10-2014

Quantifying Uncertainty in Real Time Performance Measurement for Highway Winter Maintenance Operations – Phase 2

Jillian Lyon
Iowa State University, jdlyon@iastate.edu

Zhengyuan Zhu
Iowa State University, zhuz@iastate.edu

Mark Steven Kaiser
Iowa State University, mskaiser@iastate.edu

Quantifying Uncertainty in Real Time Performance Measurement for Highway Winter Maintenance Operations – Phase 2

Abstract
Winter weather in Iowa is often unpredictable and can have an adverse impact on traffic flow. The Iowa Department of Transportation (Iowa DOT) attempts to lessen the impact of winter weather events on traffic speeds with various proactive maintenance operations. In order to assess the performance of these maintenance operations, it would be beneficial to develop a model for expected speed reduction based on weather variables and normal maintenance schedules. Such a model would allow the Iowa DOT to identify situations in which speed reductions were much greater than or less than would be expected for a given set of storm conditions, and make modifications to improve efficiency and effectiveness. The objective of this work was to predict speed changes relative to baseline speed under normal conditions, based on nominal maintenance schedules and winter weather covariates (snow type, temperature, and wind speed), as measured by roadside weather stations. This allows for an assessment of the impact of winter weather covariates on traffic speed changes, and estimation of the effect of regular maintenance passes. The researchers chose events from Adair County, Iowa and fit a linear model incorporating the covariates mentioned previously. A Bayesian analysis was conducted to estimate the values of the parameters of this model. Specifically, the analysis produces a distribution for the parameter value that represents the impact of maintenance on traffic speeds. The effect of maintenance is not a constant, but rather a value that the researchers have some uncertainty about and this distribution represents what they know about the effects of maintenance. Similarly, examinations of the distributions for the effects of winter weather covariates are possible. Plots of observed and expected traffic speed changes allow a visual assessment of the model fit. Future work involves expanding this model to incorporate many events at multiple locations. This would allow for assessment of the impact of winter weather maintenance across various situations, and eventually identify locations and times in which maintenance could be improved.

Keywords
Performance measurement, Traffic flow, Traffic speed, Weather conditions, Winter maintenance, Adair County (Iowa), RB03-013

Disciplines
Civil Engineering

Comments
The related 30-page full report, under the same title, can be found in http://lib.dr.iastate.edu/intrans_reports/

IOWA STATE UNIVERSITY
Institute for Transportation

October 2014

Quantifying Uncertainty in Real Time Performance Measurement for Highway Winter Maintenance Operations – Phase 2

tech transfer summary

An updated expected speed reduction model would allow state agencies to better identify situations for a given set of storm conditions and make modifications to improve efficiency and effectiveness.

RESEARCH PROJECT TITLE
Quantifying Uncertainty in Real Time Performance Measurement for Highway Winter Maintenance Operations – Phase 2

SPONSORS
Federal Highway Administration
Iowa Department of Transportation
(InTrans Project 13-388)

PRINCIPAL INVESTIGATOR
Zhengyuan Zhu, Associate Professor
Statistics, Iowa State University
515-294-0519
zhuz@iastate.edu

CO-PRINCIPAL INVESTIGATOR
Mark Kaiser, Professor
Statistics, Iowa State University

MORE INFORMATION
http://www.intrans.iastate.edu/

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

The mission of the Institute for Transportation (InTrans) at Iowa State University is to develop and implement innovative methods, materials, and technologies for improving transportation efficiency, safety, reliability, and sustainability while improving the learning environment of students, faculty, and staff in transportation-related fields.

Background

Winter weather in Iowa is often unpredictable and can have a large impact on traffic flow. The Iowa Department of Transportation (DOT) attempts to lessen the impact of winter weather events on traffic speeds with various maintenance operations.

To assess the performance of these maintenance operations, it is necessary to come up with a model for expected speed reduction based on different winter weather variables and normal maintenance schedules. Such a model would allow the Iowa DOT to identify situations where speed reductions were much greater than they should have been for a given set of storm conditions.

Problem Statement

In 2009, Qiu and Nixon developed a model to predict speed reduction. This model was then modified in 2011 by Greenfield et al. The researchers reviewed these previously developed models as well as discussed further modifications to introduce more variability into the model inputs. Although these modifications were an improvement, they still needed to account for variability in the model structure itself.

Project Objectives

- Predict speed changes relative to baseline speed under normal conditions, based on nominal maintenance schedules and winter weather covariates (e.g., snow type, temperature, and wind speed), as measured by roadside weather stations
- Assess impact of winter weather covariates on traffic speed changes and estimate the effect of regular maintenance passes

Research Description

The researchers chose events from Adair County, Iowa and fit a linear model with winter weather covariates (e.g., snow type, temperature, and wind speed). A Bayesian analysis was conducted to estimate the values of the parameters of this model.

Specifically, the analysis produced a distribution for the parameter value that represents the impact of maintenance on traffic speeds. To get an idea about the impact of individual weather covariates on speed reduction, the following was developed:

- An expert survey with the goal of using the survey results to incorporate variability into the structure of the previous model
- An exploratory analysis of the sensor data to help formulate a hierarchical model for storm events at individual locations

Key Findings

A dynamic linear regression model for storm events at individual locations was developed which takes into account both winter weather variables and plow operation schedules. The researchers used deviation from "normal" traffic speeds as their response instead of deviation from the posted speed limit, which is different from previous models.

Other key findings include the following:

- Using temperature in the model as measured by the absolute deviation from freezing as opposed to using the raw temperature value shows how this new model does a good job predicting the expected value of speed reduction and capturing the inherent variability of the data
- The effect of maintenance is not a constant, but rather a value that the researchers have some uncertainty about
- Examinations of the distributions for the effects of winter weather covariates are possible.
- The research model can be expanded to multiple locations

Implementation Readiness and Benefits

The researchers developed a hierarchical model that takes into account the effect of winter weather covariates as well as maintenance operations on speed reduction during snow events in Adair County, Iowa. This model proved to do a good job predicting the speed reduction from the baseline over time as well as in capturing the variability in the data.

An updated expected speed reduction model would allow state agencies to better identify situations for a given set of storm conditions and make modifications to improve efficiency and effectiveness.

Future work needs to be done to achieve the goal of using this model as a performance measurement tool. Namely, a third level in the hierarchical model needs to be added to allow for estimation of the distributions of the parameter values across all events for a given location.

Once these parameter distributions are estimated, performance as a storm event is occurring can be better assessed. Also, the effect of certain covariates on traffic speeds across multiple locations can then be compared.

References

Greenfield, Tina, Matt Haubrich, Mark Kaiser, Jing Li, Zhengyuan Zhu, and Daniel Fortin. *Winter Performance Measurement Using Traffic Speed Modeling*. Iowa Highway Research Board, Iowa Department of Transportation, 2011.

Qiu, Linn and Wilfred Nixon. *Performance Measurement for Highway Winter Maintenance Operations*. IIHR Report 474. Iowa Highway Research Board, 2009.