# Papers Related to Winter Maintenance from the 2018 TRB Annual Meeting

## Contents

This compendium of papers related to winter maintenance from the 2018 Transportation Research Board Annual Meeting was prepared by the Clear Roads pooled fund project (#TPF-5(353)). It covers the following topic areas:

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## Equipment

**Cost–Benefit Analysis of Using the Tow Plow for Winter Maintenance**
Paper number 18-01097, http://amonline.trb.org/2017trb-1.3983622/t020-1.3997695/453-1.3997851/18-01097-1.3991507/18-01097-1.3997858
Authors:

Nishantha Bandara, Lawrence Technological University
Elin Jensen, Lawrence Technological University

*Abstract:* Several relationships between winter maintenance cost elements (direct cost such as labor, material, equipment and indirect cost such as travel delay) and snowstorm severity (in terms of snow amount) were developed for two equipment fleet configurations. These configurations included Tow Plows present in the equipment fleet and Tow Plows absent in the equipment fleet. Analysis of these two equipment configurations identified the benefits of using Tow Plows in the equipment fleet for six-lane and four-lane rural freeways in Michigan at different winter storm severity levels. The developed relationships (based several different four- and six-lane lane rural freeway routes) were used to develop the most effective equipment fleet configurations for different Michigan Department of Transportation (MDOT) snow routes. Finally, the cost effectiveness of including Tow Plows in the equipment fleet was analyzed using direct cost and the total cost including delay costs. Results show substantial cost savings on the direct cost as well as total cost (including delay cost) if the recommended equipment

configuration is employed. Use of Tow Plow in the equipment fleet cleared the roadways faster, and the delay costs due to winter storms were greatly reduced. The equipment fleet configuration with Tow Plows can be modified to realize direct cost savings with the use of less regular plows as recommended in this paper.

# Information Systems and Technology

**The Optimal Location of Road Weather Information System in New York State**
Paper number 18-02170, http://amonline.trb.org/2017trb-1.3983622/t020-1.3997695/352-1.3997909/18-02170-1.3991930/18-02170-1.3997916
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Hernan Caceres Venegas, State University of New York, Buffalo
Qing He, State University of New York, Buffalo
Rajan Batta, State University of New York, Buffalo

*Abstract:* Inclement weather is a threat to the safety of transportation systems as well as the efficiency of their operation. A road weather information system (RWIS) is a network of environmental sensor stations (ESS) that collect a range of real-time data about weather and pavement conditions. These systems can support highway officials and civilians in making more informed transportation safety decisions, particularly in times of adverse weather, by giving them more accurate and localized weather information. This enables the proper maintenance activities to be executed and safety to be restored while using minimum resources. However, because of the range of network characteristics and geographical factors affecting the implementation of ESS, no widely adopted guidelines exist that outline where to implement ESS in a network beyond taking into the physical criteria of an appropriate site, although several methods have been suggested. This paper aims to take a practical approach to solving the location problem of RWIS by proposing a unified multi-objective optimization methodology that takes into account vehicular accident data, vehicle miles traveled, area coverage, access to power and maintenance, and existing ESS. This study produces an exact solution method that produces a Pareto set of multiple efficient solutions. The proposed methodology is applied to a real world case study focused on the deployment of additional ESS in the existing RWIS network across New York State. Further, a sensitivity analysis is conducted to examine the effects of different parameters and a non-preference solution is proposed.

