Optimal RWIS Sensor Density and Location – Phase II

tech transfer summary

The significant costs of a road weather information systems (RWIS) motivate governments to optimize the design of the network to provide adequate monitoring coverage.

Aurora

working to advance road weather information systems technology

February 2020

RESEARCH PROJECT TITLE
Optimal RWIS Sensor Density and Location – Phase II

SPONSOR
Federal Highway Administration Aurora Program Transportation Pooled Fund (TPF-5(290); Aurora Project 2016-03)

PRINCIPAL INVESTIGATOR
Tae J. Kwon
University of Alberta

MORE INFORMATION
aurora-program.org

Aurora
Iowa State University
2711 S. Loop Drive, Suite 4700
Ames, IA 50010-8664
515-294-8103

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.

IOWA STATE UNIVERSITY
Institute for Transportation

TPF-5(290) SPR-3(042)

Goal

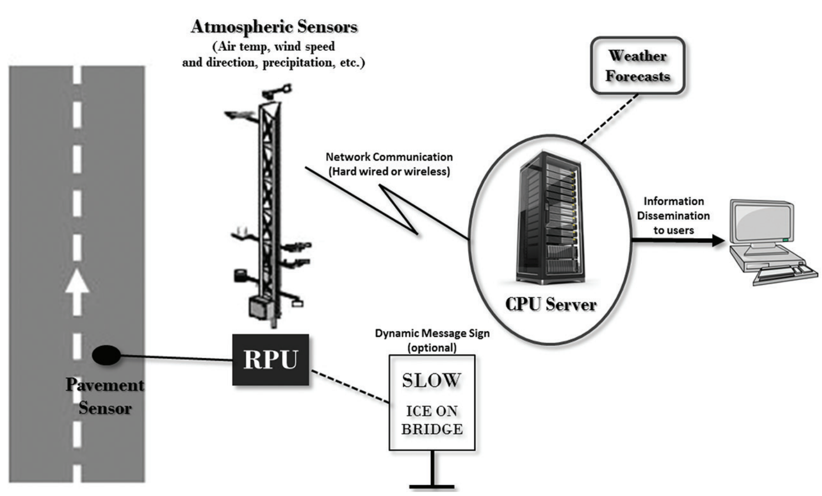
The goal of this project was to develop a methodology for optimizing the density and location of a road weather information system (RWIS) network for a given region based on its topographic and weather characteristics.

Background

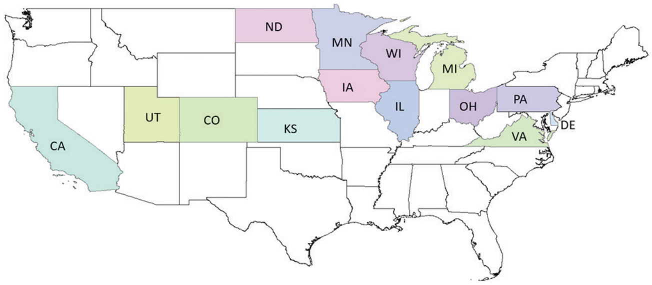
Winter road maintenance is one of the most critical activities for transportation agencies, especially for cold-region countries. The significant and critical information needed for making winter road maintenance decisions is related to road condition and weather data, which are often collected, processed, and transmitted by RWISs. Effective and efficient planning of RWIS networks is a must and needed for maximizing the monitoring coverage and benefit of RWISs. The effectiveness of an RWIS network depends on its density and spatial distribution.

Problem Statement

Many North American transportation agencies have invested millions of dollars to deploy RWIS stations to improve the monitoring coverage of winter road surface conditions. However, the significant costs of these systems motivate governments to develop a framework to optimize the spatial design of the RWIS network. The design of these networks often varies by region, and it remains an unresolved question what should be the optimal density and location of an RWIS network to provide adequate monitoring coverage of a given region.



Major components of an RWIS station



Study area for location optimization

Project Description

A series of geostatistical spatiotemporal semivariogram models were constructed and compared using topographic position index (TPI) and weather severity index (WSI) to measure relative topographic variation and weather severity, respectively. Specifically, this project considered the nature of spatiotemporally varying RWIS measurements by integrating larger case studies and examining two analysis domains: space and time. The study area captured varying environmental characteristics, including regions with flatland or varied terrain and different severities of winter weather.

The optimal RWIS density and location for different topographic and weather severity regions were determined using spatiotemporal semivariogram parameters.

