impact that these crashes impose on the public whether economic or societal. These studies are used to target areas needing improvement to make North America's transportation system better, faster, and safer.

In 2004, the total social cost of all vehicle collisions in Ontario was \$17.9 billion. Traffic fatalities accounted for less than 1% of the total vehicle collisions. However, 64% or \$11.9 billion of the total cost was attributed these fatalities. [7] Furthermore, according to the Pennsylvania Department of Transportation (PennDOT), the sum of all traffic crashes cost \$14.4 billion in 2011. [8] The statistics also show that traffic crashes due only to icy conditions (3.8%) cost \$547 million of economic loss in Pennsylvania alone. [8]

If generally applied to the more than 9,600 weather related traffic fatalities [1] [2] across Canada and the United States, the costs (using 2011 Pennsylvania Data -\$6 million per fatality) exceed \$56 billion dollars. This statistic coupled with the fact that maintaining agencies spend in excess of \$5 billion for repairs needed due to snow and ice control damage [9] is a true burden on the economy.

Moreover, Highway "Loss of Use" impacts compound the effect of weather related traffic congestion and crashes. It is estimated that for Commercial Vehicle Operators (CVO) in the United States, these weather related incidents cause the loss of 32.6 billion vehicle hours [3]. Again, this contributes to CVO losses estimated between \$2.2 and \$3.5 billion dollars annually. This impact has additional and un-measured consequences both on micro and macro economies. Many societal impacts should be considered, as well, including employee delays, added stress, and loss of confidence in transportation agencies. In summary from the information above, the estimated total impact from traffic fatalities, repair and loss of use can range from \$63.2 to \$64.5 billion dollars annually due to weather related road conditions.

History of FAST

FAST technology was originally developed in Europe and the first systems were installed in Germany and Switzerland in the mid-1980's. The first systems used both manual and automated activation methods. The first German system was estimated to have a benefit-cost ratio of 1.9, and the Swiss system a ratio of 1.45. FAST was considered a proven technology in Europe as opposed to North America. [10]

The first North American FAST pilot systems were installed by various transportation agencies in the late 1990's. The following are summaries of selected early studies. For clarification, systems referenced as "commercial" were sourced on the open market; systems referenced as "home-built" were systems designed and produced by the credited agency.

The Virginia Department of Transportation (VDOT) installed a commercial system on a 30 foot wide bridge in Fairfax County, VA in 1998. The system included both parapet and in-pavement nozzles, with surface sensors and an ESS. [10] From this study, the research concluded that FAST was considered effective for chemical delivery to road surface; deployed sensors did not differentiate road surface condition other than "dry" or "not dry;" the system could not differentiate between a range of chemicals; the research could not complete benefit-cost ratio study due to lack of data; and preventative maintenance is key to successful operation. [11]

The Kentucky Transportation Cabinet (KYTC) installed a commercial system on a similar structure to the bridge in Virginia in 1997. System included parapet/rail mounted delivery and was controlled by manual activation (dial-up) only and used a traffic camera and nearby RWIS information. [10] From this study the research found that the system encountered problems in the initial season 1998-1999; upgrades/repairs were required; the system was efficient and operated as intended; more information/upgrade was required for automated operation; due to the site "not receiving an abundant amount of precipitation, the system was not as efficient as anticipated." [6]

The Minnesota Department of Transportation (Mn/DOT) installed and analyzed a commercial system on a 2000 foot long structure over the Mississippi River in Minneapolis in 1999. The system included in-pavement delivery and was fully automated with an ESS. The site was selected based on location and the following contributing factors: close proximity to a power plant and moisture rich smoke, exhaust condensate from slowed vehicles during congestion, and location over the Mississippi river. The analysis showed the FAST system contributed to a 68% reduction in winter related accidents. The benefit-cost ratio of the system was estimated at 3.4. The report concluded that the system functioned as intended but outlined various problems with the system operation. [10]

The Utah Department of Transportation (UDOT) in conjunction with the University of Utah designed and installed a home-built anti-and de-icing system on the Northbound I-215 at Knudsen's Corner and analyzed the system from 1997 to 1998. The Southbound I-215 structure was not

modified for the purpose of control. The system included parapet mounted delivery with automatic and manual activations. This site was selected based on the following: bridge geometry that includes a curve, high traffic volume, and precipitation frequency. The analysis showed a reduction of at least 30% weather related traffic crashes, and had favorable pavement level-of-service improvements. [12]