**A Geostatistical Approach to Winter Road Surface Condition Estimation Using Mobile RWIS Data**
Paper number 18-04908, http://amonline.trb.org/2017trb-1.3983622/t020-1.3997695/352-1.3997909/18-04908-1.3991929/18-04908-1.3997914
Authors:

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Tony Qiu, University of Alberta
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*Abstract:* In winter, it is critical for cold regions to have a full understanding of the spatial variation of road surface conditions such that hot spots (e.g., black-ice) can be identified for an effective

mobilization of winter road maintenance operations. Acknowledging the limitations in present knowledge and methods, this paper proposes a systematic framework to estimate one of the key road surface condition variables, namely, road surface temperature (RST). The proposed method uses a robust regression kriging method to take account for various geographical factors such as latitude, longitude, and altitude which may affect the variation of RST. LANDSAT satellite images are also incorporated to represent the effect of landuse. A geographic information system (GIS) is used for effective data processing and analysis. A case study of three highway segments in Alberta, Canada is used to demonstrate the feasibility and applicability of the method proposed herein. The findings of this study suggest that the RST predications can be greatly enhanced with help of additional covariates included in the model. The study also shows that there is a strong dependency between the correlation range and the averaged wind speed for improved generalization potentials.

## Are Visibility Data from RWIS Ready for Application?
Paper number 18-05469, http://amonline.trb.org/2017trb-1.3983622/t020-1.3997695/352-1.3997909/18-05469-1.3991927/18-05469-1.3997910
Authors:

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*Abstract:* Adverse weather conditions, particularly those which create low visibility, increase risk for driving. However, quantifying the direct relationship between visibility distance and roadway safety is challenging due to the limitation of visibility data. As part of the integrated Intelligent Transportation System such as an automated warning system and variable speed limit, the growing deployment of Road Weather Information Systems (RWIS) makes segment-specific visibility information more accessible. It is critical to validate the data before applying RWIS visibility measurements in any traffic studies and operations. Hence, this paper is an attempt to examine the validity and viability of RWIS visibility data by comparing visibility measurements among RWIS, airport weather stations, and weather information recorded in crash reports. The results indicated that RWIS visibility measurements were significantly different from the airport counterpart, and recorded fog-related crashes didn't match the visibility data from weather stations at the crash time based on the Ohio data. Therefore, no definitive conclusion regarding the reliability of RWIS visibility can be drawn considering no verified ground truth in these comparisons. It was recommended to conduct additional measurements such as continuous in-field measurements to further validate RWIS visibility measurements, before any applications in use of RWIS visibility data are implemented.

## Monitoring the Road Surface Temperature by Evaluating the Climatological and Ambient Temperature Data Collected from Probe Vehicles Using Machine Learning Technique
Paper number 18-02505, http://amonline.trb.org/2017trb-1.3983622/t020-1.3997695/450-1.3997863/18-02505-1.3997870/18-02505-1.3997871
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*Abstract:* Monitoring road surface temperature (RST) is crucial to develop winter maintenance strategies in traffic safety and proactive congestion management. In that application, traffic operation agencies conventionally have relied on mathematical models for predicting road conditions. Typically those models employ data collected from fixed stations sporadically located over wide network and parameters that can be specific to a site. Besides, taking various interactions among metrological, geographical, and physical road construction variables into a model is almost impossible. This study proposes a new and practical framework to develop and evaluate RST prediction model via one of the off-the-shelf, the Classification Learner application embedded in MATLAB machine learning tool. To develop the model, this study uses climatological information and ambient temperature data collected from probe vehicle experiments. The performances of the developed models are then compared with RST measured from an infrared radiation thermometer. The evaluation work found the predicted RST and the observed RST were comparable indicating that the proposed procedure can be readily implemented. Three models were developed by training data set, and their overall performances were satisfactory based on average absolute error (AAE) measurement. The proposed method to develop RST prediction model can enable government agencies in developing both reliable and readily transferrable procedure for monitoring RST without the need of relying data collected from costly fixed sensors.

