A SYSTEMATIC APPROACH TO THE PLANNING OF A REGION-WIDE RWIS NETWORK

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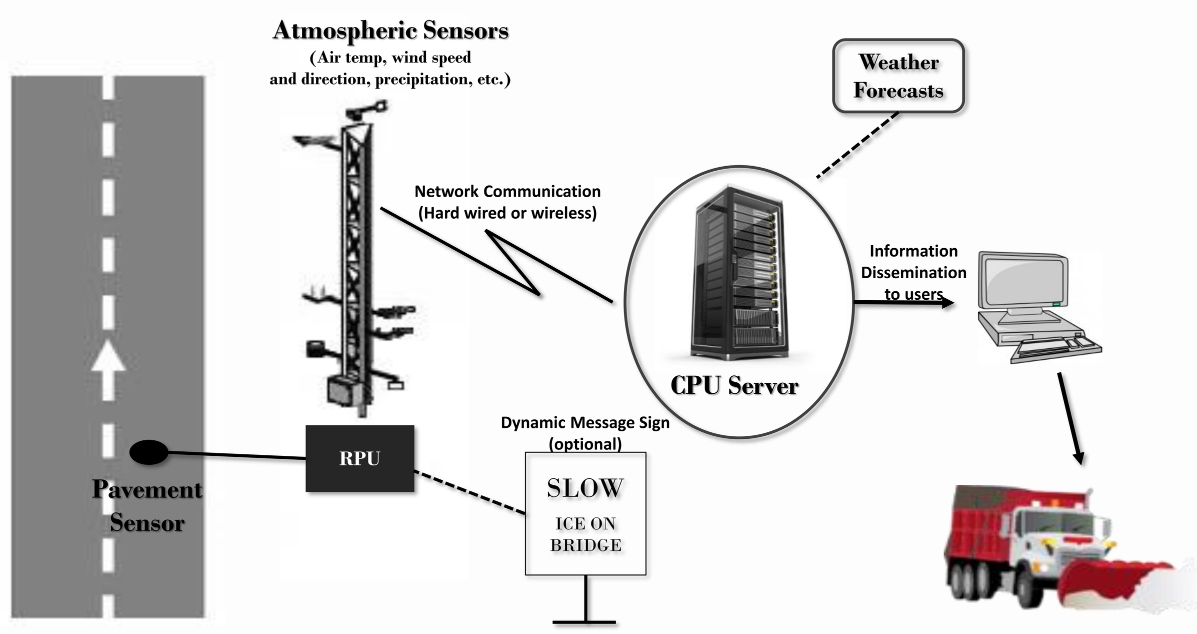
Introduction

BACKGROUND

Effective winter road maintenance (WRM) is indispensable in countries with severe winter weather events, which could cause significant increases in road collisions and traffic delay. To promote safer and more efficient driving conditions, many transportation authorities expend more than $3-billion annually on winter road maintenance, such as plowing and salting.

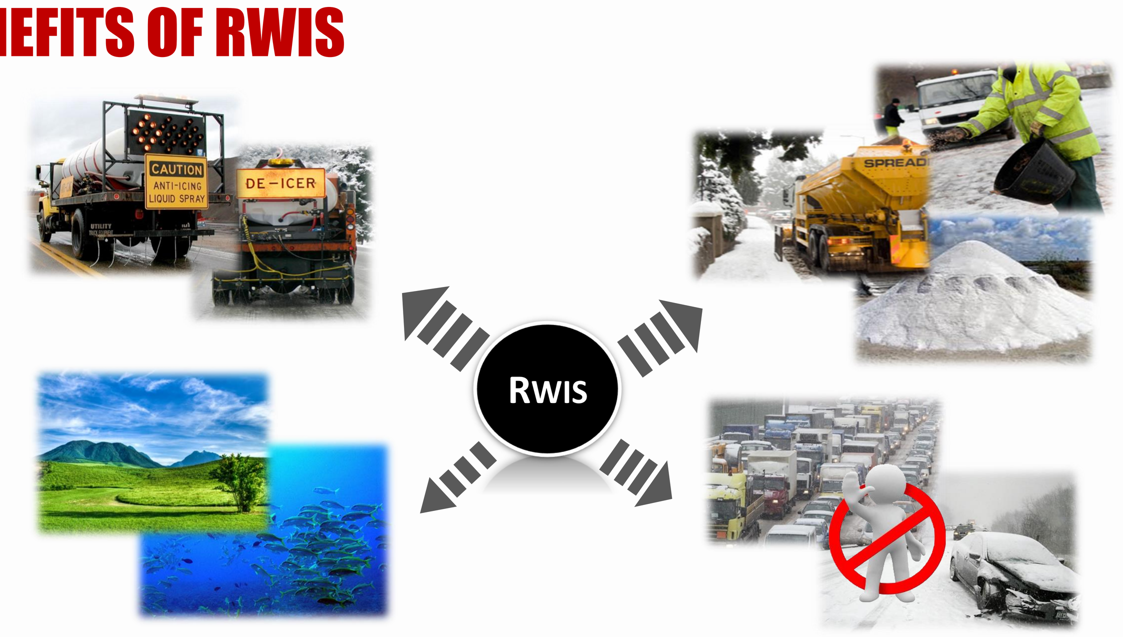
One possible approach to improve the decision-making process of WRM operations is to utilize ***Road Weather Information System***.

