Training Module Development for Evaluation of Storm Severity Index (SSI)/ Winter Severity Index (WSI) Variables

Final Report

CLEAR ROADS

research for winter highway maintenance

Focus Eduvation

Project 1047788/CR21-04July 2024

Pooled Fund #TPF-5(353)
www.clearroads.org

Clear Roads Project 21-04
Training Module Development for Evaluation of Storm Severity Index (SSI)/ Winter Severity Index (WSI) Variables

Final Report

July 2024

ACKNOWLEDGMENT

We would like to acknowledge the Clear Roads Technical Advisory Panel members, and Greg Waidley from CTC & Associates, for their support, coordination, and valuable information.

Technical Report Documentation Page

1. Report No. CR 21-04	2.	3. Recipients Accession No.
4. Title and Subtitle Training Module Development of Evaluation of Storm Severity Index (SSI) / Winter Severity Index (WSI) Variables		5. Report Date July 2024 6.
7. Author(s)		8. Performing Organization Report No. CR 21-04
9. Performing Organization Name and Address Focus Eduvation 500 W Cummings Park #2700, Woburn, MA 01801, United States		10. Purchase Order No. 11. Contract or Grant No. MnDOT No. 1047788
12. Sponsoring Organization Name and Address Clear Roads Pooled Fund Minnesota Department of Transportation Office of Research & Innovation 395 John Ireland Boulevard, MS 330 St. Paul, Minnesota 55155-1899		13. Type of Report and Period Covered Final Report [] 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract (Limit: 250 words)

The "Training Module Development for the Evaluation of Storm Severity Index (SSI) and Winter Severity Index (WSI) Variables" project, sponsored by Clear Roads and the Minnesota DOT, aims to assess the reliability of winter weather severity indices. This training is designed for Division Directors, Snow and Ice Managers, and Supervisors, equipping them with knowledge of SSI and WSI. The modules cover definitions, distinctions, measurements, benefits, and practical applications in winter maintenance. Division Directors will gain insights to support statewide SSI/WSI implementation, contribute historical knowledge, and secure funding. Managers, as primary points of contact, will lead program creation, implementation, and maintenance. Trained supervisors will ensure effective use of the indices, identifying key variables, reliable data sources, and assessing results, which are crucial for their buy-in and the program's success. Three tailored training modules, each lasting 30 to 60 minutes, have been developed for the different audience levels. Selecting interested and knowledgeable participants is essential for successful training delivery and program implementation.

17. Document Analysis/Descriptors Storm Severity Index (SSI), Winter Severity Index (WSI), SSI/WSI Implementation		18. Availability Statement No restriction. This document is available to the public through the Clear Roads Organization and the Minnesota Department of Transportation.	
19. Security Class (this report) Unclassified	20. Security Class (this page) Unclassified	21. No. of Pages 20	22. Price -0-

Executive Summary

Training Module Development for the project entitled*, Evaluation of Storm Severity Index (SSI) and Winter Severity Index (WSI) Variables*, sponsored by Clear Roads and the Minnesota DOT, arose from a desire to examine the reliability of variables used in calculating winter weather severity indices. Recognizing the need to educate and train personnel at all levels, this training component seeks to equip staff at three distinct levels within the organization – Division Directors, Snow and Ice Managers, and Supervisors – with knowledge of SSI and WSI. The training covers the definitions of both indices, their distinctions, what they measure and what they do not, how they can benefit agencies, and how agencies have and can utilize these indices in their winter maintenance operations.

It is envisioned that participation by Division Directors in the training program will foster top-down, statewide support for SSI/WSI implementation. Directors can provide valuable insights, including winter maintenance contacts and historical knowledge. Their participation will also likely be instrumental in securing long-term funding and program structure development.

Managers, who lead operational teams, can be trained to become the program's primary point of contact. They will act as dedicated champions, spearheading the program's creation, implementation, and ongoing maintenance. These managers, whether maintenance managers, engineers, or meteorologists, hold the key to ensuring the program's success.

Trained supervisors can be instrumental in grounding the project in reality. They will need to possess the skills to effectively utilize the index, identify key variables for SSI/WSI consideration, locate reliable data sources, and assess the reasonableness of results. As these personnel may ultimately be measured by the index, understanding its benefits is crucial for their buy-in and successful program rollout.