The studies that analyzed the first North American anti-icing systems have produced significant data, evaluations, challenges, and suggestions. From the research outlined above, it can be concluded there are recurring keys to success. First, adherence to site selection criteria is critical to maximizing the benefit of a FAST system. As shown in the KYTC study, the benefit was reduced because of the lack of weather of the selected site. In addition the Mn/DOT and UDOT studies reinforced proper site selection by achieving significant accident reduction as well as high benefit-cost ratio estimates. Second, accurate atmospheric and pavement data including active pavement sensor technology are imperative to the successful automation of a FAST system. As shown in the VDOT study, the lack of accurate pavement sensing, the inability to differentiate between various pavement conditions, and dependence on chemical type for accurate freeze point temperatures, severely reduced the effectiveness of the automatic operation of the system.

Further to the above conclusions, surveys of maintenance agencies have revealed the following as possible improvements: reduced cost; simplified installation and reduced maintenance needs; improved system reliability and sensor accuracy and reliability as well as the activation logic; complete automation and better detection of road conditions; user-friendly interfaces; better integration with RWIS, traffic cameras, weather forecasts and other tools. [10] Certain topics referenced as key improvement areas have been developed and implemented into the currently available technology.

Current Capabilities

As indicated previously, early studies of FAST systems produced challenges and suggestions to refine the capabilities. The evolution of technology has advanced since the referenced studies. The largest advancement is in pavement sensor technology. Current pavement sensors now combine passive and active technology to provide the information suggested by these studies.

The passive type pavement sensors have been refined to now show data concerning the pavement surface. These sensors are able to measure the temperature at the pavement surface level; provide differentiation of road state, for example: dry, wet, ice, snow, frost; measure the water film thickness of the solution on the pavement surface; and in some cases provide an accurate chemical concentration and residual chemical.

Additional refinements of this technology now provide sensors developed to use active technology that accurately measures the surface freezing point. This technology uses an active process to cool the surface up to 15°C below the current surface temperature and measures the freezing point of the solution present on the pavement. This measurement is performed at a high degree of accuracy (-

15°C-0°C +/- 0.5°C), is independent of the chemical type and concentration, and is environmentally hardened to withstand the applications of high traffic stress. This active measurement allows for the early detection and warning of the possibility of ice before the ice forms on the pavement surface.

The early detection capability of these sensors is critical to making a FAST system fully automated and able to truly perform Anti-Icing. In referencing the definition of Anti-Icing, the chemical must be applied prior to any bond forming between snow and ice and the pavement surface. Therefore, to accurately categorize a FAST system as an Anti-Icing system, the system must be able to actively measure the surface freeze point. Moreover, this capability has allowed for FAST systems to be operated autonomously and independent of user intervention in day to day operations. By being fully automated, the user/operator of the system is not required to continually monitor the current conditions and remotely activate the systems.

Also included in the surveyed topics for improvement, the responding agencies sought further definition of the activation logic used by the FAST systems to reduce the number of instances where FAST systems were activated where not warranted by conditions. [10] In commercially available systems, algorithms in the FAST system define the points of activation when certain criteria are met for each mode of adverse condition. These algorithms use data from the ESS station as well as the pavement temperature, state, and freeze point measurements as reported by the active pavement sensors.

While technological advancements have improved the capabilities of FAST systems recently, this application has expanded beyond FAST, and has also allowed the data and technology to be applied in other areas of ITS (Intelligent Transportation Systems). For example, ice detection can be integrated into both passive and active ITS applications. The sensors can be integrated with traffic volume, classification, and weigh-in-motion (WIM) systems. The information from the ice detection sensors can provide additional insight into traffic data. Another ITS application is the deployment of ice detection sensors (and potentially anti-icing spray technology) into Rollover and Downhill Vehicle Warning Systems. Rollover and Downhill Warning Systems provide drivers with a visual warning that they are in danger of rolling over on a sharp curve/ramp or are going too fast down a steep incline. The ice detection sensors provide the additional capability for these systems to display a warning message for slippery conditions. These ITS Systems can also be integrated with the anti-icing spray systems for active treatment of slippery surfaces.

