Transportation Synthesis Report

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Using Friction Measurements to Gauge Winter Maintenance Performance

Prepared for
Clear Roads Pooled Fund Study

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Request for Report

Incorporating real-time road surface friction measurements into winter maintenance activities has the potential to increase efficiency and help agencies better target their maintenance efforts to the areas experiencing the worst driving conditions. For many years, highway agencies in Japan and Europe have used friction indicators to help them evaluate winter road conditions and winter maintenance performance. More recently, some agencies in the United States have begun testing friction measurement devices. Because limited research has been performed to assess the applicability and benefits of this technology, there is a need to evaluate the feasibility of using these devices as tools for improving winter maintenance operations and mobility. As the lead state for the Clear Roads pooled fund, Wisconsin DOT asked us to locate research and information on whether friction measurements are realistic, effective and reliable winter maintenance performance indicators, with an emphasis on how transportation agencies are using friction measurements to assess road conditions.

Summary

We identified several U.S. and foreign highway agencies that are using or investigating friction measurements in winter maintenance operations or performance measurement. We present five **State DOTs' Experiences** with a friction measurement device, and several **U.S. and International Research** reports on friction measurement. Highlights include:

- Several state DOTs are using the **RT3 Real Time Traction Tool** to support winter maintenance research and practice. The RT3 measures road surface friction under winter conditions using an auxiliary wheel that attaches to a truck's undercarriage or can be towed behind a vehicle. We interviewed five agencies about their experiences with the RT3.
- NCHRP Web Document 53, *Feasibility of Using Friction Indicators to Improve Winter Maintenance Operations and Mobility*, reviews domestic and foreign practices on the use of friction indicators for winter maintenance operations **decision making** and **performance evaluation** and for providing **motorist information.**
- Minnesota DOT researchers are exploring the **automation of winter road maintenance** using real-time friction and pavement temperature measurements.
- Norway's **Winter Friction Project** used several standards and measures, including a **friction standard**, to evaluate the performance of different friction improvement methods (such as salting and sanding).

State DOTs' Experiences

This section describes one friction testing instrument and several agencies' experience using it in the field.

RT3 Real Time Traction Tool, Halliday Technologies Inc.
http://www.hallidaytech.com/products.htm
The RT3 measures road surface friction under winter conditions using an auxiliary wheel that attaches to a truck's undercarriage or can be towed behind a vehicle. The friction testing wheel is set at a slight side angle, creating a force that is measured and converted into an electrical signal, which is then transmitted to a computer inside the cab. Friction readings are presented to the operator as colored lights on a display: green indicates safe driving conditions, yellow indicates roads where caution is needed, and red indicates dangerous areas that require immediate attention. Operators and supervisors can use the data to help determine when to start and stop treatment, to modulate the amount of chemical used, and to measure effectiveness of the larger treatment process. Friction data can also be sent to a secure Web site to provide a real-time picture of changing road surface conditions.

HTI Director Don Halliday said that several transportation agencies have acquired the RT3, including seven state DOTs, the Japan Civil Engineering Research Institute, the Ontario Ministry of Transportation and the Swedish Road Authority. We spoke with five of the agencies about their use of the units, and summarize those discussions below:

Ohio DOT
Contact: Diana Clonch, Snow & Ice Coordinator, Office of Maintenance, (614) 644-7159 or Diana.Clonch@dot.state.oh.us.
"Ohio has a number of the units. Our maintenance administrator, Keith Swearingen, was instrumental in working with Halliday to develop them. We started out with a prototype that seemed to work well, and then we added four more units. At that time, they were all underbody units that were installed beneath a snowplow. Our director asked us to also look at developing a unit that could be utilized on a regular passenger vehicle such as a supervisor vehicle or other type of maintenance vehicle, so we worked with Halliday to develop the tow-behind unit. We've been extensively testing both types of units to validate their consistency within themselves, their consistency compared to other models, and the consistency, accuracy and reliability of their data. We feel pretty comfortable that the numbers we're getting from the units are very indicative of roadway conditions—the slickness, or lack of friction—on a road surface.