DESCRIPTION OF RWIS



Road weather information systems (RWIS) provide information on current and near-future road weather conditions based on the data gathered at RWIS stations.

BENEFITS OF RWIS



RESEARCH MOTIVATIONS and OBJECTIVE

- Transportation agencies are challenged by the high installation and operational costs of RWIS.
- Existing methods do not account for the trade-off between multiple location optimization criteria, and the ultimate use of RWIS information
- The objective is to develop a systematic framework to optimize the spatial design of a regional RWIS network.

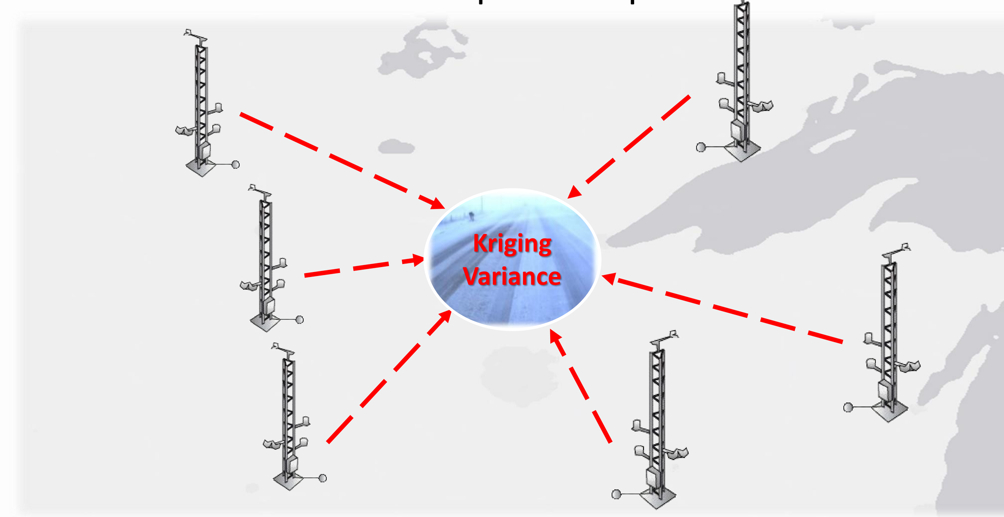
Methodology

THE IDEA – KRIGING FOR SPATIAL INFERENCE

The Basic Premise

- kriging variance is calculated to reflect the needs for installing RWIS stations for improved WRM operations (i.e., increase of monitoring capability)

