Winter Maintenance Committee

- Identify, propose, coordinate and promote research in winter highway maintenance
- Membership: 15 US, 7 international
  - Academic, government, private sector
- TRB Annual Meeting sessions
- International Conference & Workshop
  - February 2016, on-line
  - April 2016, Colorado
Sponsored Research

Recently Completed

- Strategies to Mitigate the Impacts of Chloride Roadway Deicers on the Natural Environment, Project 20-05/Topic 43-12
- Winter Operations and Salt, Sand and Chemical Management, in Environmental Stewardship manual of the AASHTO Center for Environmental Excellence, Project 20-07/Task 318
- Alternative Methods of Delivering Winter Operations Services, Project 20-07 Task 329

In Progress

- Guide for Performance Measures in Snow and Ice Control Operations, Project 14-34
Winter Severity

- Managing materials
- Managing performance
- Reporting performance
- Environmental sustainability
Introduction

DEEPAK GOPALAKRISHNA (ICF)
The challenge

Increased pressure on winter maintenance groups to measure impacts and performance
Fiscal pressures mounting
Allocation of funds between regions/years
Assigning responsibility
Rewarding success

Agencies want a consistent, reliable and easy way to measure performance that allows them to make informed decisions between regions and seasons taking into account their differences

Every storm is different and practices are different
Geographic and temporal variation of events
Diversity of agencies and contractors involved in winter weather
Winter Severity Indices

Simply – An index that combines various weather impacts into a single value that allows an agency to compare and normalize performance geographically and temporally

Not so Simply - SHRP2 (1993)

\[ WI_{\text{SHRP}} = a \sqrt{\text{t}_{\text{seasonindex}}} + b \ln \left( \frac{S_{\text{daily}}}{10} + 1 \right) + c \sqrt{\frac{d_{\text{frozen}}}{T_{\text{range1}} + 10}} + d \]

where:
- \( t_{\text{seasonindex}} \) = average value of \( t_{\text{dayindex}} \) over season \((0 \leq t_{\text{seasonindex}} \leq 1)\)
- \( t_{\text{dayindex}} \) = 0, if minimum air temperature \( (T_{\text{min}}) \) is above 32° F (0° C)
  1, if maximum air temperature \( (T_{\text{max}}) > 32° F \) (0° C) while \( T_{\text{min}} \leq 32° F \) (0° C)
  2, if \( T_{\text{max}} \leq 32° F \) (0° C)
- \( S_{\text{daily}} \) = Mean daily values of snowfall (millimeters)
- \( d_{\text{frozen}} \) = Mean daily values of the number of days with minimum air temperature at or below 32° F (0° C) \((0 \leq d_{\text{frozen}} \leq 1)\)
- \( T_{\text{range1}} \) = Mean monthly maximum air temperature minus the mean monthly minimum air temperature (° C)