"We currently have about a dozen of the underbody units and eight to 10 tow-behinds and use the data in a number of ways. It helps operators make a good call for when, and how, to treat roads and bridges—that can be critical in the event of black ice formation or when freezing rain is transitioning to ice. The data is also retrieved for review in tabular or graphical form, allowing maintenance managers to see where improvements could be made in the process; for example in fine-tuning route assignments, application and placement of equipment, and identifying locations of potential overkill or weak areas. We're to a point now, within the agency, to look at when and how to fully integrate the RT3 into winter maintenance operations: type of units needed and how many of each, where should they be deployed, when and where to incorporate this tool into the decision making process. In the long run, we would like to see data that is collected from the units being used to help alert motorists to hazardous driving conditions. RT3 data would also be a great tool for providing an indicator of continuity of service across jurisdictional boundaries."

Utah DOT
Contact: Lynn Bernhard, Maintenance Methods Engineer, (801) 964-4597 or lynnbernhard@utah.gov.
"We have two units installed on SUVs. Our experience so far has just been a test bed, learning how to use the equipment—we don't yet have the RT3 in production as a decision making or performance recording tool. But we have used the grip readings as an empirical evaluation of the condition of roads—'this road is much worse than that road'—that kind of thing. The measurements that we've gotten match our visual identification of road conditions.

"We intend to use the RT3 to monitor and predict winter maintenance efforts on the highway. Once we know what we're getting, we also track how much effort we're putting in—how many trucks, how much salt and sand, how long they're out—we're tracking that in another system. We have confidence we'll be able to match road traction performance with effort and with storm type. And we're going to come up with operating curves that we'll use to say, 'With this type of storm and with this type of effort, we predict this is what's going to happen,' so we can put out the warnings to drivers. We want to use the traction data with

our predictive models to do roadway condition forecasts that then can be published on variable message signs and on our commuter link Web site. Right now we're gathering all this data about the road conditions by hand—the guys call in and report it twice a day, and it just isn't real timely.

"We anticipate equipping probably 150 of our 600 plow trucks with the Halliday wheels, so that when the operators are out pushing snow, we'll be getting continuous conditions readings on their roads. The measurements from the field will be transmitted electronically to our Traffic Operations Center in Salt Lake City, and we will have the data there, with location, time, temperature and traction. We are going to procure the geographic positioning interface that will provide us with that information."

Virginia DOT
Contact: Dan Roosevelt, Research Scientist, (434) 293-1924 or dan.roosevelt@vdot.virginia.gov.
"We have three RT3s, all installed on dump trucks that operate in the field. Readings from the RT3 give the snowplow operator a feel for the grip on his vehicle. For example, if an operator is riding down the road and the pavement looks black, and he's not sure whether it's icy or just wet, he can use the readings from the RT3 to determine what the slip or grip is, and then decide whether he wants to put down more chemical. The operators who I've dealt with concerning the units have been pleased with the information they've obtained from the units—it's been valuable and useful to them. Data from the RT3 can be stored and retrieved for review—a data-logger was developed specifically for this unit that records data every two seconds, stamps it for time and date, and GPS-locates it. You can also collect data from the RT3 by plugging it directly into a laptop computer, and it will download data as it is produced by the load cell on the unit—you can get 10 friction readings per second. We're using this capability experimentally.

"One thing we're finding is that the location where you measure friction makes a lot of difference—there can be a lot of variation across a roadway in terms of what your friction is. You can measure in the wheel tracks and get one reading, and you can measure between the wheel tracks where there's still snow accumulated on the pavement and get a much different reading. Usually, your readings between the wheel tracks are considerably lower than the ones from the wheel tracks. We're using the RT3 as well in a couple of research projects we're doing on a surface overlay product that provides a gradual release of deicing chemical. We're using the unit during snowstorms on the test location and the control section to see whether there's any difference in friction."