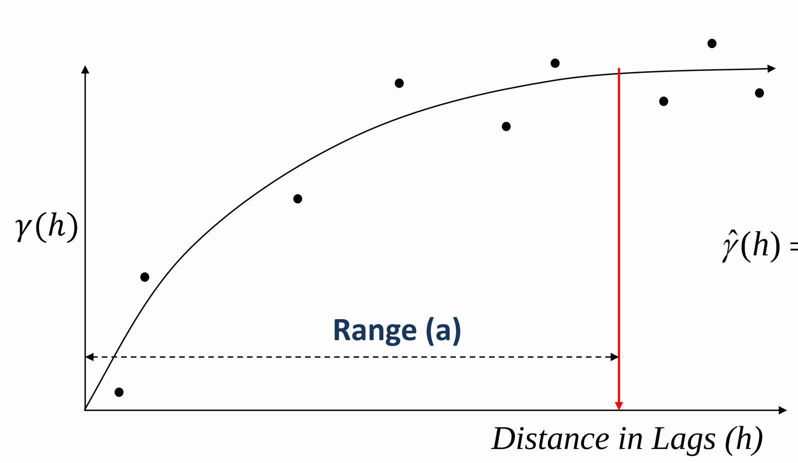
A Simple Example:



Collective use of information from individual RWIS stations

SEMIVARIOGRAM – BUILDING A SPATIAL STRUCTURE

Semivariogram is used to quantify the underlying spatial structure of the regionalized random variable to be monitored.



$$\hat{\gamma}(h)=\frac{1}{2m(h)}\sum_{k=1}^{m(h)}\left[z(x_k+h)-z(x_k)\right]^2$$

PROBLEM FORMULATION

The objective is to minimize the sum of average kriging variance and maximize the coverage of collision-prone areas based on the configuration of RWIS network.

A solution set — *Sum of average Kriging error variance* — *Sum of average collision frequency*

$$\min_{X\subset\Omega}\ \phi(X)=\left[\frac{1}{N}\cdot\sum_i\left(\sqrt{\sigma^2[\hat{z}(i)\mid X)]}\cdot\omega_1\right)+\frac{1}{M}\cdot\sum_i\left(\mu_i^{-1}\cdot\sum_k y_{k,i}\right)\cdot\omega_2\right],\ \forall i\in N,\ \forall k\in M$$

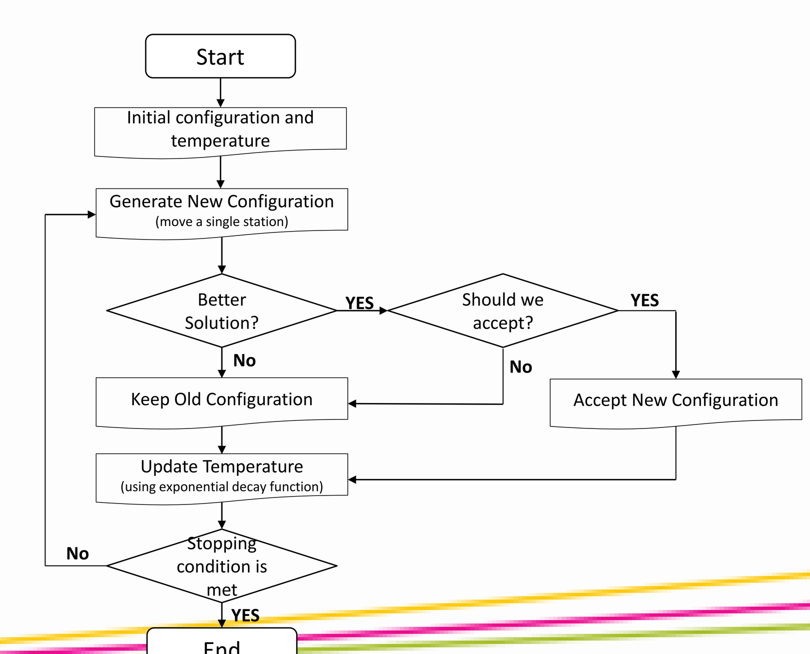
s.t.

$$y_{k,i}\in\{0,1\}\ \ \forall i\in N,k\in M$$ *Decision variable*

$$\sum_i\sum_k c_{k,i}\cdot y_{k,i}\le B,\ \forall i\in N,k\in M$$ *Cost limit of deploying RWIS*