- Source: Development of a Roadway Severity Index, WTI, 2005

- Not the band.
Growing usage but evolving field

<table>
<thead>
<tr>
<th>State/Author(s)</th>
<th>Seasonal WSI</th>
<th>Storm-by-Storm Index</th>
<th>WSI Primary Function</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qiu (2008)</td>
<td>No</td>
<td>Yes</td>
<td>Traffic operations and maintenance</td>
<td>Storm severity index that observes severity on a storm-by-storm basis. Index is used in a final traffic operation formula.</td>
</tr>
<tr>
<td>Strong et al. (2005)</td>
<td>Yes</td>
<td>No</td>
<td>Traffic operations</td>
<td>Approximates seasonal accident rates based on winter severity.</td>
</tr>
<tr>
<td>Bosely et al. (1993)</td>
<td>Yes</td>
<td>No</td>
<td>Maintenance</td>
<td>SHRP winter index. Designed to assign a seasonal winter severity score to any location without geographic discrimination.</td>
</tr>
<tr>
<td>Cesarini and Decker (2011)</td>
<td>No</td>
<td>Yes</td>
<td>Human intrinsic value</td>
<td>A local winter storm scale that basis winter severity on public perception.</td>
</tr>
<tr>
<td>Decker et al. (2001)</td>
<td>Yes</td>
<td>No</td>
<td>Maintenance</td>
<td>Uses SHRP winter index to compare expenditure between three geographically distinct UDOT maintenance sheds.</td>
</tr>
<tr>
<td>Idaho</td>
<td>Yes</td>
<td>Yes</td>
<td>Maintenance</td>
<td>Created a storm-by-storm index that takes road surface state conditions into account.</td>
</tr>
<tr>
<td>Indiana</td>
<td>Yes</td>
<td>No</td>
<td>Maintenance</td>
<td>Created their own winter index based off of criteria interest and surveying maintenance crews.</td>
</tr>
<tr>
<td>Iowa</td>
<td>Yes</td>
<td>No</td>
<td>Maintenance</td>
<td>Winter index that favors time constant. Considers duration of precipitation and snow consistency.</td>
</tr>
<tr>
<td>Kansas</td>
<td>Yes</td>
<td>No</td>
<td>Maintenance</td>
<td>Uses SHRP winter index.</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>In Progress</td>
<td>No</td>
<td>Maintenance</td>
<td>WSI under development by contractor.</td>
</tr>
<tr>
<td>Minnesota</td>
<td>Yes</td>
<td>No</td>
<td>Maintenance</td>
<td>Uses SHRP winter index.</td>
</tr>
<tr>
<td>Ontario</td>
<td>Yes</td>
<td>No</td>
<td>Maintenance</td>
<td>Created a modified version of the SHRP winter index.</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>Yes</td>
<td>No</td>
<td>Maintenance</td>
<td>Created a modified version of the SHRP winter index.</td>
</tr>
</tbody>
</table>

- Source: UDOT Research Report, Utah Winter Severity Index Appendix A

- Still an evolving field. (Source: FHWA RWMP Performance Measures, 2012-2013 update, N=25 States)
Objectives of the Webinar

Share real-world experience in development and use of WSI

Provide guidance on how an agency can get started with developing their own WSI
Speakers

Michael Adams, Wisconsin DOT
Jakin Koll, Minnesota DOT
Steven Otto, Alberta Transportation
The Wisconsin DOT Winter Severity Index

Mike Adams
Wisconsin DOT RWIS Program Manager
July 29, 2015
Overview

- Wisconsin DOT background
- Why we use it
- Development history
- How we use it
- Future plans
Wisconsin DOT

- All maintenance contracted to counties
- Responsible for 34,000 lane-miles
- Statewide average snowfall: 65 inches
Why Use a Severity Index?

- “No two storms are alike”
- Need to normalize costs
- Explain cost variance
- Winter funding reallocation
- Operations analysis
Development History

1996
• Formed ad hoc committee
• Determined important criteria
• Examined data availability
• Computed indices back to 1992

2005
• Modified definition of “incidents”

2010
• Enhanced reporting
Index Criteria

- Snow amount
- Number of snow events
- Number of freezing rain events
- Storm duration
- Incidents
TOTAL SALT USE PER LANE MILE AND AVERAGE SEVERITY INDEX

Salt Use (Tons Per Lane Mile) vs. Severity Index

- Salt Use per Lane Mile (Y-axis)
- Severity Index (Y-axis)
- Years from 1992 to 2015 (X-axis)

Legend:
- SALT USE
- AVG STATEWIDE SEVERITY INDEX

Analysis:
- The chart shows the total salt use per lane mile and the average severity index from 1992 to 2015.
- There is a notable variation in salt use and severity index over the years.
- The severity index is represented by a red line, while the salt use is represented by grey bars.

Conclusion:
- The data suggests a correlation between salt use and severity index, indicating the effectiveness of salt usage in managing winter conditions.
So, How Do We Use It?
“Real-Time”

![Map of Wisconsin with color-coded severity index values ranging from light green (1 to 29.9) to dark red (40+). The state-wide average is 43.1.](image)

![Another map of Wisconsin with a different color scheme indicating winter severity.](image)
WisDOT uses model to help allocate funds to counties for winter maintenance

- Based on statewide average number of storms and winter events
- Based on equipment and manpower used per facility