Wyoming DOT
Contact: Chuck James, Engineer Technician Supervisor, Blowing Snow Research Team, (307) 777-4138 or chuck.james@dot.state.wy.us.
"We've primarily used the RT3 as a research instrument, for some studies that we are doing on blowing snow and black ice. In one instance, we had the RT3 on and were going down the Interstate. The road was snow-packed. We were getting some low friction values—the RT3 was indicating that the road was pretty slick. A snowplow then came off of the on-ramp and merged in front of us. The snowplow was dropping gravel, and when we reached the area where the gravel had fallen, the RT3's friction values changed dramatically, indicating significant improvement. I think it's a valuable instrument, and would be a particularly useful tool in metropolitan areas, especially back East, where they get a lot of black ice and high traffic."

Ontario Ministry of Transportation
Contact: Max Perchanok, Research Coordinator, Provincial Highways Management Division, (416) 235-4680 or max.perchanok@ontario.ca.
"We have a little bit of experience using the RT3. We had a similar model for about a week or two last winter—it was operated by one of our consultants. I think that operated through three winter storms. And this year we had one for three days, just for a short demonstration. The purpose of using it last year was to support an operational test of different salting methods. We wanted to see whether the methods would eliminate frost, and make sure that we had the same traction level on our normally icy spots—bridge decks—that we had on the adjacent pavement. For that purpose the consultant ran the unit over about 30 kilometers of highway that included a number of bridge decks, and they are doing an analysis of friction levels on the bridge decks and the non-bridge decks.

"Going forward, we are considering using friction as a performance measure for winter operations, so that's why we had the unit this year. We've been doing a demonstration of that idea using a different friction device, and we wanted to have some comparison with the Halliday wheel. Right now we have a compared pavement standard, so it's kind of a subjective interpretation of when we have bare pavement. We trying to see whether the objective measure is better for us than the subjective measure, and if we do that, what friction level are we looking for."

U.S. and International Research

Feasibility of Using Friction Indicators to Improve Winter Maintenance Operations and Mobility, NCHRP Web Document 53 (Project 6-14): Contractor's Final Report, November 2002.
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w53.pdf
This research reviewed domestic and foreign practices on the use of friction indicators for winter maintenance operations decision making and performance evaluation and for providing motorist information. The study found that data collected from low-cost, reliable friction measuring devices could be analyzed with other data, such as pavement temperature and traffic and weather conditions, and used to allocate snow-fighting resources in real-time. The research suggests that a traction control system is the most promising technology for practically and safely measuring friction in winter conditions, followed closely by deceleration and slip devices. Forecasting surface friction based on models that use data such as temperature and traffic was also identified as a promising technique.

Report highlights include the following topics (page numbers refer to the PDF version of the document):

- Page 33: The Norwegian Public Roads Administration's use of the 'Digi-slope' friction measuring device to **evaluate different types of deicing materials**. The device operates when a test vehicle brakes at 40 kph with locked wheels. NPRA uses it to evaluate brine suitability under varying temperatures, precipitation intensity and road conditions.
- Page 35: Japan's use of friction measurements to **determine de-icing application amounts** and the **effectiveness of deicer effusion methods**.
- Page 40: Three methods of using friction measurements for winter maintenance performance evaluation:
    - The **threshold level** approach: defining a friction value as the cutoff point between safe and unsafe conditions
    - The **contaminant classification** approach: defining the types of surface contaminants that are permitted under specified weather conditions
    - The **spatial homogeneity** approach: determining spatial variability between friction readings, with a goal of maintaining similar driving characteristics over long distances so that drivers can adjust to road conditions.
- Page 41: Details of an experiment conducted by the Swedish National Road and Traffic Research Institute to **study driver behavior on winter roads,** which concluded that drivers are very poor at evaluating different friction conditions and would benefit from a simple friction indicator that could communicate friction conditions to them. The NCHRP study authors note that since little information on road friction is currently communicated to motorists, it may be necessary to teach drivers the significance of the relationship between road friction and vehicle handling.
- Page 49: Description of a **deceleration device** called the C-mu used in Norway, which uses a measuring principle based on recording braking time and the speed when braking starts and ends.
- Page 53: Description of an **ABS-based friction measuring system,** the AeroTechTelub MoRRS (Mobile Road Reporting System).
- Page 70: Summary of **survey responses** from roadway agencies. Respondents believed the use of friction measurements would improve winter maintenance operations.