Selecting individuals who are genuinely interested in the project and willing to contribute their expertise is vital for successful training delivery.

Three distinct training modules, each ranging from 30 to 60 minutes in length, have been developed for Division Directors, Snow and Ice Managers, and Supervisors, respectively. While the core topics covered in each module share similarities, the level of detail varies depending on the audience.

Table of Contents

List of Figures

List of Abbreviations

ASOS	Automated Surface Observing System
AWOS	Automated Weather Observing System
AWSSI	Accumulated Winter Season Severity Index (Boustead et al., 2015)
CoCoRaHS	Community Collaborative Rain, Hail & Snow
COOP	Cooperative Observer Program
EC	Environment Canada
GHCN	Global Historical Climatology Network
GIC	Geographic Information System
MassDOT	Massachusetts Department of Transportation
MDSS	Maintenance Decision Support System
NLDAS	North American Land Data Assimilation dataset
NWS	National Weather Service
RAP	Rapid Refresh
RAWS	Remote Automatic Weather Station
RCC	Regional Climate Center
RWIS	Road Weather Information System
RWSBEE2	Road Weather Severity Based on Environmental Energy 2 (Baldwin et al., 2015)
SNODAS	Snow Data Assimilation System
SSI	Storm Severity Index
WSI	Winter Severity Index

A. SSI/WSI Training: What Each Audience Will Learn

SSI/WSI for Division Director: Topics Covered

- Storm Severity Indices (SSI) and Winter Severity Indices (WSI) fundamentals
- Key differences between SSI and WSI
- Winter maintenance applications of SSI and WSI
- Management needs addressed by SSI and WSI
- Successful agency implementation of SSI and WSI
- Data required for SSI and WSI calculations
- Evaluation of available data for SSI and WSI use

SSI/WSI for Snow and Ice Managers: Topics Covered

- Foundational understanding of SSI and WSI
- Distinguishing between SSI and WSI
- Practical applications of SSI and WSI in winter maintenance
- Management needs addressed by SSI and WSI
- Successful agency implementation of SSI and WSI
- Data required for SSI and WSI calculations
- Data availability and categorization within the agency
- Tabulating and ranking indices for actionable information
- Optimal index selection for the agency's needs
- Data collection methods for SSI and WSI calculations
- Data integration and calculation of index values
- Reporting requirements associated with SSI and WSI usage
- Actionable recommendations for SSI and WSI implementation

SSI/WSI for Supervisors: Topics Covered

- Understanding the differences between SSI and WSI
- Management needs addressed by SSI and WSI
- Utilizing SSI and WSI to achieve agency goals
- Specific indices covered in the Clear Roads report
- Basic principles of SSI and WSI calculations
- Methods for reporting SSI and WSI values
- Actionable recommendations based on SSI and WSI data

B. Key Concepts Covered Across the Three Training Modules

Storm Severity Index (SSI) and Winter Severity Index (WSI) in a Nutshell

SSIs/WSIs are used by surface transportation agencies to assign a "unitless" value to the perceived severity of the weather from a maintenance perspective.

These indices introduce objectivity into the analysis of storm and winter data by generating a single numerical value (index) for each event. This value is calculated using an algorithm that incorporates various meteorological measurements. Different indices utilize varying parameters, such as pavement temperature, air temperature, or even a combination of both.

The selection of an appropriate index should be based on two key considerations:

1. **Data Availability:** The index should leverage data that the agency can readily access.
2. **Performance Measurement Alignment:** The chosen index should effectively capture the specific performance aspects the agency aims to measure.

By following these selection criteria, agencies can ensure that the chosen SSI or WSI provides the most relevant information for optimizing winter maintenance operations.

Challenge in Winter Maintenance Evaluation

A persistent challenge in evaluating winter maintenance activities lies in the inherent variability of winter weather. Individual storms and winter seasons exhibit a wide range of severity, making comparisons difficult.

Need for Quantifiable Severity Metrics

To effectively assess an agency's performance, a standardized method for quantifying storm and seasonal severity is necessary. This quantification facilitates objective comparisons between events, moving beyond subjective qualitative descriptions. SSIs and WSIs serve as objective measures for quantifying weather events. These indices enable numerical comparisons between storms or winter seasons, allowing statements like "the past winter was 35% more severe than the previous one." By translating qualitative data into quantitative terms, SSIs and WSIs provide a standardized approach for evaluating storm and winter severity.