Make adjustments based in part on severity index

- Cannot receive allocation unless severity is above statewide average
- Cannot receive allocation unless costs exceed modeled allocation
Counties Receiving Winter Distribution Last 3 Years
Strengths and Weaknesses

- **Strengths**
  - Can compare county to itself
  - Basis for decision-making

- **Weaknesses**
  - Self-reported data
  - Can’t necessarily compare one county to another
  - “Size bias”
Future Plans

- Use objective MDSS data as basis
  - Pooled fund MDSS has tools to create severity indices based on actual weather
  - Remove reporting biases
- Perhaps update funding model with severity index information rather than using statewide average
Old vs New

Winter Severity Index Values:
- Green: 43.7 - 72.1
- Yellow: 72.2 - 91.4
- Orange: 91.5 - 110.9
- Red: 111.7 - 148.5
- Dark Red: 148.5 - 155.2

Winter Severity (SD) Index Values:
- Green: 87 - 99
- Yellow: 100 - 113
- Orange: 114 - 120
- Red: 129 - 196
- Dark Red: 137 - 309
Minnesota DOT (MnDOT) Weather Severity

TRB Webinar on Weather Severity
July 29th, 2015
Overview

- Intro to MnDOT
- Why MnDOT wanted to look at Weather Severity
- Old Weather Severity Index
- Why did MnDOT decide to change?
- New Weather Severity Index
- Where do we go from here?
2014-15
Annual Winter Maintenance Report
At A Glance

Total Cost of Winter
$86.1 Million

30,546
Lane Miles

84%
Frequency Achieving Bare Lanes

1,400
Full-time Drivers
250 Backup Drivers

839
Plows

39.4"
Statewide Snowfall Average

40,000
Tons Sand
174,000
Tons Salt

148
Truck Stations
Intro to MnDOT

### Snapshot of winter: 2-year comparison

<table>
<thead>
<tr>
<th>Category</th>
<th>Measure</th>
<th>2013-14</th>
<th>2014-15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure</td>
<td>Lane Miles</td>
<td>30,597’</td>
<td>30,546’</td>
</tr>
<tr>
<td>Weather</td>
<td>Snowfall</td>
<td>69.9”</td>
<td>33.6”</td>
</tr>
<tr>
<td></td>
<td>Snowfall, statewide across districts</td>
<td>75.6”</td>
<td>39.4”</td>
</tr>
<tr>
<td></td>
<td>Number of winter events, statewide average and range across districts</td>
<td>34.2</td>
<td>28.4</td>
</tr>
<tr>
<td>Materials</td>
<td>Salt used</td>
<td>275,857 tons</td>
<td>173,688 tons</td>
</tr>
<tr>
<td></td>
<td>Average weighted cost of salt per ton</td>
<td>$71.14</td>
<td>$74.36</td>
</tr>
<tr>
<td></td>
<td>Salt brine used</td>
<td>2.7 million gallons</td>
<td>2.2 million gallons</td>
</tr>
<tr>
<td>Costs and Performance</td>
<td>Total plowing, salting and sanding costs</td>
<td>$156 million</td>
<td>$87.9 million*</td>
</tr>
<tr>
<td></td>
<td>Total plowing, salting and sanding costs per lane mile, statewide average</td>
<td>$4,435</td>
<td>$2,819</td>
</tr>
<tr>
<td></td>
<td>Frequency of achieving bare lane after winter event (70% target)</td>
<td>79%</td>
<td>87%</td>
</tr>
<tr>
<td>Labor and Services</td>
<td>Regular labor hours</td>
<td>718,591</td>
<td>501,095</td>
</tr>
<tr>
<td></td>
<td>Overtime winter labor hours</td>
<td>223,624</td>
<td>94,461</td>
</tr>
</tbody>
</table>

*Based on fiscal year
Why the Need for Weather Severity?