The information can be provided to maintenance agencies and allows for the integration into Maintenance Decision Support Systems (MDSS). MDSS is another tool that has been developed and is being integrated by maintenance agencies. The number of MDSS systems being used by maintenance agencies has increased from 0 to 35 States from 2004 to 2008. SEE TABLE 2. [13] The information provided can be applied to localized areas outside of the footprint of the FAST system to allow decision makers to allocate resources more efficiently based on real-time data as well as enhancing forecasting capabilities for these agencies.

Significant improvements in functionality, information, and reliability have been made to promote the safety of roadways and reduce the impact of weather related crashes. These advancements are also contributing to the maintenance agencies success in reducing costs and labor commitment. By following strict site selection criteria for FAST system implementation, agencies are able to reduce costs by not having to dispatch equipment and manpower to remote locations to spot-treat in situations that the FAST system would otherwise mitigate with an amount of chemical appropriate for the situation. This translates into savings of costs for travel, equipment use, and excess chemical. Second, as discussed previously, Mobile Anti-icing is a canvassing strategy generally applied in anticipation of icing conditions based on forecasting. While effective in its appropriate application such as high-impact high-probability events (large snow storms), mobile anti-icing in certain instances may apply unnecessary chemical if forecasted weather does not materialize, especially on lower-impact events such as localized or “scattered” conditions. Again, this reinforces that FAST can increase the overall efficiency of Anti-icing operations as a complement to Mobile Anti-Icing.

Experience

The following are summarized case studies of FAST system installations that have shown positive improvements at the respective sites including weather related traffic crash reduction and positive benefit-cost ratio.

Ministry of Transportation of Ontario – 401/416 Ramp Bridge – Prescott, ON

In 2000, the Ministry of Transportation of Ontario (MTO) selected the Highway 401/416 ramp structure near Prescott, ON for FAST system application. The structure is 165 metres long, 11.2 meters wide with a 4.7 meter traveled lane with a design speed of 130km/h and Average Annual Daily Traffic (AADT) of 3000 vehicles. The traveling surface is paved on a superelevated curve. The bridge was selected by applying site selection criteria of: history of accidents; localized micro-climate due to the proximity to the St. Lawrence River, lake-effect snow events, high moisture wind; high traffic; distance from nearest maintenance facility; and bridge geometry. The structure was completed in 1998. During the first winter season, the structure experienced 14 weather related crashes. [14] [15] SEE FIGURES 1-3.

Environment Canada undertook a study on the impacts of the FAST system. It is reported that the first season following the operation of the system, no weather related traffic crashes had occurred. [15] This is a 100% reduction in crashes over the first season. In reviewing the benefit-cost ratio of the system, the final estimated result is 1.13. [15] SEE CHART 3.

The study also contained information on the reduced environmental impacts as a result of the FAST system installation. MTO had instructed the maintenance contractor to cease the use of chloride salt on the ramp as a result of the success of the system. [14] This shift in methodology has several positive consequences. Notwithstanding the environmental impact of chlorides, it is estimated that \$10,669 per year will be saved on repairs to the structure as a result of corrosion. [15]

Utah Department of Transportation – I-215 Knudsen’s Corner Bridge – Salt Lake City, UT

This paper previously examined a home-built pilot FAST system installed by UDOT on the I-215 Knudsen Corner Bridge. The results of the previous study engaged UDOT to install a fully automated system on both the Northbound and Southbound structures. The commercial system installed was selected based on the requirement from UDOT that it would be fully automated using Active and Passive pavement sensor technology. [16]

After the installation of the system on the bridge, the local maintenance department reported that there had not been a single weather related crash on the structure. As described, “...this may be the best indicator that the system is working.” [16] For various reasons, this report did not provide a definitive benefit-cost.