Difference between SSI and WSI

What They Measure: SSI measures an individual storm, while WSI measures a winter season weather. A simple way of creating a winter index is to create a storm index for every day in the winter season and add up the scores of the SSI for each day of the winter.

What They Focus On: SSI offers a granular view of a specific storm, enabling detailed analysis of operational responses. Conversely, WSI provides a broader perspective, facilitating comparisons across an entire winter season.

What They are Used For: Agency selection between SSI and WSI hinges on the desired analysis: storm-by-storm comparisons necessitate SSI, while WSI is better suited for winter-long evaluations.

Application of SSI and WSI in Winter Maintenance Operations

A significant challenge arises when comparing the operational demands of distinct winter storms. As illustrated in the following table, Storm 1 and Storm 2 present contrasting scenarios in terms of severity.

	Pavement temperature range	Storm duration	Precipitation type	Precipitation amount
Storm 1	27-30° F	6 hours	Light snow	3 inches of snow
Storm 2	18-21° F	4 hours	Freezing rain	½ inch of ice

Figure 1: Table presenting contrasting scenarios in terms of storm severity

Storm Variability: Storm 1, characterized by warmer temperatures and light snowfall, necessitates minimal de-icing material and allows for easier snow removal. Conversely, Storm 2, with colder temperatures and freezing rain, demands a more intensive application of salt due to reduced effectiveness and the difficulty of removing ice from roadways.

Quantifying Material Application: Determining the appropriate amount of de-icing material for each storm is crucial. While Storm 2 undoubtedly requires more salt than Storm 1, the exact quantity remains a question. SSI and WSI, by quantifying storm severity and winter severity respectively, offer valuable insights in this regard.

Expected Salt Usage: Calculating the SSI for Storm 1 and Storm 2 allows for a comparison of their severity. If Storm 2's SSI is 1.9 times higher than Storm 1's, a logical expectation would be to utilize 1.9 times more salt during Storm 2.

Accounting for Variability: Acknowledging the inherent complexity of winter storms, a degree of variance in salt application is inevitable. However, a well-defined range can be established based on the SSI values. In this instance, an acceptable range for salt usage in Storm 2 might be between 1.7 and 2.1 times the amount used in Storm 1.

Identifying Improvement Opportunities: Deviations from the expected range indicate potential areas for improvement. For example, using 2.5 times more salt in Storm 2 suggests inefficiencies in salt usage during such storms. Investigating operational practices during Storm 2 might reveal opportunities for optimization. It is also important to consider the possibility that the SSI may not be entirely suitable for this specific comparison.

Alternative Interpretation: Conversely, utilizing only 1.2 times more salt in Storm 2 could signify either exceptional efficiency or inefficiency in handling Storm 1. By analyzing Storm 2's operational strategies, potential improvements can be identified and implemented to enhance efficiency in dealing with storms similar to Storm 1.

In essence, SSI and WSI facilitate standardized comparisons of operational performance across agencies. This approach mirrors the practice of normalizing salt usage based on lane miles covered. Similarly, any performance metric can be normalized using the appropriate weather severity index, enabling objective comparisons that account for weather variations.

Fulfilling Management Needs through SSI and WSI

As articulated by F. W. Taylor, effective management hinges on the ability to "know what you want to do and to do it in the best and cheapest way." This principle is particularly relevant in winter operations, where the primary objective is achieving established service goals. These goals, while varying across agencies, typically involve restoring roadways to a bare pavement state within a specified timeframe following a storm event.

The definition of "bare pavement" can differ. Some agencies may prioritize clearing only designated wheel tracks, while others may target complete snow and ice removal from curb to curb. Additional agencies may utilize road surface grip as a performance metric to be achieved or maintained throughout a storm. Regardless of the specific goal, achieving it efficiently and cost-effectively remains paramount.

Challenges in Evaluating Operational Approaches

A crucial challenge for organizations lies in determining the "best and cheapest" approach among various operational strategies. As organizations experiment with different methods to address operational hurdles, a standardized method for objective comparison is necessary. This is precisely where SSI and WSI play a critical role.

Best Use of SSI and WSI for Agencies

SSI and WSI primarily serve as normalization tools for facilitating comparisons between winter maintenance operations. However, the underlying purpose for normalization can vary significantly across agencies.

