Winter Severity Indices and Road Maintenance

WWOSC Montreal 2014

Jean Andrey, Lindsay Matthews, Derrick Hambly

Brian Mills
Ottawa’s snow-removal tab $13M over budget for start of 2014

Cities running out of cash for snow removal as icy Canadian winter hits hard

Snow removal costs strain Calgary roads budget

Record snowfall in December pushes city over budget

Provincial snow clearing goes over budget

Ryan Ross
Published on March 29, 2014

Ottawa Citizen April 29, 2014
Globe and Mail Feb 18, 2014
CBC News Jan 02, 2014
Check source
Impact of Winter Weather on Roads

- Winter storms routinely result in travel disruptions and congestive delay.

- Weather is an important risk factor for road safety. Snow and icy/snowy pavement increase the risk of collisions and injuries.

> 1.5 billion (CAD) is spent on annual winter road maintenance by road authorities in Canada

- Top photo from CBC Montreal Dec 2012
Winter Road Maintenance

- Decision-support tools are increasingly important in winter maintenance

1. At the operational level, maintenance decision-support tools (MDSS) are intended to ‘suggest’ specific actions such as the form and rate of chemical application.

2. At the tactical/strategic level, the focus is on the justification of past expenditures, the specification of maintenance contracts with service providers, and the evaluation of the budget implications of alternative maintenance practices/materials. For these applications, there has been a longstanding interest in winter severity indices.
Winter Severity Indices

- Indices are widely used as a way of translating atmospheric/meteorological conditions into information that is socially relevant.

- Use of growing degree days and radiation to calculate a climatic severity index related to energy performance of buildings (Salmeron et al., 2013, Energy and Buildings) – ecofriendly house in Barcelona

- Some Ski resorts are translating windchill into a comfort index and clothing advisories

- The road weight restriction image is from Richmond Hill for gravel and older roads; a thawing index calculated from insitu measurements allows for optimal timing of the restricted period
Key Considerations

- *Modeling vs. index*
- *Temporal vs. spatio-temporal variations*
- *Interpretability vs. fit*
- *Specific vs. general applicability*
It is obvious that weather is associated with maintenance activity. But note that any individual weather variable is only modestly correlated with maintenance activity—at the daily level.
Winter Road Maintenance = \( fn (x_1, x_2, \ldots x_n) \)

- **Observed Weather** (precip form, temp trend)
- **Forecast Weather** (radar, POP)
- **Road Conditions** (wet, snow packed)

- **Road Characteristics**
- **Terrain, Vegetation**
- **Traffic Characteristics**

- **Level of Service Standards**
- **Maintenance Practices**
### Modeling – Some Examples

<table>
<thead>
<tr>
<th>WRM Variable</th>
<th>Explanatory Variables</th>
<th>Approach</th>
<th>Observations</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual salt use / road km (Norway)</td>
<td>avg monthly temperatures</td>
<td>Multiple linear regression</td>
<td>Regression coefficients for monthly temperatures vary $R^2 \approx 0.5$</td>
<td>Vanäätäinen (2001)</td>
</tr>
<tr>
<td>Ln (avg daily salt use / lane km / month) (Canada)</td>
<td>avg temp deviation % days snowfall % days freeze. rain, east-west dummy</td>
<td>Multiple linear regression with Bayes updating</td>
<td>Most explanation from east-west dummy $0.18 \leq R^2 \leq 0.72$ for various regions</td>
<td>Suggett et al., (2007)</td>
</tr>
<tr>
<td>Hourly salt application rate (Ottawa, Canada)</td>
<td>Numerous: weather forecasts and observations, warnings, radar, RWIS</td>
<td>Classification trees</td>
<td>Overall 66% hours correctly classified High accuracy for ‘zero’ and ‘medium’ salt application rates</td>
<td>Andrey et al., (2008)</td>
</tr>
</tbody>
</table>
### Indices – Some Examples

