The severity of it

Group establishes framework to work with tight budgets

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$2,696 per lane-mile.

That is how much the Wisconsin Department of Transportation spent on snow removal, deicing and other winter-maintenance activities in the 2010-11 winter season. This cost reflects how formidable a task winter maintenance is in states with snowy climates; in Wisconsin alone it took more than 573,000 tons of salt and 352,000 hours of labor to maintain state-owned roadways that winter. In many northern states, winter maintenance accounts for almost half of annual maintenance budgets, and the Federal Highway Administration estimates that state and local agencies nationwide spend more than $2.3 billion a year to control snow and ice.

"About 35 to 45% of our annual maintenance budget is winter maintenance," said Tim Croze, region support engineer at the Michigan Department of Transportation. "In some areas, it's as high as 60 to 70%."

In an era of budgetary belt tightening, maintenance budgets are generally declining even as costs increase, and transportation agencies are under constant pressure to justify their budgets or find ways to reduce them by increasing the efficiency of winter-maintenance operations.

At the same time, budget needs for winter maintenance are as unpredictable as the weather. Agencies generally plan for an average winter and then hope for the best. But if the winter turns out to be more severe than average, agencies may find themselves needing to make the case for more money.

Working the numbers

To effectively defend a requested budget, an agency needs to quantify the performance of winter-maintenance operations, establishing what the agency gets for its money in terms of lane-miles cleared and other metrics. And agencies need an objective way to identify efficient practices, evaluate the relative costs of different strategies and compare expenditures from one storm, year and region to another. Ultimately, this would help them both to justify budgets and to develop policies that save money.

To facilitate apples-to-apples comparisons across time frames with varying weather conditions, many agencies use a winter-severity index—a tool that assigns a number to winter-weather severity based on the factors expected to affect maintenance expenditures, such as snowfall and freezing rain. These numbers can show that an agency that keeps its winter-maintenance expenditures the same even as the winter-severity index increases is improving the efficiency of its winter-maintenance operations. Or they might show that a slight drop in expenditures from one year to the next actually means reduced efficiency, if the index shows that a mild winter has followed a much harsher one.

A severity index gives an agency a framework to evaluate whether expenses are in line with the actual conditions experienced, helping justify budgets as well as identify opportunities to improve efficiency. However, agencies' ability to compare their operations against those of their peers has long been limited by the fact that each agency's index draws from its own unique weather-data resources.

To address this issue, a group of winter-maintenance professionals set out to develop a framework for comparing winter severity across agency boundaries. Through the national Clear Roads winter-maintenance research consortium (www.clearroads.org), state departments of transportation from around the country leveraged their resources to address this shared data challenge with a recently completed research project, Mapping Weather Severity Zones. The result is a collection of maps and data resources that allow visualization and analysis of typical winter severity for geographical zones across the U.S.

In developing these winter-severity maps, researchers at Iteris consulted with representatives of state departments of transportation to select indicators of weather severity based on how they affect winter-maintenance costs. The winter-severity index they developed includes obvious factors, such as snowfall amount, but also indicators more difficult to quantify, such as the occurrence of blowing and drifting snow, which can dramatically increase the difficulty of snow-removal operations.

"Even when there is no measurable snowfall, a road may require replowing because wind has blown snow right back onto it," Croze said.

Also important is the duration of snowfall.

"A light snowfall can be labor-intensive for maintenance staff if it is drawn out, because it requires that crews spend a longer amount of time fighting it," said John Mewes, chief scientist at Meridian Environmental Technology (a business unit of Iteris Inc.) and principal investigator for the Clear Roads project.

Consequently, the parameters researchers chose for the project's winter-severity index include annual averages for the duration of snowfall and blowing and drifting snow. They also include annual averages for snow accumulation and the duration of freezing rain.

"Freezing rain is notoriously difficult to take care of and a costly problem for DOTs," Mewes said. "It requires far more salt to address freezing rain than snow, where much of the moisture can be mechanically removed with the plow blade."