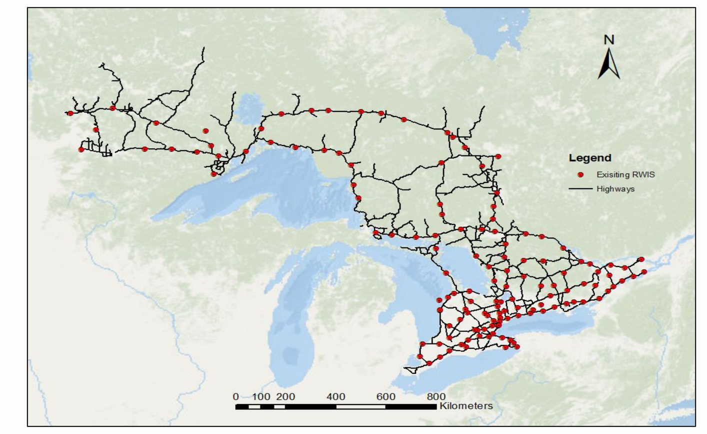
$$\sum_i\sum_k y_{k,i}=M,\ \forall i\in N,k\in M$$ *Ensuring the deployment of a fixed number of RWIS*

OPTIMIZATION WITH SPATIAL SIMULATED ANNEALING

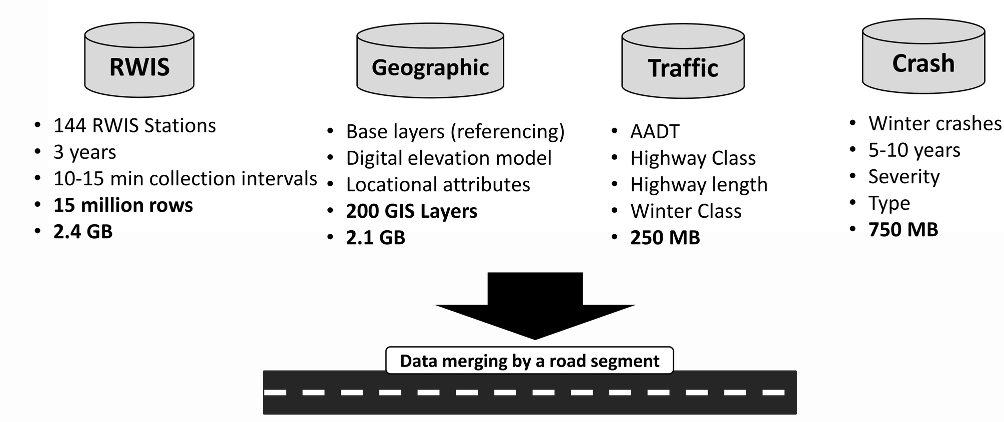


Case Study

ONTARIO RWIS NETWORK

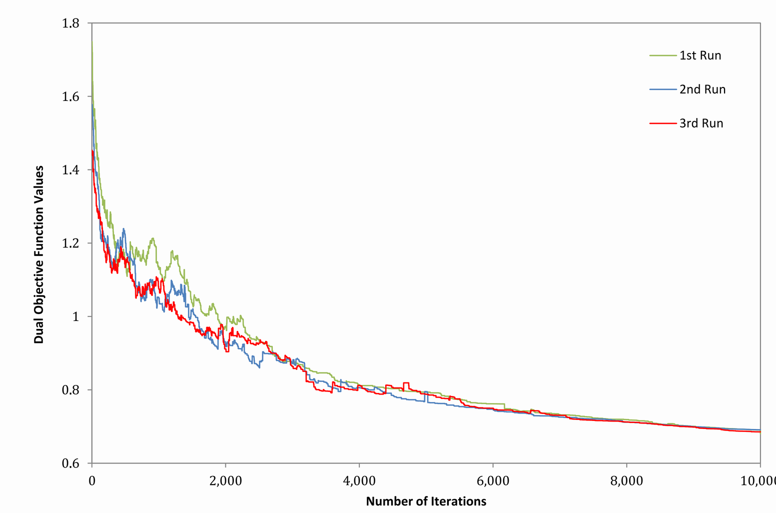