- Show how weather varies from year to year
  - Help validate costs of maintenance to upper management, legislature, public, etc.
  - Managing Performance

- Better Stewards of the Environment
  - Is agency being efficient with material usage?
Old Weather Severity Index

- Used 4 variables
  - Snow events
  - Freezing rain events
  - Snow amount
  - Storm duration

- Represented our response to the weather not the weather severity

- Info gathered from maintenance personnel
  - Not consistent from area to area on how it was gathered

- Mixed acceptance
  - Criticized for not including other weather that we deal with on roads; i.e. wind/blowing snow, etc.
New Approach

- Management sought way to compare winters
  - District to District as well as year to year

- Didn’t want it to reflect our response to the weather

- Wanted consistent way to gather data

- Needed to consider additional variables
  - Include all weather variables that affect road maintenance
New Method Approach/Methodology

- Uses data from surface weather observations at Airports and RWIS stations, radar, satellite, numerical models, meteorologist inputs, etc. to get the best representation of the weather that occurred in the State.
  - Removes subjectivity and inconsistencies in data gathering

- It’s safe to say that pretty much everything that is important in the weather as it impacts roads is considered in the process.
Weather Variables include:

- Air temperature
- Dew point/relative humidity
- Wind direction/speed/gusts
- Precipitation type/amount (liquid, ice, snow)
- Cloud cover, and its impacts on solar (shortwave) and infrared (longwave) radiation
- Pavement temperature
- Sub pavement temperature
- Blowing snow
Features

- **Objective**
  - Not influenced by agency’s response to events

- **Scalable**
  - Can produce Statewide results or area to area comparisons
Uses

- Share with Public
  - Winter at a Glance
    - Keep public engaged in our operations
  - Legislature
    - Help validate costs

- Comparison of Winter Road Weather Severity
  - Year to Year
  - Month to Month
  - Area to Area
MnDOT Weather Severity Index
last 3 years
Winter Severity Index
2013-14

Statewide Average = 128
Units for all values are: Severity Index Value
Next Steps

**Winter Maintenance Response Index**

*Features:*

- Uses same weather variables
- Output is based on Labor, Materials and Equipment
- Uses individual plow sections
- Not normalized – reflects costs as entered by DOT, can vary area/area and year/year
- Objective – not influenced by agency response to events
- Flexible – can be used for varying time periods, day/day, month/month, year/year, winter to date, region to region
- Scalable – results can be shown as statewide, maintenance area, subarea, truck station or plow route
Winter Maintenance Response Index

**Uses:**

- Provides costing information to make business decisions
- Compare against cost data from maintenance management systems and/or data recorded using Automated Vehicle Location systems
  - See difference between actual costs and theoretical costs
    - Efficiency indicator
- Can run past winters data to show cost of new practices or products
  - What if scenarios
- Can show cost of increasing or reducing level of service in similar weather conditions
- Can be used to develop and verify best practices
What’s Needed to Get Started?

- Clearly define what your goals/objectives are
  - Do you just want to compare weather severity?
    - Relatively easy
  - Do you want to compare costs of maintenance?
    - More difficult as you have to use actual costs, differing level of service across areas, etc.
      - Salt might cost $40/ton in south and $115/ton in the north
      - Might have weaker winter in an area that ends up costing more because of the higher level of service needed.

- Involve and engage the right people from the beginning
  - Upper Management
  - Maintenance Decision Makers
Thank You!
CREDITS:

Research and data analysis done for Alberta Transportation at the Dept. of Geography and Environmental Mgmt. University of Waterloo, Ontario, Canada

by

Dr. Jean Andrey, Lindsay Matthews, and Derrick Hambly

jandrey@uwaterloo.ca
Alberta’s Provincial Highway Network
19,480 centre-line miles

17,420 paved
2,060 gravel

Does not include city or local rural roads
Climate = Dry, Cold

Annual Precipitation: 10” (25 cm)
Average Summer Temps: 50 to 85° F (+12 to +30° C)
Average Winter Temps: 20 to -8° F (-6 to -22° C)
Salt Management

Environment

• Voluntary participation
Salt Management


- Voluntary participation
- Salt Management Plan developed by agency
Salt Management


- Voluntary participation
- Salt Management Plan developed by agency
- Reporting when more than 530 tons (500 tonnes) road salts used annually
Salt Management


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Alberta’s Winter Severity Index