## Use of Onboard Vehicle Sensors to Assess Road Weather Conditions for Integration with Connected and Automated Vehicles

Paper number 18-05103, [http://amonline.trb.org/2017trb-1.3983622/t020-1.3997695/352-1.3997909/18-05103-1.3991928/18-05103-1.3997912](http://amonline.trb.org/2017trb-1.3983622/t020-1.3997695/352-1.3997909/18-05103-1.3991928/18-05103-1.3997912)

Authors:
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  Andrew Alden, Virginia Polytechnic Institute and State University
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*Abstract:* The use of vehicle native sensors to provide real-time identification of hazardous road surface conditions such as black ice would allow drivers to receive cautionary warnings on compromised road sections, thus reducing crash risks. The main objective of this study was to further investigate a previously proven tire microslip phenomenon based on relative rotational displacements of a driven and nondriven wheels. Data obtained from different vehicle platforms were analyzed to establish a correlation between variables collected by the onboard sensors and the roadway surface conditions under several driving scenarios (e.g., different constant speeds and road grades, icy road surfaces, etc.). Additionally, a dimensionless tire-pavement interaction factor, Traction Index (TI), was developed as an indicator of road surface slipperiness and slope for various time lengths. The results of multiple test runs conducted on roads conditions ranging from dry to snowy to icy showed small but statistically discernable differences in the TI values. Changes in these observed values were clearly associated with transitions from dry to slippery pavement conditions. Lower TI values were always obtained for slick surfaces and uphill directions due to the increased relative rotational displacement for the driven versus nondriven wheels. Such information can be shared among vehicles through connected and automated vehicle technologies to warn travelers of adverse weather ahead or be applied to optimize winter road maintenance.

**Winter Road Surface Condition Recognition Using a Pretrained Deep Convolutional Neural Network**

Paper number 18-00838, http://amonline.trb.org/2017trb-1.3983622/t005-1.4000488/386-1.4000903/18-00838-1.3993093/18-00838-1.4000948

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*Abstract:* This paper investigates the application of the latest machine learning technique – deep neural networks for classifying road surface conditions (RSC) based on images from smartphones. Traditional machine learning techniques such as support vector machine (SVM) and random forests (RF) have been attempted in literature; however, their classification performance has been less than desirable due to challenges associated with image noises caused by sunlight glare and residual salts. A deep learning model based on convolutional neural network (CNN) is proposed and evaluated for its potential to address these challenges for improved classification accuracy. In the proposed approach we introduce the idea of applying an existing CNN model that has been pre-trained using millions of images with proven high recognition accuracy. The model is extended with two additional fully-connected layers of neurons for learning the specific features of the RSC images. The whole model is then trained with a low learning rate for fine-tuning by using a small set of RSC images. Results show that the proposed model has the highest classification performance in comparison to the traditional machine learning techniques. The testing accuracy with different training dataset sizes is also analyzed, showing the potential of achieving much higher accuracy with a larger training dataset.

## Materials

**Ice Melting Rates at −5°C, −10°C, and −15°C Using Chloride Solutions: A Physical Explanation**

Paper number 18-00134, http://amonline.trb.org/2017trb-1.3983622/t020-1.3997695/453-1.3997851/18-00134-1.3997860/18-00134-1.3997861

Authors:
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*Abstract:* Deicing chemicals [are] an important tool to keep roads passable and safe during winter. The most common deicing chemical, sodium chloride, works well at temperatures close to 0°C but its effectiveness decreases at low temperatures. One common belief is that this reduced effectiveness stems from a reduction of the ice melting rates. Previous studies have indicated that the melting rate is connected to the diffusive flux of water in a deicing solution, and the aim of this paper was to study whether this hold[s] true also at low temperatures. An experiment was performed where aqueous solutions of sodium, magnesium and calcium chloride melted ice at three different temperatures: -5°C, -10°C and -15°C (23 °F, 14 °F and 5 °F). Our results confirmed that the diffusive flux of water correlated well with the ice melting rate at all temperatures. The observed decrease in melting rate at low temperatures was explained by a decreased driving force for diffusion. Because of this, the eutectic temperature of a chemical becomes more important the lower the temperature becomes. The diffusive

flux in deicer solutions could be a useful property. By calculating the diffusive flux of different deicing chemicals, would hence be a way to range them by their melting rates at different temperatures.