Excluded from the index were factors that seem plausible at first glance but turn out not to be suitable for a weather-severity index, such as the number of snowstorms in a season. That is because different storms may have very different maintenance implications, and the boundaries between distinct storms can be vague. The duration of storms is a much better indicator of the effort an agency will have to spend on winter maintenance, Mewes said.

Meteorologically realistic

Quantifying winter severity consistently across all states presented some challenges, including a lack of reliable data that has traditionally hampered winter-severity indexes. For example, meteorological data from most weather stations operated by the National Weather Service and Federal Aviation Administration—chosen for consistency nationwide—do not contain reliable records of snowfall amounts.

"Measuring snowfall is notoriously difficult, and we don't get good measurements of snowfall from automated stations," Mewes said. "Measuring depth may require that personnel use rulers at various locations to factor out the effects of snowdrifts." Automated stations also lack data on the rate of snowfall and information on blowing and drifting snow.

To add to these challenges, in some areas National Weather Service stations are too sparsely located to provide enough data to reliably establish multiple severity zones within one state. And weather stations in general have biases that are often much stronger than the underlying variations in weather conditions from one location to the next.

"One surprising outcome of the study was the finding that there are often bigger variations between two weather stations on the opposite side of a town than there are between two stations hundreds of miles away," Mewes said.

To overcome these challenges, researchers opted to leverage historical output from computer weather models. These models provide a better representation of where and when weather conditions vary and offer "the most meteorologically realistic picture of the true nature of variability in winter-weather conditions across the country," Mewes said.

"By averaging a decade of data, we get the noise of individual storm-to-storm errors to wash out," he said. "And so we get a good sense of the relative severity of conditions between locations."

This model data was then loosely fitted to aggregate observations from weather stations in order to ensure the weather data underlying the project was grounded in reality. The researchers used a suite of algorithms to derive hour-by-hour estimates of historical snowfall rates and the occurrence of blowing and

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drifting snow, including its depth and propensity to blow in the presence of varying wind speeds. Another benefit of the use of computer modeling was the ability to define severity not merely for a few zones per state, but virtually continuously across a grid of 0.25° latitude by 0.25° longitude blocks nationwide.

The end product was a high-resolution map for overall winter severity across the continental U.S., as well as separate maps for each winter-severity parameter. Researchers also produced gridded data sets, shape files and comma-separated-values files.

Gridded data sets provide users with the underlying information used to generate the maps, and comma-separated-values files allow the data to be used in spreadsheet applications. Shape files can be used in graphical information systems to facilitate the visualization of severity data alongside other data.

"For instance, you could overlay a map of weather severity on a map of salt usage," Mewes said. "This way you could assess whether there was room for improvement in operations by making comparisons to areas with a similar severity index."

With a better understanding of winter-weather severity, winter-maintenance professionals will be able to better justify their budgets to legislatures, Mewes said. The maps also are a tool agencies can use to explain their operations to the public, policy makers and other engineers.

"WYDOT has used the winter-weather severity map on a PowerPoint slide to help explain why and how our weather compares to surrounding states," said Clifford Spoonemore, maintenance staff engineer for field operations at the Wyoming Department of Transportation (WYDOT). "This also helps us explain why we have continued to use grit material instead of shifting to chemicals and salt."

By facilitating comparisons across storms, the maps will ultimately allow agencies to improve the efficiency of their winter-maintenance operations by helping them better estimate the costs of snow and ice removal and compare the relative costs of in-house crews and contractors, according to Paul Brown,

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snow and ice engineer at the Massachusetts Department of Transportation and the Clear Roads project champion. They also could help users demonstrate that a new maintenance technology, while more expensive initially, will lead to lower costs in the long run.

"Understanding weather severity is key to making better maintenance decisions," said Brian Burne, highway-maintenance engineer for the Maine Department of Transportation, which is also making use of the maps. "They're a great tool for becoming as efficient as possible."

