Standardized Framework for Winter Weather Road Condition Indices

tech transfer summary

A standardized national framework for winter weather road condition indices can support a safer, more coordinated national response to winter weather impacts on transportation systems.

Objective

The objective of this project was to develop a standardized national framework for winter weather road condition indices (WWRCIs) that reflects both operational realities and safety impacts across diverse climatic and geographic contexts in the United States.

Background

Winter weather poses significant challenges to transportation safety and operations, causing increased crash risks, traffic congestion, and elevated maintenance demands. To address these challenges, state and local agencies across the United States have developed WWRCIs to support decisions related to roadway operations, public information, road closures, and winter maintenance responses based on prevailing conditions.

Problem Statement

In the absence of a standardized national framework, substantial variation among WWRCIs has arisen in how road conditions are defined, assessed, and communicated. These inconsistencies can create confusion for travelers and limit the ability of transportation agencies to compare performance, share best practices, and benchmark winter operations effectively.

A standardized national WWRCI framework offers an opportunity to establish a consistent, reliable, and transparent approach for assessing and communicating winter road conditions.

Snowplow in use during winter weather conditions

Aurora
working to advance road weather information systems technology

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RESEARCH PROJECT TITLE
Standardized Framework for Winter Weather Road Condition Indices

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The Aurora program is a partnership of highway agencies that collaborate on research, development, and deployment of road weather information to improve the efficiency, safety, and reliability of surface transportation. The program is administered by the Center for Weather Impacts on Mobility and Safety (CWIMS), which is housed under the Institute for Transportation at Iowa State University. The mission of Aurora and its members is to seek to implement advanced road weather information systems (RWIS) that fully integrate state-of-the-art roadway and weather forecasting technologies with coordinated, multi-agency weather monitoring infrastructures.

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Research Description

Three foundational tasks were conducted to inform the development of the standardized national WWRCI framework:

- A literature review examined how the parameters typically used in WWRCIs affect driver safety, crash rates, traffic congestion, and efficiency in responding to winter weather.
- A national survey of state transportation agencies captured attitudes, current practices, and priorities regarding WWRCIs and agencies' overall approach to addressing winter weather mobility and safety. Representatives from 24 states participated in the survey.
- An in-depth evaluation of 19 WWRCIs currently in use across the United States and internationally explored the indices strengths and weaknesses and their potential for establishing a cohesive, nationwide standard.

Building on these foundational analyses, a standardized national WWRCI framework and associated implementation guidance was developed.

A case study was conducted to demonstrate implementation of the framework using real-world data from a documented winter weather event. The event selected was a blizzard in Story County, Iowa, in December 2022. Various weather, road condition, and traffic data elements were identified and mapped to the framework to produce a meaningful road condition index.

Key Findings and Results

Survey of State Agencies

- Agencies prioritize planning winter maintenance activities and informing the public about current conditions. Decisions regarding dynamic message signs, variable speed limits, and road closures are also common.
- Few agencies have an active winter weather condition index, but many are developing or considering one. Current indices are used for pre-storm planning, during-storm surveillance, and post-storm analysis.
- Agencies' maintenance and operations divisions are the primary users of the indices, utilizing them for advisory purposes rather than regulatory enforcement. First responders, emergency management personnel, and the general public were identified as the main stakeholders.
- Agencies prefer regional over national weather indices, largely due to the varied weather conditions across different regions. This preference suggests that regional indices are perceived to be more relevant and applicable to local conditions.
- Many agencies share winter weather road condition data and documentation with other state DOTs, facilitating knowledge exchange and the development of best practices across states.

Framework

- The framework is structured around nine core dimensions that influence road safety, mobility, maintenance operations, and travel reliability during winter conditions. Each represents a distinct category of risk or operational concern that can be monitored and analyzed to inform the agency's response.
- The core dimensions are as follows:
  - **Precipitation-Related:** Impacts of different precipitation types and intensities
  - **Resource Utilization:** Quantified operational effort and deicing materials used
  - **Road Recovery Time:** Time required for roads to return to safe conditions after a storm
  - **Surface Condition:** Physical condition of pavements due to winter events
  - **Temperature-Related:** Ambient thermal conditions influencing road surface states
  - **Traffic Flow Impact:** Impact of winter conditions on traffic mobility and reliability
  - **Visibility-Related:** Visual range for drivers under adverse winter weather conditions
  - **Wind-Related:** Wind events influencing snow drift, visibility, and vehicle stability
  - **Winter Maintenance Status:** Status of winter maintenance operations on surface state
- For each dimension, the framework includes subdimensions, recommended indicators, underlying rationale, common data sources, timeliness expectations, and a weight consideration reflecting the dimension's relative importance.
- Application of the framework results in a road condition index score that can support operational awareness, decision-making, and post-event assessment.
- The framework is designed to be a flexible tool that agencies can tailor to their capabilities and data infrastructure. Smaller jurisdictions may choose to prioritize a subset of high-impact dimensions, while larger agencies may fully implement all dimensions.

Case Study

- The calculated index values for the winter storm in December 2022 successfully captured the storm's temporal evolution and aligned well with the qualitative narrative of the event. The framework was able to distinguish between warning, active hazard, and recovery phases.
- The framework demonstrated resilience in handling missing data, allowing for the exclusion of specific dimensions without invalidating the entire index. By adjusting the aggregation weights to focus on the available indicators, the system produced a coherent and actionable index value.
- The case study validated the importance of a multidimensional approach. While meteorological data (snowfall) indicated storm severity, the inclusion of speed and volume reductions provided a proxy for the actual operational reality experienced by road users.
- The use of standard data sources already available to most transportation agencies, such as weather archives, road sensor readings, and commercially available traffic data, confirms the framework's feasibility.
- Challenges in applying the framework included identifying appropriate weights for the indicators, subdimensions, and dimensions; adapting the framework to limited data, which necessitated the omission of some dimensions and subdimensions; and discerning the influence of factors unrelated to weather on dimensions such as Traffic Flow Impact.

Recommendations for Implementation

A pilot application is recommended to validate the framework's adaptability to varying regional and operational capacities and establish data governance and training structures for effective implementation. The pilot application should address the following critical areas:

- Pilot agencies should calibrate the framework's scoring logic to their specific operational realities and organizational structures to ensure that the index drives actionable operational decisions.
- The pilot application should demonstrate that the framework functions effectively for agencies in diverse climatic regions and for both large state agencies with advanced infrastructure and smaller local agencies with limited resources.
- The pilot application should serve as a stress test for the framework's resilience, specifically its ability to handle data gaps and integrate emerging technologies.
- To maximize the framework's utility, a pilot application should demonstrate its integration with existing decision support and data systems, including emerging connected vehicle data.
- Insights gained from the pilot application would directly inform the final toolkit provided to transportation agencies through revisions to the implementation guidance and the development of training modules for agency staff.

Implementation Readiness and Benefits

The final report for this project explains the proposed WWRCI framework in detail and provides guidance on its implementation. While the case study demonstrated the framework's feasibility, the recommended pilot implementation will help the framework evolve from a theoretical model into a practical, standardized tool.

By promoting consistent definitions, indicators, and measurement principles, the proposed WWRCI framework can improve the accuracy and interpretability of information provided to drivers, support interagency coordination during winter events, and help agencies better evaluate winter maintenance performance, optimize resource allocation, and integrate emerging data sources and technologies into their winter operations.