1) Pilot Project 2013/14
Pilot Project Area

- RWIS Stations
- Airport
Data Sources

1. Road Weather Information System stations
   1. Atmospheric conditions (air temperature, relative humidity, atmospheric pressure, wind direction and speed)
   2. Pavement temperature
   3. Other pavement conditions (freeze point, subsurface pavement temperature, and pavement surface condition (i.e. dry, wet, ice covered))

2. Environment Canada Records
   1. Air temperature
   2. Precipitation
   3. Weather conditions (i.e. falling snowfall, freezing rain, blowing snow)
Monthly WSI calculation

• Daily score:
  – 0 = no maintenance
  – 1.5 = continuous maintenance (truck hours)

• Data used:
  1. Snowfall (snowfall data from Environment Canada)
  2. RWIS pavement ice warnings (ice warnings based on RWIS data)
  3. Freezing rain (precipitation data from Environment Canada, temperature data from RWIS)
  4. Potential for icing (precipitation data from Environment Canada, temp. data from RWIS)
  5. Series of cold days (temperature data from RWIS)
  6. Rain with low temperatures (rainfall data from Env. Canada, temp. data from RWIS)
  7. Blowing snow (Windspeed data from RWIS, snowfall data from Environment Canada)

• Daily scored added to make Monthly Score
WSI Model Accuracy

\[ y = 86.979x + 59.938 \]

\[ R^2 = 0.9742 \]
Alberta’s Winter Severity Index

2) Expanded Project 2014/15
Expand study area to whole province

Looked at other maintenance activities for calibrating the model
• Salt use
• Sand use

Looked at different time frames
• Weekly
• Every 2 weeks
• Seasonal

Looked at different sub-areas in the province
• Climate zones
• Contract areas
• Sub-contract areas (3 – 6 shop beats)

New for 2014/15 Study
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Changes to Input Data

Environment Canada Data:
• Snowfall Duration Not Available
  (only Snowfall amount)
• Potential for Icing + Freezing Rain Not Available
  (changed to new “Rain with low temperature”)

Added “Shoulder Season Correction”
<table>
<thead>
<tr>
<th>Weather Event</th>
<th>Weather Condition</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Snowfall amount</td>
<td>Low amount of snow (0.4 to 1.9 cm)</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>Moderate amount of snow (1.91 to 4.9 cm)</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td>High amount of snow (&gt; 4.91 cm)</td>
<td>1.1</td>
</tr>
<tr>
<td>2 Surface ice warning</td>
<td>&lt; 0.4 mm daily snowfall, and at least 20% of road surface ice warnings</td>
<td>0.6</td>
</tr>
<tr>
<td>3 Series of cold days</td>
<td>Daily precipitation &lt; 0.4 mm, Conditions for ice warnings not met, and Max temp in previous three days &lt; -18 °C</td>
<td>0.5</td>
</tr>
<tr>
<td>4 Rainfall with low temperatures</td>
<td>Daily snowfall &lt; 0.4 mm, Conditions for ice warnings not met, Conditions for series of cold days not met, Daily rainfall ≥ 0.4 mm, and Min temp &lt; 0 °C</td>
<td>0.5</td>
</tr>
<tr>
<td>5 Blowing snow</td>
<td>Daily precipitation &lt; 0.4 mm, Conditions for ice warnings not met, Conditions for series of cold days not met, Conditions for rainfall with low temperatures not met, Wind speeds ≥ 20 km/h and Snowfall accumulations of previous three days ≥ 5 cm</td>
<td>0.5</td>
</tr>
<tr>
<td>6 Shoulder season adjustment factor</td>
<td>If ANY of the WSI weather triggers have been met AND the average mean temperature for the 14-day period centred on the day for which the score is being assigned is &gt; 0 °C</td>
<td>-0.2</td>
</tr>
</tbody>
</table>
Results for 14-day WSI winter 2013/14 data (one contract area only)
Results for monthly WSIS Oct 2008 – Apr 2014 data
Next Steps:

Alberta Transportation will start calculating a 14-day WSI on a sub-contract and provincial basis, starting this winter.

The WSI will be used for:

- media releases,
- analysis of contractor performance,
  - budget analysis,
  - salt use reporting

And we’re spreading the word about our WSI model to anyone who will listen
Questions are guaranteed in life; Answers aren't.