Winter's true costs

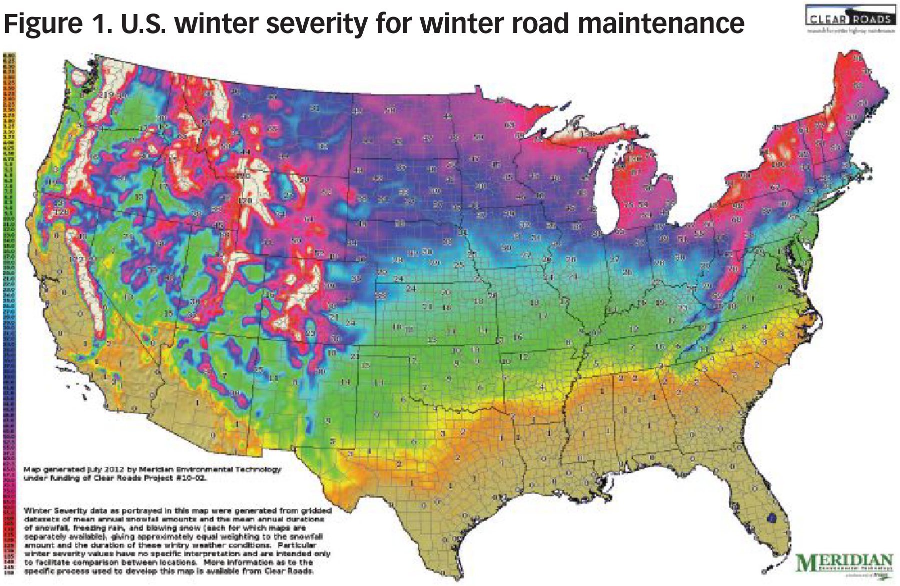
The Mapping Weather Severity Zones project supports Clear Roads' larger Understanding the True Costs of Snow and Ice Control project, which is developing a software tool for calculating the true costs of snow and ice removal. Currently in spreadsheet form, this tool allows users to calculate the winter-maintenance costs of a particular storm by inputting equipment, labor and materials costs along with storm characteristics. A second phase of the project will develop a web-based interface for this tool and integrate it with the winter-severity index data developed by Meridian. Agencies will be able to use this tool to develop what-if analyses for various inputs, identify cost drivers, compare storm costs and characteristics, evaluate impacts of policies on cost and compare storms across time periods and contract types.

The ultimate objective is to be able to compare winter-maintenance operations across agencies. But this goal has been elusive because agencies use different methods to collect weather and operational data. Agency-to-agency comparisons also need to factor in differing levels of service, or how agencies clear roads to get them back to typical traffic levels.

"Our costs in Massachusetts are different than those of Wyoming," Brown said. "An agency in an urban area will be more likely to spend more to maintain a high-volume roadway that serves as a vital link for commuters than an agency in a rural area would spend on a road with less traffic."

"It's not unusual to use 10 times as much salt on a high-volume as opposed to rural road," Mewes said. "So the level of resources required to maintain different roads with the same

Figure 1. U.S. winter severity for winter road maintenance



weather conditions can differ by orders of magnitude."

As the True Costs project moves forward, standardizing data collection across agencies and accounting for level of service will further enhance agencies' ability to compare winter-maintenance costs with states that have similar climates and roadways, allowing them to consider new budget scenarios based on successes in other areas. The winter-weather severity maps developed by Mewes are a good start in making these cross-agency comparisons.

"These maps will help us find areas with similar weather patterns to ask them whether there are practices that they have found to be particularly efficient," said Allen Williams, district maintenance engineer at the Virginia Department of Transportation.

"There are tremendous benefits to being able to compare agency snow- and ice-removal costs," Brown said. "These maps are an important first step." **WM**

The Clear Roads pooled fund project (TPF-5(218)) focuses on rigorous testing of winter-maintenance materials, equipment and methods for use by highway-maintenance crews. This ongoing project is led by the Minnesota Department of Transportation, with 25 member states across the country.

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