Winter Maintenance Budgeting Based on the Relationship between Winter Severity and Historical Costs

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Introduction and Methodology

Planning for roadway snow and ice control (RSIC) activities is a persistent challenge for VTrans due to variability in winter severity and a limited understanding of the relationship between severity and RSIC cost. The purpose of this project was to develop a forecasting tool suitable for estimating the cost of achieving the Agency's performance targets across a range of weather conditions.

Utilizing a decade of RSIC cost data from VTrans' MATS database and weather data from the National Oceanic and Atmospheric Administration, the investigators explored the relationship between RSIC costs and the Accumulated Winter Season Severity Index (AWSSI), finding that this relationship defines 3 distinct "Snow Regions" in Vermont (Figure 1).

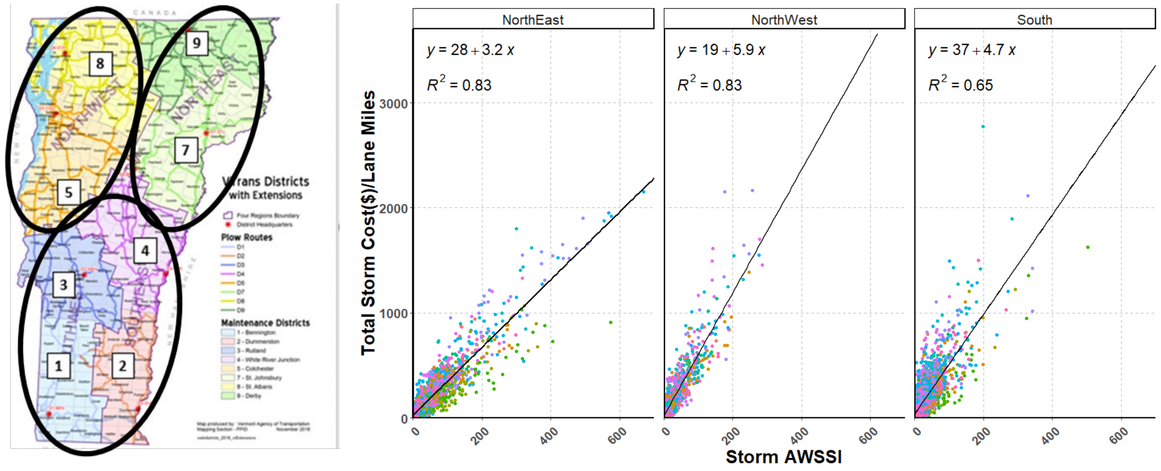

Figure 1. Vermont's "Snow Regions" (circled at left) with Corresponding Regression Models of RSIC Cost and AWSSI

The correlation between severity and RSIC costs was initially analyzed at the seasonal and daily levels. The seasonal analysis included cost and severity measurements for 39 VTrans "parent" garages for the 10 winter seasons for a total of 390 data points and the daily analysis included a total of nearly 72,000 data points. Both the seasonal and daily models showed a positive relationship between cost and severity, but the correlations were relatively weak. The correlation between cost and severity is reduced at both temporal levels due to the accrual of AWSSI scores related to temperature and existing snow depth on days with no precipitation. The daily correlation is further reduced by the inconsistency between the discrete, daily severity scoring and the more continuous nature of SIC activities, which are responsive to current and forecasted weather conditions. To address these issues the research team aggregated the daily data to multi-day "storm events". The dataset of aggregated storm events consisted of approximately 9,300 data points. At the level of the storm-event, the correlations between RSIC costs and severity jumped up to 0.74.

Using the regional regression models of RSIC cost and storm-event AWSSI, a cost forecasting tool was developed to provide forecasts for total or per-lane-mile RSIC costs based on the forecasted winter severity, input by the user as a mean and standard deviation of the AWSSI, and the number of storms expected.

Forecasting Tool

The MS Excel tool opens to a User's Guide, with the following instructions:

Select a garage or region from the dropdown list on the "Winter Specs" sheet (Figure 2). Choose one of Vermont's 39 "parent" garages, 8 maintenance districts, 3 "Snow Regions", or the entire state. The lane-miles of responsibility associated with the selected region are automatically populated in the next cell down (this cell can not be edited). Manually enter the frequency and severity of the winter storms for the simulation in the bright green cells. For guidance, the historical frequency, AWSSI, and standard deviation of AWSSI for storms in that region are provided. When the "Run Simulation" button is clicked 10,000 winter seasons are simulated according to the user's specifications.

Welcome to the VTrans Winter Simulation and SIC Cost Estimating Tool

Developed by the University of Vermont Transportation Research Center

Description		User Specification	Instructions and guidance
Geographic Extent	Garage or Region	District 7	:k the garage or region you are interested in from the list
	Lane-Miles	909.1	is the no. of lane-miles associated with this garage or region
Winter Season Severity	Number of Storms	50	27 is the typical historical number of storms in a season for this geographic
	Average Storm AWSSI	20	44 is the historical average AWSSI for this geographic extent
	Std Dev of Storm AWSSI	40	62 is the historical std. dev. of the AWSSI for this geographic extent
	Max AWSSI	521	is the historical maximum AWSSI for this geographic extent
	Min AWSSI	1	is the historical minimum AWSSI for this geographic extent

Run Simulation

Instructions:
1. Select a garage or region from the dropdown list (in yellow)
2. Enter the frequency and severity of the winter storms for the simulation (light green)
3. Click the "Run Simulation" button and 10,000 winter seasons are simulated according to your specifications.
4. You will be taken to the resulting cost estimates on the "Results" sheet

Figure 2. "Winter Specs" sheet in the forecasting tool

Estimated Winter Season SIC Costs

Snow Region	Average	Upper 75th %	Lower 25th %	Sub-Region
Northeast	$ 6,558,437	$ 8,422,544	$ 3,792,989	Statewide
Northwest	$ 7,881,269	$ 10,824,219	$ 3,514,716	Statewide
South	$ 14,262,229	$ 18,355,336	$ 8,189,973	Statewide
Statewide Total	$ 28,701,934	$ 37,602,099	$ 15,497,678	

Estimated *Per Lane-Mile* Winter Season SIC Costs

Snow Region	Average	Upper 75th %	Lower 25th %	Sub-Region
Northeast	$ 3,627	$ 4,658	$ 2,098	Statewide
Northwest	$ 4,937	$ 6,780	$ 2,202	Statewide
South	$ 4,852	$ 6,244	$ 2,786	Statewide
Statewide Average	$ 4,524	$ 5,927	$ 2,443	

Notes:
Northeast snow region includes Districts 7 and 9
Northwest snow region includes Districts 5 and 8
South snow region includes Districts 1, 2, 3 and 4
Estimates include an added factor of 2.3% for administrative costs and transfers

Figure 3. "Results" sheet in the forecasting tool

The algorithm then advances to the "Results" sheet to show the cost estimates (Figure 3). In the Results sheet, cost estimates are provided in total and on a "per-lane-mile" basis. Average cost, upper 75th percentile, and lower 25th percentile across all simulations are reported. Cost estimates include an added expansion factor to capture costs that are not directly attributable to a specific storm. Examples of these costs are staff bonuses, administrator time, and salt transfers between storms. Garage and district costs are provided in the Snow Region where they occur, and the garage or district specified is shown in the "Sub-Region" cell. The "Results" worksheet is populated automatically by the code and is not edited.

Potential Impacts and VTrans Benefits

This tool will enable VTrans to make data-driven decisions about appropriate levels of investment in RSIC for a given winter forecast and improve RSIC performance management by comparing actual SIC performance outcomes and cost-effectiveness to those seen in the historical data.

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