## The Effect of Additives on the Low-Temperature Ice-Melting Capacity of NaCl

Paper number 18-00107, http://amonline.trb.org/2017trb-1.3983622/t020-1.3997695/757-1.3997725/18-00107-1.3991025/18-00107-1.3997730

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*Abstract:* Winter maintenance of high-traffic volume roads requires chemicals for the strategy of obtaining sufficient friction. Challenges often arise in very cold temperatures because the effect of the chemicals is reduced in low temperatures. The most commonly used chemical for winter maintenance operations is sodium chloride (NaCl), also called salt. NaCl has a eutectic point of -21°C, but its ability to melt snow and ice (ice-melting capacity) drastically decreases when passing temperatures as high as -10°C to -15°C. To improve performance of deicing chemicals, including increasing the ice-melting capacity in cold temperatures, additives to salt are often used. There is a lack of knowledge as to how these additives actually affect low temperature ice-melting capacity. Ice-melting capacity testing is often done using SHPR H-205.1 and 205.2; however, recent research has shown that the SHRP test produces inaccurate results. Calorimetry has been used successfully to measure ice-melting capacity. This paper uses calorimetry to study the effect of additives on the low temperature ice-melting capacity of NaCl. $MgCl_2$, $CaCl_2$, KFo, CMA and sugar was added to NaCl in -18°C. The chemicals were also tested individually. The measures were done in a recently improved custom-made calorimeter described in the paper.

The results showed that solid chemicals had far higher melting capacity than solutions. In a solid state NaCl had the highest ice-melting capacity of the tested deicing chemicals. However, the results are different for solutions. For example, all of the tested chemicals had higher ice-melting capacity than NaCl when used both individually and as additives to NaCl, except KFo as additive and sugar. $CaCl_2$ had the highest ice-melting capacity of the solutions, melting 285% more than NaCl in -18.6°C. This was followed by $MgCl_2$, KFO, Mix NaCl/$CaCl_2$, Mix NaCl/CMA, CMA, and mix NaCl/$MgCl_2$. Using chlorides as additives ($MgCl_2$ and $CaCl_2$) resulted in a melting capacity between that of NaCl and $MgCl_2$ and $CaCl_2$; the improvement depended on the amount of $MgCl_2$ or $CaCl_2$. However, when KFo and CMA were used, the results were different. KFo had a destructive influence on melting capacity when mixed with NaCl, while mixing CMA with NaCl produced a higher melting capacity than what the two components had done individually. The sugar froze at -18°C.

## Evaluation of Disodium Succinate Hexahydrate as an Alternative Deicer

Paper number 18-01002, http://amonline.trb.org/2017trb-1.3983622/t020-1.3997695/757-1.3997725/18-01002-1.3991024/18-01002-1.3997728

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*Abstract:* The goal of this study is to identify a chemical substance that will be suitable for use as a deicer alternative to sodium chloride (NaCl), with a specific focus on disodium succinate hexahydrate (DSH). The performance of DSH as a deicer was evaluated through a series of laboratory and field tests to determine if DSH meet transportation agencies requirements. Freezing point, metal corrosion, ice melting performance, toxic constituents, and damage to plants were tested in the laboratory, and field tests were conducted to evaluate the deicing and anti-icing performance of DSH. DSH was found to cause almost no corrosion to mild steel and to foster the growth of the test plants when a small amount of DSH was applied to the soil. Considering DSH's freezing point and material cost, application of the mixture of NaCl and DSH is considered to be a solution. A mixture of 80% NaCl and 20% DSH shows a freezing point close to that of NaCl, is 80% less corrosive to mild steel than NaCl is, and mitigates the concentration of chloride ions and the inhibitory effects of NaCl on plants. The results of the field tests suggest the possibility that the application of the NaCl/DSH mixture exhibits anti-icing and deicing performance comparable to that of conventional NaCl application. Considering DSH's solubility in water and utilization of existing facilities and equipment, it is recommended that DSH be used in liquid form as a pre-wetting agent or a liquid deicer.