UDOT recommended that the department should continue to install systems. Further, the report recommends that the systems be Anti-icing and not De-icing technology. [16]

Pennsylvania Department of Transportation – I-80 Anderson Creek Bridge – Clearfield County, PA

PennDOT identified the bridge carrying I-80 over Anderson Creek Road and Anderson Creek in Clearfield County, Pennsylvania as a candidate for a FAST Anti-Icing system as a result of high traffic crashes and persistent icing conditions. The twin structures are at the low point of a valley and long grades of Interstate 80. The normal operating speed limit in the area is 65 mph. [17]

In a statement from PennDOT District 2-0, the effect of the Anti-Icing system installed on the structures is classified as:

“Safety Benefits

Prior to the installation of the Anderson Creek Bridge Anti / De-Icing System, there were 21 crashes on the bridge from 1995 to 2002 (average of 2.63 crashes per year). Since the Anderson Creek Bridge Anti / De-Icing System was installed in the Spring 2002, there have been five (5) crashes on the bridge from 2003 to 2010 (average of 0.63 crashes per year). Therefore, the system installation resulted in a reduction of crashes from an average of **2.63 crashes per year** to **0.63 crashes per year** on the bridge.” [17]

Based on the experience above, the referenced agencies have installed subsequent FAST systems. MTO has installed six additional systems, UTAH has installed four additional systems, and PennDOT has installed 12 additional systems. Furthermore, the Province of Alberta has recently installed two FAST systems. These systems are still under contract and Alberta Transportation is evaluating their performance.

Conclusion

The information contained in this paper has shown that weather related traffic crashes are a severe problem facing North America's transportation system. With these crashes come a host of issues including economic shock such as crash and delay costs as well as societal impacts such as added stress and decreased confidence in transportation agencies. Fixed Automated Spray Technology Anti-Icing systems are a viable tool to reducing weather related traffic crashes.

The technology has been regarded as a proven solution throughout Europe for many years. As demonstrated, North American transportation agencies have extensively researched FAST systems. This research has produced consistent results, indicating that FAST systems are effective when selected using the proper application methodology. The critical factors to applying FAST include: use of proven site selection criteria; active sensor technology to perform freeze point detection; and full automation of the system. Also proven, critical components that the industry has determined to be useful have been delivered and are available on the open market by several vendors.

There are certain challenges that transportation agencies are faced with in implementing technologies such as FAST Anti-Icing systems. The largest challenge is future planning and budgeting for FAST systems. In using past research and considering current capabilities of the technology, agencies can show that the benefits will serve as proper and influential justification for the cost of installing these systems. Furthermore, FAST systems' merits do not come without burden. Although the technology has been refined to withstand the outdoor environments and constant exposure to traffic, maintenance is ultimately required. FAST systems require an involved preventative and proactive maintenance and training program. By embracing this fact and remaining engaged, the maintaining agencies will continue to realize the full potential and benefits of the FAST Anti-icing systems. Ultimately, to reduce weather related traffic crashes and provide a better, faster and safer transportation system.

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Tables

Table 1 – Weather Related Crash Statistics [3]

Table: Weather-Related Crash Statistics (Annual Averages)				
Road Conditions	Weather	Weather-Related Crash Statistics		
		Annual (Approximately)	Rates	Percentages
Wet Pavement		1,128,000 crashes	18% of vehicle crashes	75% of weather-related crashes
		507,900 persons injured	17% of crash injuries	81% of weather-related crash injuries
		5,500 persons killed	13% of crash fatalities	77% of weather-related crash fatalities
Rain		707,000 crashes	11% of vehicle crashes	47% of weather-related crashes
		330,200 persons injured	11% of crash injuries	52% of weather-related crash injuries
		3,300 persons killed	8% of crash fatalities	46% of weather-related crash fatalities
Snow/Sleet		225,000 crashes	4% of vehicle crashes	15% of weather-related crashes
		70,900 persons injured	2% of crash injuries	11% of weather-related crash injuries
		870 persons killed	2% of crash fatalities	12% of weather-related crash fatalities
Icy Pavement		190,100 crashes	3% of vehicle crashes	13% of weather-related crashes
		62,700 persons injured	2% of crash injuries	10% of weather-related crash injuries
		680 persons killed	2% of crash fatalities	10% of weather-related crash fatalities
Snow/Slushy Pavement		168,300 crashes	3% of vehicle crashes	11% of weather-related crashes
		47,700 persons injured	2% of crash injuries	8% of weather-related crash injuries
		620 persons killed	1% of crash fatalities	9% of weather-related crash fatalities
Fog		38,000 crashes	1% of vehicle crashes	3% of weather-related crashes
		15,600 persons injured	1% of crash injuries	2% of weather-related crash injuries
		600 persons killed	1% of crash fatalities	8% of weather-related crash fatalities
Weather-Related *		1,511,200 crashes	24% of vehicle crashes	
		629,300 persons injured	21% of crash injuries	
		7,130 persons killed	17% of crash fatalities	

