In the past two decades or so, anti-icing has been gradually adopted by North American highway agencies as a proactive approach to addressing winter driving safety.

Fixed automated spray technology (FAST) systems are designed as a fixed-asset technology for anti-icing at specific target areas, such as bridges, tunnels, ramps and other elevated roadways. They remotely sense the potential for frost or ice formation on pavement in light of atmospheric and pavement data from a road weather information system (RWIS) or an environmental sensor system (ESS) and apply chemical freezing-point depressant in a timely manner.

FAST systems have emerged as an important way to supplement mobile winter-maintenance operations by enabling winter-maintenance personnel to treat selected locations before snow and ice problems arise. A recent study by the Western Transportation Institute determined the cost effectiveness of all the existing FAST systems for the Colorado Department of Transportation (CDOT). Components of the study included a literature review, a national survey, a CDOT survey and a safety analysis.

The literature review revealed considerable knowledge of and experience with FAST systems. Documented experience with FAST systems in North America and Europe has revealed a mixed picture. On the one hand, several studies have indicated reductions in mobile-operations costs and significant reductions in crash frequency, resulting in favorable benefit-cost ratios. On the other hand, there has been a variety of problems related to activation, system maintenance and training. Recently the application of FAST systems has increased in North America.

Installing a FAST system is complex, and the challenges are often site-specific. Difficulties can be expected during operations, particularly in areas related to software, activation processes...
Roads and pumping systems. However, the existing studies show that FAST systems can be cost-beneficial if their locations are carefully chosen and if the systems are supported with reliable environmental sensors. Although there are a number of studies that reported on the successes and failures of FAST design, planning, installation, operation and maintenance, very few studies have involved a formal benefit-cost analysis of FAST systems due to the lack of experience and well-documented data. As more FAST systems are installed to reduce weather-related traffic accidents and to maintain a high level of service on winter roadways, more studies on benefit-cost analysis supported by relevant data are recommended to help agencies maximize their return on investment.

### How does it work?

The national survey had 25 respondents, with two from Canada and one from the United Kingdom and the rest from the U.S., representing agencies from 12 different states (Alaska, Illinois, Kansas, Kentucky, Montana, New Hampshire, New York, North Dakota, Pennsylvania, Maine, Wyoming and Wisconsin) and one vendor from California. The survey documented the use of currently available systems and highlighted the successes and lessons learned from FAST practitioners. A few key points are as follows:

- Almost every installed FAST system (reported in this survey) needed significant maintenance activities for its successful operation. In some cases, a FAST system failed to operate even after repeated maintenance activity;
- Initial cost of a FAST system is significantly higher than the annual operating and maintenance costs. However, respondents believe the payback period could be as short as one year for a properly functioning FAST system; and
- The benefits of using FAST perceived by the agencies include reduction of winter-related accidents, savings on material use and labor and reduction of negative environmental impacts.

### Exact locations

The CDOT survey involved personnel who use FAST systems, and a field trip was conducted to observe selected sites that use the technology. Inconsistency in proper functioning of FAST systems among various CDOT regions is mostly due to poor design, poor quality of installation and lack of maintenance practices for some cases.

Location selection is an important factor for the success of a FAST system. Further, FAST systems may not be of benefit for some types of bridges. Short-span bridges (span length less than 50 ft) located in a straight lane with high traffic volume do not necessarily need a FAST system. This is due to the fact that incoming traffic can bring brine/abrasive with their tires, which treats most of the bridge surface. However, a FAST system can be beneficial to short-span bridges if there is an intersection and/or traffic signal at the end of the bridge.

Respondents prefer to install FAST systems on long-span bridges that have significant slopes and curves. In addition, respondents suggest accident-prone areas as another location to install FAST systems. A tunnel exit could be an example of an accident-prone zone. During slippery road conditions, drivers tend to drive slowly while they approach a tunnel. Once they hit the tunnel, drivers tend to increase their speed due to better road conditions inside the tunnel. However, when they exit from the tunnel, drivers tend to maintain the same speed without realizing the slippery road conditions outside the tunnel. Vehicles exiting tunnels at relatively high speed (during slippery conditions outside tunnels) are more prone to accidents, especially if the exit from the tunnel is a bridge on a sharp horizontal curve.

Involving maintenance crews in every aspect of design, installation and operation of FAST systems could help reduce the maintenance issues. This is due to the fact that maintenance crews tend to have a better knowledge of the locations that are selected for a FAST system. For example, the information from a maintenance crew about the ease of accessibility to various structures within the bridge could be helpful in selecting a location to install valve systems. Installing a valve system in an appropriate location may well help the maintenance crew to perform a mainte-
There are a number of considerations in FAST design. Survey respondents suggest installing side rails near the shoulder of asphalt pavement if side rails are not already in place and having strong and thick outer walls for nozzles to withstand stress induced by the vehicle.

that it is not difficult to access during a heavy snowstorm. Efforts to cut costs during installation will only come back as high maintenance costs in the future.

There are a number of considerations in FAST design as well. Maintenance crews expressed their concern about the clogged nozzles, which prevent the system from functioning. Selecting proper locations to mount spray nozzles may help to reduce the clogging problem. Mounting on the side rail or side wall was the most preferable choice because of easy access to nozzles, no clogging from abrasives and less damage to nozzles.