LARGE-SCALE DATA PROCESSING USING GIS



THE OPTIMIZATION AND ITERATION SCHEDULE

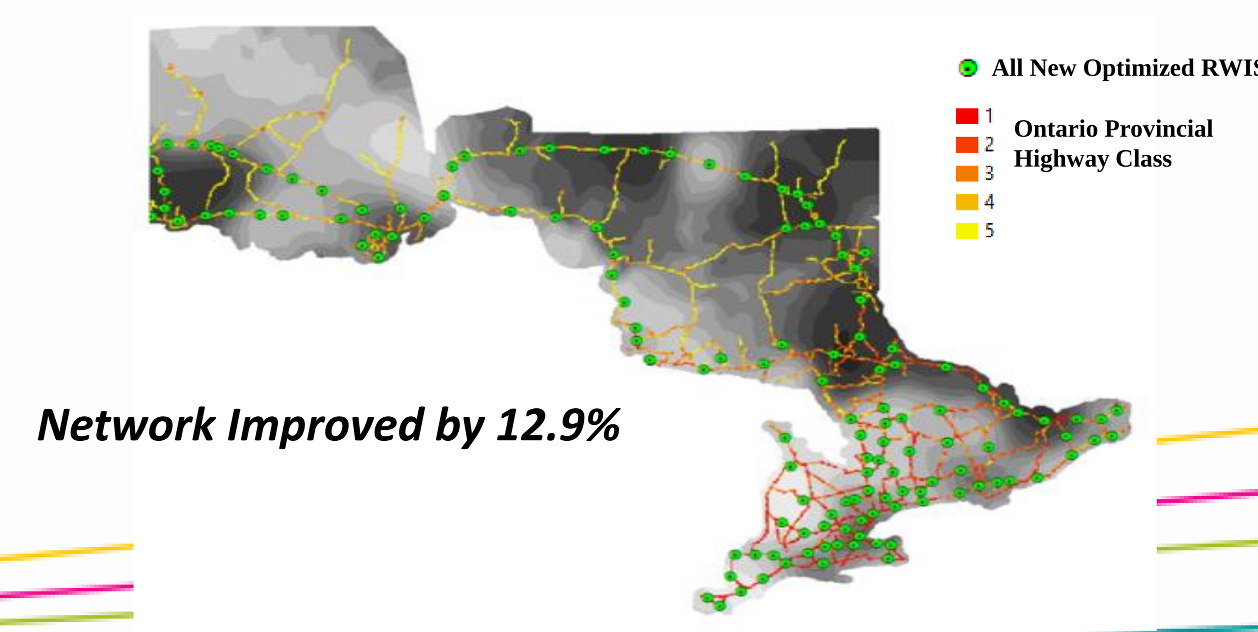
- The optimization was run over a total of 10,000 iterations in generating each optimal network design solution
- Analyses were performed on a windows operating desktop equipped with a 3.39 GHz processor and 8.00 GB of RAM