Key Findings

- A spatiotemporal analysis concluded strong dependency of spatial and temporal autocorrelation ranges of RWIS measurements with TPI and WSI values from their associated regions. The zone with the highest topographic variation (a mountainous region) had a shorter range of spatiotemporal structure, whereas zones with lower TPI values (e.g., flatland regions) had a higher range. Similarly, areas with less severe weather tended to have a higher spatial range, whereas areas with more severe weather had a lower range in spatial autocorrelation.

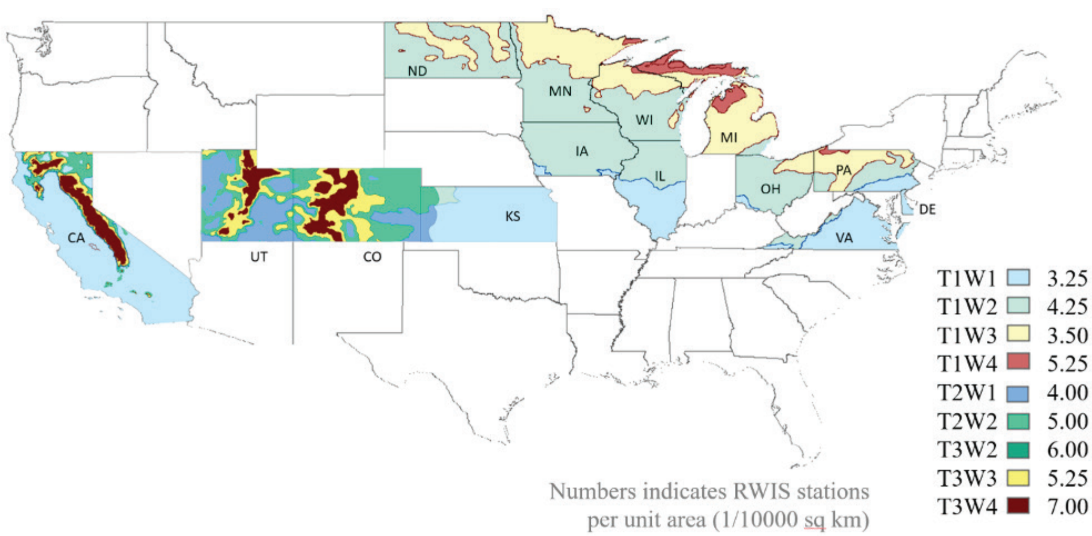
- The RWIS location allocation framework was extended to account for both spatial and temporal attributes of road weather conditions and provided more complete and conclusive location solutions. In addition, the framework reestablished in this work provides an important basis for strategically locating regional RWIS stations, which are optimal in collecting measurements over space and time.

- A series of RWIS density curves were generated, and an optimal RWIS chart was created for the first time in literature, providing a decision-support tool to transportation authorities that need to plan an RWIS network without having road weather and surface condition data.

- The desired RWIS density shows a strong dependency on topography and weather characteristics of the region under investigation. Higher RWIS density is required for regions with high topographic variation and high incidence of severe weather, while lower RWIS density is needed for less varied topographic regions with less incidence of severe weather to achieve similar levels of monitoring coverage.

Implementation Readiness and Benefits

The solutions developed in this project were integrated into LoRWIS (www.lorwis.com), a prototype web-based RWIS location visualization platform for demonstrating the proposed models and the resulting solutions.



Optimal RWIS density map

Recommendations for Further Research

- The geographic study area included in this project consisted of largely flatlands, with few hilly and mountainous regions due to data availability issues. Hence, more case studies consisting of wider geographic regions should be conducted for a better understanding of the relationship between spatial range of autocorrelation in road surface temperature (RST) and the topographic and weather features to develop a more robust quantitative relation between these parameters.

- The study period of this project was limited to one winter season including six months from October 2016 to March 2017. Thus, larger temporal ranges could be considered to improve the level of confidence in the outcomes.

- Universal kriging or kriging with external drift could be applied considering meteorological parameters (wind speed and direction, precipitation, humidity, cloud cover, vegetation cover, etc.) to better capture the dependency of RST data (or other key parameters, including road surface condition index) on local meteorological parameters.

- Lastly, a sensitivity analysis could be conducted to investigate how the resulting optimal densities would change with respect to some of the factors considered in the analysis, especially those coefficients used to generate WSI (or even a winter severity index model) and TPI classification schemes.