However, in some scenarios mounting on the shoulder or between lanes is unavoidable. In particular, a bridge that has four or more lanes needs spray nozzles mounted on the shoulder or between lanes so that deicers can reach all lanes. Also, if the side rail or side walls are far away from the lanes, then nozzles may have to be mounted on the shoulder or between lanes.

Respondents prefer plastic nozzles to avoid the corrosion issue. Spray nozzles mounted in the asphalt pavement could get buried due to the melting of asphalt pavement during warm weather.

Respondents also suggest installing side rails near the shoulder of asphalt pavement if side rails are not already in place and having strong and thick outer walls for nozzles to withstand stress induced by the vehicle. Furthermore, the pattern of nozzles should be designed in such a way that it is sufficient to provide chemical coverage to the whole structure. Finally, the nozzle design should be improved for easy removal and maintenance.

Valves are another important part of the FAST system; they open automatically to shoot deicers at the prescribed settings. Most respondents in Colorado recommend changing from solenoid valves to motorized ball valves. Further, location of valves should be carefully selected to ensure easy access for maintenance. The respondents also prefer using stainless steel, polypropylene, nylon 12, rubber hose and schedule 80 PVC (instead of brass) for the pipe lines.

The maintenance crews strongly recommend having a fluid tank that can store enough chemicals so that it does not need to be refilled too often. In particular, they prefer a fluid tank with a minimum capacity of 1,000 gal. Respondents also suggest having aboveground storage facilities for a fluid reservoir, a fluid pump and associated components, instead of an underground vault. The malfunctioning of the fluid pump may occur due to electrical issues and thus require periodic maintenance. Finally, the triggering mechanism is another important component for the successful operation of a FAST system.

All respondents prefer a fully automated system that can be triggered by a computer with web-based PC software. The input for the trigger mechanism is provided by the pavement sensors. Respondents prefer using “noninvasive” sensors—sensor technology that is not embedded in the pavement. Respondents emphasize locating the noninvasive sensors on the center of a bridge instead of on the entry or exit of a bridge. The center of a bridge provides a better representation of the actual prevailing conditions on the bridge.

To improve the user acceptance of this type of technology, the key is to integrate cost-effective technologies that reliably detect relevant changes in pavement surface conditions. Some advances in the use of roadside sensor technologies for road condition monitoring have been seen in recent years. As such, FAST systems may become a valuable tool for transportation agencies engaged in winter operations, as they can complement or reduce the number of mobile winter applications and the amount of materials required.

Taking some crunch out of crashes

The research team employed accident-prediction models to estimate the number of crashes before and after FAST deployment, in order to better quantify the impacts the systems had on crashes. The analysis examined safety effects of the CDOT FAST systems deployed at different locations for various types of highways. An observational before-and-after study with empirical Bayes technique was employed to determine the effect of FAST systems on crash frequencies. The deployment of FAST systems contributed to a reduction in the number of annual crashes on multilane rural highways by 2%, urban interstates by 16-70%, rural interstates by 31-57% and interchange ramps between interstates by 19-40%.

Furthermore, a crash-rate method was used to investigate the effect of different FAST deployments on crash severities, with a focus on winter-weather-related
accidents. The use of FAST systems has reduced crash severities at many sites. As a result, the systems examined have potentially provided safety benefits of $196,428 per winter season during the after-deployment study period. This figure does not account for sites where no winter weather crashes had occurred during the before or after periods, as crash rates could not be established for them.

When choosing future deployment locations in light of safety, a number of points should be considered. It is unclear if FAST systems deployed on rural two-lane roads have any significant effect on improving safety. Some of the results from this work indicate that safety may have deteriorated, although these sites experienced low crash numbers, and the occurrence of even one winter-weather crash could give the appearance of deteriorated safety after installation. In light of this, FAST may be better applied on higher-traffic roads when the intent is largely to prevent or reduce crashes. If maintenance concerns are paramount (e.g., need for quicker response time), then FAST installations may provide an advantage on a two-lane road.

On rural, multilane, divided highways, the deployment of a FAST system appears to have produced a small improvement in safety and would likely produce a comparable result when applied in similar locations. Urban-interstate applications of FAST systems produced the most positive results, with crash reductions of between 16% and 70% observed. While the FAST systems alone did not account for these reductions, they likely played a large role. Consequently, it can be concluded that high-volume urban interstates are likely the best sites for FAST deployments, given that the benefits of the system reach the largest number of vehicles.

Rural-interstate FAST deployments showed effectiveness in reducing crashes in some cases, but also indicated increases (some large) in crashes at other locations. Some of these increases were at sites that were later decommissioned, which may indicate that maintenance problems during the course of the deployment itself limited the effectiveness of the system. However, given the extra time and long distances required to perform maintenance at rural-interstate sites, FAST systems may provide safety benefits, if they are maintained in a suitable operating condition throughout the winter season.

Finally, FAST deployments on interchange ramps between interstates produced encouraging results, with crash reductions found for two of three locations. However, future deployments on interchange ramps should be limited to those that serve high traffic volumes, as was the case with the systems evaluated in this work.

Shi is senior research scientist at the Western Transportation Institute and a research professor at Montana State University. Muthumani is a research associate, Winter Maintenance & Effects Program, at the Western Transportation Institute. Veneziano is a research scientist, Safety and Operations Program, at the Western Transportation Institute.

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