Automated Winter Road Maintenance Using Road Surface Condition Measurements, Minnesota DOT, TRB Research in Progress database.
http://rip.trb.org/browse/dproject.asp?n=10618
This project's objectives include automating winter road maintenance using real-time measurements from a friction measurement system and a pavement temperature measurement sensor, and evaluating the performance of an automated winter maintenance system on a Safeplow.

Methods for Measuring and Reporting Winter Maintenance Activities, T. Vaa, *Transportation Research Record No. 1741*, 2001, pages 152 to 158.
http://pubsindex.trb.org/document/view/default.asp?lbid=688983
Norway's Winter Friction Project addressed the practical, technical and economic problems that arise in providing good friction conditions on winter roads. The project began in 1997 and a final report was scheduled for 2002. Field studies consisted of a testing program to document the performance of different friction improvement methods. A friction standard was among the measures used to evaluate the difference in conditions achieved on salted and sanded roads.

The Potential of Friction as a Tool for Winter Maintenance, Final Report of Project TR 400, Iowa DOT, February 1998.
http://www.operationsresearch.dot.state.ia.us/reports/reports_pdf/hr_and_tr/reports/tr400.pdf
This study explores the possibility of using friction as an operational tool in winter maintenance, with a focus on the relationship of friction to traffic volume, traffic speed and accident rates. The report discusses the steps required to bring friction from its current state as a research tool to full deployment as an operational tool. Researchers concluded that friction devices could be developed to become an integrated part of winter maintenance activities, likely through expert systems control.

Highlights include:

- **Section 3.2, Friction Studies.** Winter maintenance studies in which measuring friction was a primary goal.
- **Section 3.3, Friction as a Standard of Winter Maintenance.** Discussion of Finland and Norway's experiences using friction measurements as a way to set standards for winter maintenance.
- **Section 5, System Integration and Development.** Review of potential problems with friction measuring equipment, and suggested approaches to address them.

On-line Estimation of Friction Coefficients of Winter Road Surfaces Using Unscented Kalman Filter
T. Nakatsuji and P. Ranjitkar, Hokkaido University; I. Hayashi, Hitachi Ltd.; T. Shirakawa and A. Kawamura, Kitami Institute of Technology; Paper Number 07-2136, TRB 86th Annual Meeting Compendium of Papers CD-ROM.
This study developed an online system that uses the unscented Kalman filter to estimate the friction coefficient of winter road surfaces from vehicular motion data measured by a probe vehicle equipped with a GPS device and a motion sensor. Following a brief description of Kalman filter theory, the authors present a procedure for estimating the friction coefficient in a feedback manner using the new filter.

Joint Winter Runway Friction Program Accomplishments
Thomas Yager et al., presented at the Virginia DOT and Virginia Tech Pavement Evaluation 2002 Conference
http://pms.nevadadot.com/2002presentations/33.pdf
This paper describes the activities and accomplishments of the Winter Runway Friction Measurement Program, a joint effort of the National Aeronautics and Space Administration, Transport Canada and the Federal Aviation Administration. The program, which had recently completed its seventh winter season of testing, aims to standardize ground vehicle friction measurements and to establish reliable correlations between ground vehicle friction measurements and aircraft braking performance. At the time of this report, 18 different makes of ground test devices (44 vehicles in total) had been evaluated. Researchers envisioned that test results could also be applied to vehicular safety where winter conditions are severe.