Season-Long Comparisons: Agencies focused on comparing performance between internal groups across an entire winter season, similar to the Wisconsin DOT's county-level comparisons, should utilize the WSI. Conversely, SSI is more appropriate for comparing performance within these groups during specific storms.

Addressing Operational Pain Points: Agencies facing recurring challenges with specific weather events, such as ice storms, can benefit from detailed analysis using SSI. By normalizing performance against storm severity, agencies can identify the most effective operational approaches across various groups (e.g., counties, districts, depots). This facilitates knowledge sharing and allows for implementing best practices based on real-world experience.

Environmental Considerations: Agencies concerned with chloride contamination can leverage WSI for season-long performance evaluation. This enables them to track salt usage per lane-mile across different locations and severity levels. Lower salt usage per severity point indicates more efficient application in achieving service goals.

Clear Roads Report: Ten Data Collection Methods

There are ten data collection methods considered in the Clear Roads report. These are:

1. The Accumulated Winter Season Severity Index (AWSSI; Boustead et al., 2015)
2. The Boselly Method (Boselly et al., 1993)
3. The Idaho Method
4. The Iowa Method
5. The Matthews Method (Matthews et al., 2017a,b)
6. The Minnesota Method
7. The Pennsylvania Method
8. The Road Weather Severity Based on Environmental Energy 2 (RWSBEE2) model (Baldwin et al., 2015)
9. The Utah Method
10. The Walker Method (Walker et al., 2018)

The following table provides a high-level summary of each method, including: variables, data sources, the spatial and temporal resolution of the index, and how the index defines a storm and a winter season.

		Feature					
		Variables	Data Source(s)	Spatial Resolution	Temporal Resolution	Defined Storm	Defined Winter Season
Method	AWSSI	Air temperature Snow accumulation Snow depth	GHCN [1] State mesonet [2]	At GHCN sites	Daily data Daily calculation	Points only accumulate if daily temp ≤ 32°F or there is snow.	Start: Daily max temp [3] is ≤ 32°F, daily snowfall ≥ 0.1 in., or it is Dec 1st. End: Daily max temp always >32°F, snowfall no longer observed, or it is March 1st.
	Boselly	Air temperature Snow accumulation	NWS [4] network (MassDOT) RWIS, ASOS/ AWOS, RAWS [5]	At weather stations, and averaged over district or area	Daily data Daily calculation	Index is calculated daily or summed over a defined period	Nov 1 – Mar 31 (MassDOT) User-defined to capture storms (WSDOT)
	Idaho	Wind speed Layer thickness Road temperature	RWIS	At RWIS	15-minute data Calculated per storm	Start: Precip [6] is detected and road temp <32°F. End: 2 hours after precip no longer detected	November 1 – Mar 31; may be extended due to actual weather conditions or agency decision

						on road.	
	Iowa	Number of snow and freezing rain events Snowfall amount Hours of snowfall, freezing rain, blowing snow, and sleet Road temperature	Operator logs RWIS	Per garage	Hourly & daily data Calculated per storm	Occurrence of snow, freezing rain, blowing snow or sleet	October 15 – April 15; or before or after if frozen precip occurs
	Matthews	Snow accumulation Pavement condition Precipitation type Air temperature Wind speed	EC[7] network RWIS	Per maintenance area	Daily data Daily calculation	No defined storm; every winter day receives a score	October – April
Method	**Minnesota**	Air temperature Road temperature Dew point/RH[8] Frost/black ice occurrence Wind speed, gusts and direction Precipitation type, duration, amount Cloud cover (short- and longwave radiation) Surface pressure Blowing snow	MDSS[9] ASOS/AWOS	Per district and statewide	Sub-hourly and hourly data Calculated per season	"Any winter weather occurrence that consumes resources necessary to prevent, minimize or regain the loss of bare lanes."[10]	October 1 – May 1, but extended on either side if winter weather occurs
	Pennsylvania	Snow accumulation Freezing rain accumulation Precip duration Air temperature	RWIS	Per county	Sub-hourly data Calculated per day and/or per storm	A single calendar day represents a single storm, unless there is a precip break of at least 8 hours within the day	October 1 – May 1
	RWSBEE2	Roughness length[11] Air temperature Wind speed Road temperature	MDSS RAP[12] NLDAS[13] SNODAS[14] Stage IV	$^1/_8$° latitude/ longitude (approx. 75-square-mile) grid	Hourly data Calculated in real time (hourly)	N/A (hourly calculation)	Nov-Mar