<table>
<thead>
<tr>
<th>Index Scores</th>
<th>Underlying Model</th>
<th>Comments</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>-40 (Alaska) to +40 (US Gulf Coast)</td>
<td>Linearly additive terms; 3 weather (2 temp, 1 snow)</td>
<td>Weights based on predefined importance Model not transferable</td>
<td>Thones et al. (1990)</td>
</tr>
<tr>
<td>0 to 100 (percentile for monthly salt use)</td>
<td>Regression model; 3 weather variables and 1 locational variable as explanatory terms</td>
<td>Model had modest explanation Index scores not easily linked back to weather events</td>
<td>Suggett et al., (2007)</td>
</tr>
<tr>
<td>0 to 1 for events Event scores aggregated</td>
<td>6 categorical weather variables assigned scores using regression; scores combined to produce storm score</td>
<td>Expert input considered Not empirically correlated with WRM</td>
<td>Nixon and Qiu (2005)</td>
</tr>
</tbody>
</table>
Key Considerations

- Model vs. index
- Temporal vs. spatio-temporal variations
- Interpretability vs. fit
- Specific vs. general applicability
- Correlations between pairs of jurisdictions vary from +0.98 to -0.14
- Similar situation for other regions of Ontario and Canada
Potential Uses of a Winter Severity Index

<table>
<thead>
<tr>
<th>Use</th>
<th>Variations</th>
</tr>
</thead>
<tbody>
<tr>
<td>To benchmark/normalize winter maintenance activities within a jurisdiction, e.g., as it relates to budget or service contracts</td>
<td>Temporal</td>
</tr>
<tr>
<td>As an input variable on evaluations of altered maintenance practices/materials within a jurisdiction</td>
<td>Temporal</td>
</tr>
<tr>
<td>To compare resource use across jurisdictions, e.g., to identify opportunities for improved efficiency</td>
<td>Spatio-temporal</td>
</tr>
</tbody>
</table>
• Models and indices developed for a particular region and are not transferable to other regions.
• Multi-jurisdictional / national models and indices that focus on absolute measurements of maintenance (tonnes of salt used, 100s vehicle km) have achieved only moderate fit.
• The use of deviations/anomalies is a more promising approach

- Still limit in using same index for very different climates/maintenance regimes; these are for Ontario-Quebec-Atlantic ... west has different responses to weather events
Key Considerations

- Model vs. index
- Temporal vs. spatio-temporal variations
- Interpretability vs. fit
- Specific vs. general applicability

- A tradeoff between multiple sources of weather/road condition information as well as both forecast and observed conditions and a small number of easily identified triggers.
The approach taken to document the association between winter weather and both materials use and snow dumping is a winter severity index recently developed for Environment Canada (Andrey and Matthews, 2012). This index assigns a score between zero and one for each winter day, and these are added in order to obtain monthly or seasonal values that reflect winter weather severity.

But what does a ‘1’ mean – continual maintenance? Still to be verified.
Key Considerations

- Model vs. index
- Temporal vs. spatio-temporal variations
- Interpretability vs. fit
- Specific vs. general applicability
The science and management of snow and ice control is evolving, and often has a regional signature that relates to local climatic conditions as well as the road network.

- Anti-icing
- Application of sodium chloride for de-icing
- Snow plowing
- Snow removal and dumping
- Sanding/application of gravel or aggregate
- Vehicle hours/km
- $ spent
Considerations Going Forward

1. An index is preferable to a model.
2. Construction of an index should begin with the day or weather event as the base unit of analysis.
3. Index scores should be interpretable – both in an absolute sense and in a relative sense.
4. The number of unique day/event types should be limited to a manageable number, and the scoring of each must reflect the demand for winter maintenance.
5. More attention should be paid to the limits of generalizability by climatic region, transport system, and maintenance regime.
6. There is interest in using these indices at finer temporal resolutions and also with seasonal forecasts.

- 1. in that I provides added value in terms of communicating about the reason for budget and other variations in maintenance
- 2. this way scores are assigned for weather composites rather than for weather variables as is done in regression – avoids collinearity issue, biased coefficients
- 3. upper limit indicates continual maintenance or maintenance as on March 2\textsuperscript{nd} event; as index score increases activity increases in predictable way
- 4.