Table 2 – United States Transportation Agency MDSS Usage [12]

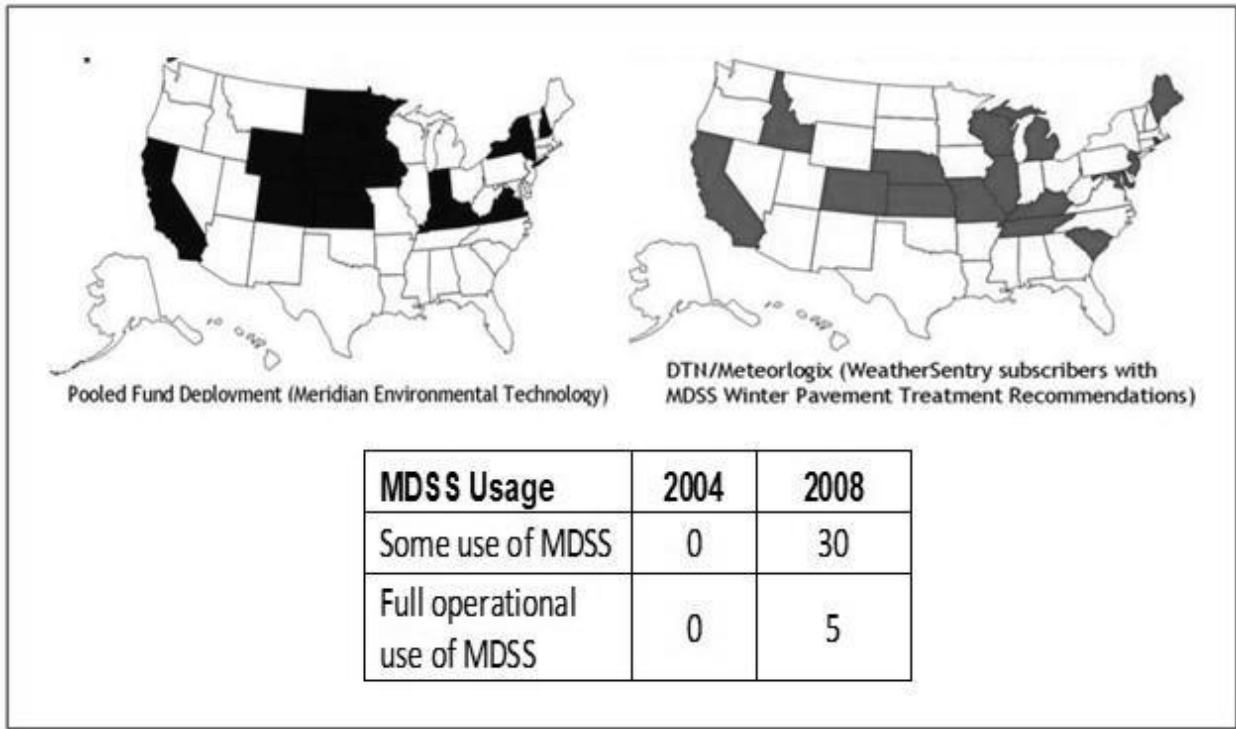


Table 3 – Benefit Cost Demonstration, 401/416 Ramp, Prescott, ON [14]

Costs	
Design, Construction, Commissioning	\$300,000
Operating	\$30,000
Total Costs	\$330,000

Benefits	
Collision Avoidance	\$165,600
Reduced Corrosion	\$10,666
Reduced Travel Delays	\$198,072
Total Benefits	\$374,338

Figures

Figure 1 - View of pavement surface with Spray Disk and Pavement Sensor—401/416 Ramp, Prescott, ON.



Photo Courtesy of Boschung America, LLC

Figure 2 – Side view of 401/416 Ramp.



Photo Courtesy of Boschung America, LLC

Figure 3 - View of FAST Hydraulic (near) and RWIS station (far) - 401/416 Ramp, Prescott, ON.



Photo courtesy of Boschung America, LLC

Figure 4 – View of the I-215 Knudsen’s Corner Bridge.



Photo courtesy of Boschung America, LLC

Figure 5 - Side view of the I-215 Knudsen’s Corner Bridge.



Photo courtesy of Boschung America, LLC