### Effect of Sodium Chloride on the Asphalt Pavement Surface
Paper number 18-00479, http://amonline.trb.org/2017trb-1.3983622/t020-1.3997695/422-1.3997881/18-00479-1.3995951/18-00479-1.3997888
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*Abstract:* Sodium chloride (NaCl) is ionic compound, easily dissoluble in water, used as a preventive or postponed measure to improve the pavement surface friction during the cold season. Although premature deterioration of vehicles and infrastructure, and deleterious effects of the environment have been observed, 200,000 tons of NaCl are spread in Norway every winter. Metals and concrete have been observed to be particularly affected by the presence of the brine. Although several studies have measured no significant alteration of the asphalt characteristics in plausible conditions, its deleterious effect on other [materials], or on bituminous mixtures in extreme scenarios, leads to a negative perception of its use on asphalt pavement. This article aims therefore to address the controversy by investigating previous studies and evaluating possible salt damage in a stable cold climate.

## Pavements and Bridges (Alternative Deicing Systems)

### Temperature Variations Within the Concrete Pavement Thickness After Heating for De-Icing
Paper number 18-03002, http://amonline.trb.org/2017trb-1.3983622/t022-1.3997225/387-1.3997538/18-03002-1.3995977/18-03002-1.3997547
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*Abstract:* A method of deicing utilizing electrical heating cables embedded within 200 mm-thick concrete slabs in order to avoid the adverse effects of traditional deicing Mg and Na salt on the pavement surface structure was presented in this paper. In this study, to meet the uniform temperature requirement on the concrete pavement surface for deicing, the temperature variation within the thickness was determined in laboratory experiments. A model of heating the concrete slabs with cables was modeled at -25 °C. The minimum necessary heating duration for deicing (0-4 °C) the concrete pavement's surface was determined for three different concrete grade (C25, C30, C35) samples. Electrical heating cables were placed 70 mm below the surface of samples and were set at four different temperatures  (-12.8 °C, -14.7 °C, -17 °C, -21.3 °C). The study gave the early time durations to heat the concrete surface for varying concrete types. It was concluded that heating concrete pavement are an efficient method for deicing the concrete pavements without causing any tensile-related cracks. The temperature variations among the thickness levels were similar in all concrete samples examined in this research program. The concrete classes examined didn't have a significant effect on warm-up duration of concrete pavements. With an input power of 538 W/m2, the temperature of concrete slab surface rose above 0 °C in 8 hours with an approximate heating rate of 0.05 °C/min. When compared to NaCl deicing agent method's cost, the initial cost of heating with carbon fiber cables may seem high, but the annual operating costs are much lower.

## Study on the Physical and Chemical Ice Removal Effects of Asphalt Pavement

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*Abstract:* This study aims at developing a new snow-melting asphalt mixture based on the physical and chemical interactions. This type of asphalt mixture (PCAM-13) has high efficiencies of physical-based ice-breaking and chemical-based ice-melting, which increases the speed of ice removing and improves the driving safety in the winter. Two types of chemical anti-freezing agent are used to replace some fine aggregates between 0 mm to 3 mm and some mineral powder for a size smaller than 0.0074 mm, respectively. Compared to the unmodified SMA-13 mixtures, the ice removing effect of PCAM-13 is significant and the most efficient temperature range is between -12˚C and 0˚C. The electrical conductivity is measured using the repeated load test on the asphalt mixture slab, which is used to determine the change of the salt dissolve rate. It is found that the more anti-freezing agent used, the more dissolved salt is observed except the temperature is below -15˚C or the thickness of the cube is larger than 10 mm. The use of PCAM-13 is found to be affected by the temperature, thickness of ice and the magnitude of loading. From the measurement of the repeated load test, under the same environmental condition and magnitude of loading, the ice on the PCAM-13 mixtures is more prone to break and become separated from the asphalt slabs compared with the SMA-13 mixtures. Meanwhile, no significant ice cube melting on the control SMA-13 is observed, which means that the advantage of PCAM-13 mixtures is remarkable.