		Shortwave & longwave radiation Sensible and latent heat fluxes Vertical temperature profile Precipitation type Visibility Wind gust Snow depth Precip accumulation	precipitation [15]				
	Utah	Road condition/grip Snowfall rate (visibility proxy) Road temperature Wet-bulb temp Wind gust Precip occurrence	RWIS	At RWIS	20-min data Calculated in real time (every 10 min)	When SII [16] remains >0 for a certain period of time	November 1 – April 30
Method	**Walker**	Snowfall total Snowfall rate (derived) Wind speed Air temperature District area Visibility Duration	ASOS GHCN	Per district	Hourly data Calculated per storm	When an ASOS is observing frozen precipitation	October – April

Figure 2: Table showing high-level summary of each data collection method

Evaluation of Readily Available Data for SSI/WSI Method Selection

Agencies possess varying data acquisition capabilities. This directly affects their suitability for different SSI/WSI methods.

The Clear Roads report provides a table outlining the data variables required by each data collection method. It is important to note that this table may not encompass all variables, with some methods utilizing unique data points like wet bulb temperature or friction measurements.

Method	Variable											
	Air Temperature	Wind Speed	Visibility	Pavement Temperature	Pavement Condition	Precipitation Type	Snow Accumulation	Snow Depth	Snowfall Rate	Radiation and Heat Flux	Blowing Snow	Freezing Rain
AWSSI	X						X	X				
Boselly	X						X					
Idaho		X		X	X							
Iowa				X		X	X				X	X
Matthews	X	X			X	X	X					
Minnesota	X	X	X	X	X	X	X	X	X	X	X	X
Pennsylvania	X					X	X					X
RWSBEE2	X	X	X	X		X		X		X	X	
Utah		X	X	X	X	X			X		X	X
Walker	X	X	X				X		X			

Figure 3: Table outlining data variables required by each method, Clear Roads report

Additionally, the table excludes fundamental storm characteristics like snow occurrence, frequency, and duration. These are likely considered implicitly within each method's calculations.

The data sources for these variables are diverse, as detailed in the accompanying table (reference the Clear Roads report for details).

Method	Variable												Data Sources									
	Air Temperature	Wind Speed	Visibility	Pavement Temperature	Pavement Condition	Precipitation Type	Snow Accumulation	Snow Depth	Snowfall Rate	Radiation and Heat Flux	Blowing Snow	Freezing Rain	RWIS	Operator Logs	MDSS	Mobile Observations	ASOS/AWOS, EC	COOP	RAWS	GHCN	Model Analyses	State Mesonet
AWSSI	X						X	X												X		Y
Boselly	X						X						X				X		Y			
Idaho		X		X	X								X									
Iowa				X		X	X				X	X	X	X								
Matthews	X	X			X	X	X						X				X					
Minnesota	X	X	X	X	X	X	X	X	X	X	X	X	X		X		X				X	
Pennsylvania	X					X	X					X	X									
RWSBEE2	X	X	X	X		X		X		X	X				X						X	
Utah		X	X	X	X	X			X		X	X	X									
Walker	X	X	X				X		X								X			X		

Figure 4: Table outlining variables collected from different data sources, Clear Roads report

This revised version retains the core message about data availability impacting method selection but removes redundancy and emphasizes the importance of the Clear Roads report as a reference.

Index Method Selection

The ability of an agency to use any given index method will depend not only upon their need but also upon their ability to access the data needed by any given index method.

Certain of the variables are only collected by a limited set of the data sources. For example, pavement temperature and pavement condition can be collected by RWIS, operator logs, MDSS, and mobile observations.

If an agency does not have any of the data sources such as RWIS, operator logs, MDSS, and mobile observations available to them, then they cannot use methods that require those variables.

Therefore, the selection of an index for any particular agency is constrained by the purpose for which the agency intends to use the calculated index values, and also by the variable measurements and data sources available to the agency. In selecting an index, agencies should be aware of both types of constraints.