Application

ALL-NEW RWIS STATIONS

- For evaluating the location quality of the current RWIS network

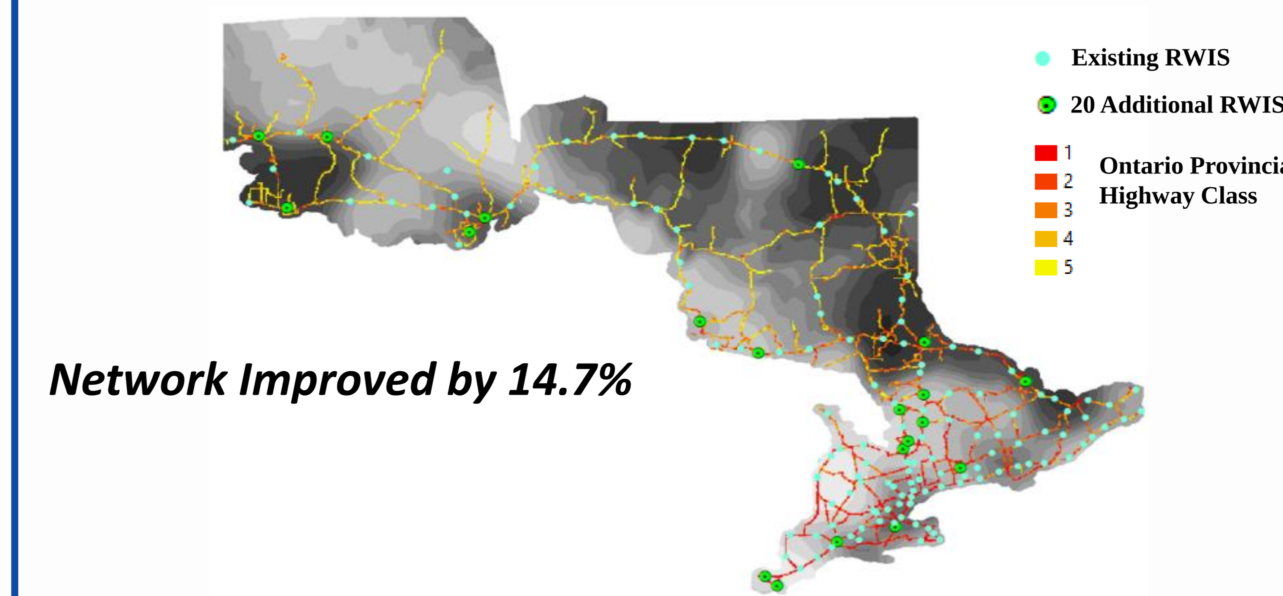


Network Improved by 12.9%

Application cont'd

EXPANSION OF RWIS NETWORK

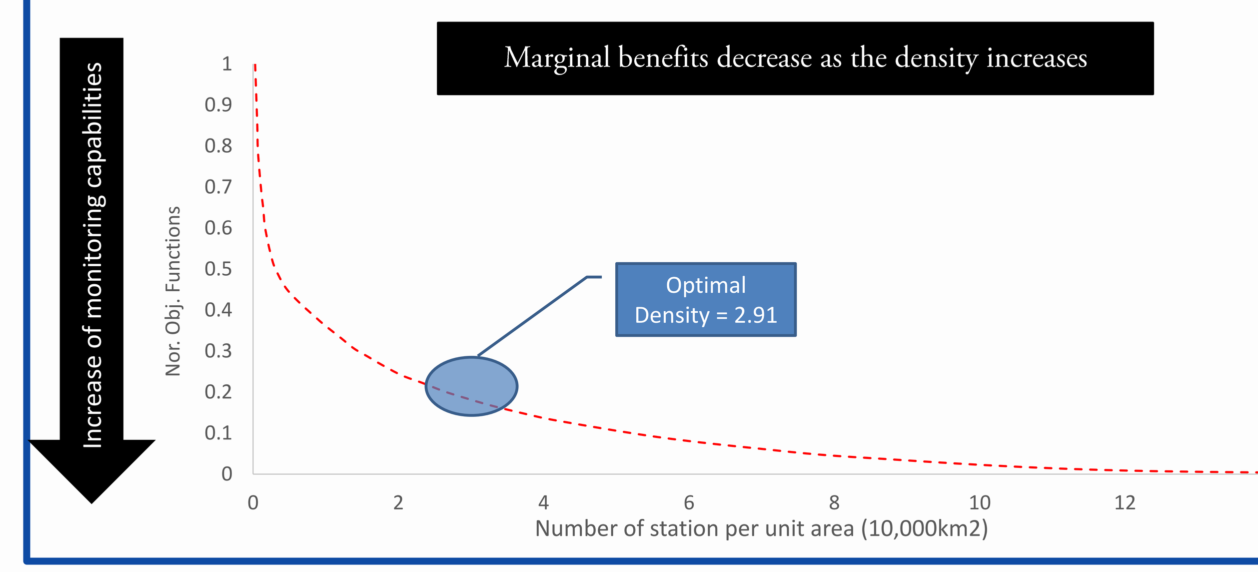
- For determining the location for additional RWIS stations



Network Improved by 14.7%

OPTIMAL DENSITY

A Comparison of RWIS Density Charts - per unit area (10,000km^2)



Conclusions

- The proposed method is the first of its kind that provides transportation agencies with a tool that helps them evaluate the current RWIS network and determine the optimal location and density of RWIS stations.
- The proposed method represents the first attempt to address the challenging problem with a formal mathematical programming approach.
- More case studies should be conducted to investigate the generality and sensitivity of the model results to external conditions including network size, size of grid, parameters used in the SSA, and input parameters including use of other traffic variables and weather variables.

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Aurora working to advance road weather information systems technology