# Snowplow Route Optimization

### Snow and Ice Removal Route Optimization in Kentucky

Paper number 18-05730, http://amonline.trb.org/2017trb-1.3983622/t005-1.4000488/abj60-1.4000493/18-05730-1.3990816/18-05730-1.4000494

Authors:

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*Abstract:* This research describes a GIS-based methodology developed for the Kentucky Transportation Cabinet (KYTC) to improve the efficiency of Kentucky's snow and ice removal program. The state's program uses a system of snowplow routes that must factor in the location and attributes of trucks, facilities, materials, and roadways. While functionally effective, the program had never been evaluated for efficiency. Researchers at the Kentucky Transportation Center (KTC) used ArcGIS to assess the performance of KYTC's current snowplow routing procedures and identify strategies for optimizing them. The research established optimized routings for four counties located in two of the state's highway districts. ESRI's Network Analyst and the Vehicle Routing Problem toolset were used for this process. Early models were county-based, meaning that trucks were assigned to routes within counties based on truck type and route priority. These early models achieved some optimization but it was limited and routes were overly complex. In subsequent models, researchers devised more optimal results by modeling routes at the multi-county or district level. These successful models eliminate nine snowplow trucks across four counties, resulting in savings of $225,000 per year. In addition to cost savings, optimizing the routing system can improve efficiency, increase safety, and reduce the amount of time needed to treat roadways. This report documents the challenges, successes, and lessons learned from this research. Specific examples are provided to demonstrate the advantages of route optimization. Subsequent research will expand upon the four successful counties and attempt to optimize the snow and ice removal throughout the state.

### The Role of Route Optimization in Benefiting Winter Maintenance Operations

Paper number 18-02887, http://amonline.trb.org/2017trb-1.3983622/t020-1.3997695/757-1.3997725/18-02887-1.3991023/18-02887-1.3997726

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*Abstract:* For winter maintenance purposes, the Ohio Department of Transportation (ODOT) deploys a fleet of approximately 1,600 snowplow trucks that maintain 43,000 lane miles of roadway. These trucks are based out of 200 garages, yards, and outposts that also house a combined total of 650,000 tons of salt (1). The deployment of such a large number of trucks over a vast maintenance area creates an operational problem in determining the optimal maintenance routes and fleet size. Traditionally, ODOT has used county borders as maintenance boundaries for ODOT garages. However, by removing these borders and optimizing the snowplow routes, ODOT may benefit from significant time and cost savings.

The results of this project provide ODOT a tool to determine the minimum number of trucks needed to maintain the necessary roadways within Districts 1, 2, and 10. In addition, the project recommends to ODOT a tool to assign assets to specific facilities and the most optimal routes for each truck in a district. This research indicates the possibility of reducing the fleet size within Districts 1, 2, and 10 by a total of 29 trucks while maintaining the same level of service. Apart from fleet size reduction, the route optimization can decrease the amount of time in which to treat each road in the three districts by 17 hours for one iteration.