Data Required to Calculate SSI and WSI: Variables

There are more than 25 different variables as being used in the data collection methods. They were organized into five variable categories:

1. Atmospheric Variables
   - Air temperature
   - Wet-bulb temperature
   - Wind speed, gust, direction
   - Visibility
   - Vertical temperature profile
2. Pavement Variables
   - Road temperature
   - Surface condition
   - Friction/grip
   - Layer thickness
3. Precipitation variables
   - Precipitation type
   - Snow occurrence
   - Snow accumulation and depth
   - Snowfall rate
   - Blowing snow
   - Freezing rain occurrence, duration, and accumulation
4. Radiation variables
   - Shortwave and longwave radiation
   - Sensible and latent heat fluxes
5. Temporal variables
   - Frequency of events
   - Duration of events

Data Source Breakdown

The following list divides 17 data sources by category. The “special mention” category is used to include sources that fall outside of the other categories.

- **Road weather-specific data sources**
    a. Road Weather Information System (RWIS)
    b. Operator logs
    c. Maintenance Decision Support System (MDSS)
    d. Mobile observations
- **Federal government-managed weather station networks**
    a. Automated Surface Observing System/Automated Weather Observing System (ASOS/AWOS)
    b. Cooperative Observer Program (COOP)
    c. Remote Automatic Weather Station (RAWS)
    d. Environment Canada (EC) network
    e. Global Historical Climatology Network (GHCN)
- **Modeled data analyses**
    a. Rapid Refresh (RAP) model
    b. North American Land Data Assimilation (NLDAS) dataset
    c. Snow Data Assimilation System (SNODAS)
    d. Stage IV precipitation analysis
- **Special-mention networks and databases:**
    a. State-owned mesoscale network (mesonet)
    b. Community Collaborative Rain, Hail & Snow (CoCoRaHS)
    c. Regional Climate Center (RCC) databases
    d. Other external databases

Data Requirements for SSI and WSI Calculation: While any SSI can be aggregated to generate a WSI, specific data needs for each index vary. Calculating index values at individual locations necessitates multiple data streams, and the data volume scales with the number of locations.

Data Management Challenges: Collecting, processing, storing, and managing the data required for index calculations presents a complex challenge.

Geographic Considerations: Index values likely require integration into a Geographic Information System (GIS) for spatial analysis. Agencies with existing GIS systems need to determine whether to incorporate index data or develop a separate system.

SSI vs. WSI Data Distinction: Only five methods (Idaho, Iowa, Pennsylvania, Utah, and Walker) from the ten listed in the Clear Roads report provide true per-storm SSI values. RWSBEE2 calculates hourly, Minnesota uses sub-hourly and hourly data, and AWSSI, Boselly, and Matthews utilize daily data, potentially offering at least daily index values during storm events.

Collection and Integration of Needed Data

There are three issues surrounding the frequency of data collection requirements. The frequency with which data needs to be collected can significantly impact the burden on the agency. For instance, requiring data every hour is less onerous than requiring the same data every 15 minutes. Thus, a number of steps need to be considered by an agency to address the issue of data collection for the index calculations.

First Issue: How particular information is available for an agency: The data in file format that can easily be ingested by the index calculator can be considered fully available. However, the data will need to be linked to a geographic location. GIS overlay will be required if data are being collected in several different locations.

Second Issue: How to collect information from different locations: If the various pieces of information are being collected from different locations, then some sort of interpolation process will be needed. For example, pavement temperature is not being collected at the same location as visibility. In such a situation, a spatial interpolation process may be required.

Third issue: How to address the temporal concern: If the frequency of data required by the index calculator is different from the frequency at which the input data is provided, some additional interpolation will be needed.

Reporting the Index Data

Decisions made to report the index data:

- If the index is being calculated at various locations across a large geographic area, mapping or GIS display might be appropriate.
- If only a single index value for one location is being calculated, it may be best to track the index value over time for that one location.
- Consider the needs of the agency as part of the data collection and integration process.

Ranking the Indices

Selection of the most suitable indices for an agency can be achieved through a ranking process based on ease of implementation. This process leverages a systematic elimination strategy.

Availability	Air temperature	Wind Speed	Visibility	Pavement Temp	Pavement condition	Precip Type	Snow Accumulation	Snowfall Depth	Snowfall Rate	Radiation and Heat Flux	Blowing Snow	Freezing Rain
Fully Available												
Partially Available												
Accessible												
Not currently available												

Figure 5: Table to identify indices for ranking

First, agencies can leverage the completed data availability table to identify indices incompatible with their current data acquisition capabilities. For example, an absence of radiation and heat flux data would render the Minnesota and RWSBEE2 methods unusable.

Method	Air Temperature	Wind Speed	Visibility	Pavement Temperature	Pavement condition	Precipitation Type	Snow Accumulation	Snowfall Depth	Snowfall Rate	Radiation and Heat Flux	Blowing Snow	Freezing Rain	Total Earned	Total Points Available	Percentage
AWSSI	X						X	X							
Boselly	X						X								
Idaho		X		X	X										
Iowa				X		X	X				X	X			
Matthews	X	X			X	X	X								
Minnesota ❌	X	X	X	X	X	X	X	X	X		X	X			
Pennsylvania	X					X	X					X			
RWSBEE2 ❌	X	X	X	X		X		X			X				
Utah		X	X	X	X	X	X		X		X	X			
Walker	X	X	X						X						

Figure 6: Example 1 - Table to identify indices for ranking

Once incompatible methods are eliminated, a scoring system can be implemented to evaluate the remaining indices. This system assigns a score of three points to data categories where all necessary information is readily available, two points for categories with partially available data, and one point for categories where data is accessible but requires additional processing or acquisition efforts.

Method	Air Temperature	Wind Speed	Visibility	Pavement Temperature	Pavement condition	Precipitation Type	Snow Accumulation	Snowfall Depth	Snowfall Rate	Radiation and Heat Flux	Blowing Snow	Freezing Rain	Total Earned	Total Points Available	Percentage
AWSSI	3						2	2					7	9	77.8%
Boselly	X						X								
Idaho		X		X	X								6	9	66.7%
Iowa				X		X	X				X	X			
Matthews	X	X			X	X	X								
Minnesota ❌	X	X	X	X	X	X	X	X	X		X	X			
Pennsylvania	X					X	X					X	8	12	66.7%
RWSBEE2 ❌	X	X	X	X		X		X			X				
Utah		X	X	X	X	X	X		X		X	X			
Walker	X	X	X						X						

Figure 7: Example 2 - Table to identify indices for ranking

To illustrate the application of this scoring system, consider a scenario where an agency's completed table indicates limited data availability. In this instance, the AWSSI method would receive a score of seven (three points for air temperature, two points each for snow accumulation and depth) out of a maximum possible score of nine, translating to a percentage score of 77.8%. This approach facilitates the ranking of feasible methods based on their alignment with existing data resources.

It is important to acknowledge that a higher score does not definitively identify the optimal index. While it suggests a better fit for a particular agency, other factors beyond data availability may influence the suitability of a specific index for an agency's unique needs and operational environment.

Given these limitations, agencies are advised to evaluate potentially suitable methods in practice before making a final selection. This may involve trial implementations or pilot studies to assess the effectiveness of each index in the context of the agency's specific requirements and data collection capabilities.

Review of Challenges and Best Practices for Storm Severity and Winter Severity Indices

Almost all agencies that employ an SSI/WSI encounter challenges of some variety. Weather and the road environment are complicated systems with many variables contributing to the ultimate road state. It is an inexact science to assign a single numerical value to the perceived severity. Additionally, the definition of severity itself will differ among maintenance departments.

Another challenge when considering the use of an SSI/WSI is with the data used by the algorithms. Weather data frequently suffers from at least one of the following issues: poor resolution, poor quality, or it is non-existent altogether. The data may not be sampled at desirable locations, may be error-prone, or may not be the exact data required by the algorithm. Thus, this project sought to summarize the myriad types of data used by agencies around the world and evaluate the reliability of each data type and data source in an SSI/WSI context.

Despite challenges faced by many agencies, most have found success in using their index as a normative part of maintenance management, performance measurement, or public relations. Ten successful SSI/WSI methods are described, and their variables, data, and data sources are evaluated. From the evaluation, recommendations are presented for the agency interested in building or improving upon an SSI/WSI.

This page intentionally left blank.

CLEAR ROADS

research for winter highway maintenance

Lead state:

Minnesota Department of Transportation
Research Services
395 John Ireland Blvd.
St. Paul, MN 55155