# Traffic and Driver Behavior

**Effect of Weather Conditions on Car-Following-Related Driving Behavior**
Paper number 18-04522, http://amonline.trb.org/2017trb-1.3983622/t020-1.3997695/281-1.3997928/18-04522-1.3993261/18-04522-1.3997929
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*Abstract:* Adverse weather is widely considered to contribute to the reduction of roadway capacity and traffic flow performance. This research intends to analyze the effect of different adverse weather conditions on traffic flow from the perspective of driving behavior under different roadway and traffic conditions. A driving simulator is utilized to conduct an experiment of 30 participants. Weather conditions (fog, rain and snow), roadway conditions (level, uphill and downhill) and traffic conditions (low speed condition and high speed) are simulated in the simulator. During the experiment, participants drive behind controlled vehicles at speed and headways of their choice. Car-following-related measures of headway time, following variation, maximum and minimum speed difference, and acceleration are selected to describe the characteristic of microscopic driving behavior. It is found that driving behavior was affected significantly by the weather condition. Extreme weather conditions such as strong fog, heavy snowstorm and downpour have the most impact on driving behavior. The effects of roadway and traffic condition in different weather conditions are also investigated. In addition, weather conditions are classified into six impact levels based on the impacts on driving behavior. The research findings can be used to calibrate traffic simulation models and predict traffic performance under different weather conditions.

**Complementary Methodologies to Identify Weather Conditions in Naturalistic Driving Study Trips: Lessons Learned from the SHRP 2 Naturalistic Driving Study and Roadway Information Database**
Paper number 18-00720, http://amonline.trb.org/2017trb-1.3983622/t020-1.3997695/281-1.3997928/18-00720-1.3993264/18-00720-1.3997935
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*Abstract:* Adverse weather conditions play a considerable role in the safety and efficiency of the transportation network. Many studies have aimed to quantify the impact that different weather conditions have on transportation safety and mobility; however, most studies have evaluated the network capacity, average speed, and other macroscopic measures without capturing specific driving characteristics. In order to understand specific driving behavior and performance characteristics that exist during different environmental conditions, high resolution vehicle data and video footage are required. The SHRP2 sponsored the generation of a large Naturalistic Driving Study (NDS) database – which provides vehicle time series data, front and rear video, driver video, external sensor readings, and driver surveys – and the Roadway Information Database (RID) – which is a complementary database with geospatial data for commonly driven roads in the NDS and other ancillary data sources, including annual traffic, roadway geometry, accident reports, weather conditions, and 511 alerts. The purpose of this study is to leverage these SHRP2 databases and weather data from the National Climatic Data Center (NCDC) to extract trips that occur during adverse weather conditions. The extraction of weather-related trips from a NDS is unprecedented, and this study presents three complementary methodologies used in parallel to acquire relevant trips from the SHRP2 NDS database. A semi-automated data reduction procedure was developed to process the raw trip files into a format that further analysis and modeling could be completed. This novel approach to NDS trip acquisition and reduction could be extended to other naturalistic driving studies worldwide.

## Understanding and Predicting Highway Travel Time with Spatiotemporal Features of Network Traffic Flow, Weather, and Incidents

Paper number 18-06358, http://amonline.trb.org/2017trb-1.3983622/t005-1.4000488/634-1.4000702/18-06358-1.3996495/18-06358-1.4000705

Authors:

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*Abstract:* Travel time on a route varies substantially by time of day and from day to day. It is critical to understand which factors this variation stems from, weather, incidents or recurrent travel demand, and to what extend the travel time is related to those factors in the network context. This helps a better decision making for infrastructure planning and real-time operation. We propose a data-driven approach to understand and predict highway travel time using spatio-temporal features of network traffic flow, weather and incidents. Those features include time and location of traffic speeds, traffic counts, incidents, weather and events, which are acquired in real time from multiple data sources. The prediction model comprehensively selects the most related features from high-dimensional feature space by LASSO, principle component analysis and regression analysis. In addition, based on those selected features, we test and compare the performance of LASSO, stepwise regression and random forest for short-term travel time prediction on a 6-mile highway corridor of I-270 Northbound near Washington, DC. We found that some bottlenecks scattered in the network can imply the congestion on this corridor at least 30 minutes in advance. In addition, travel time is statistically related to some incidents, morning/afternoon travel demand, visibility, precipitation, wind speed/gust and weather type. Random forest reaches the lowest prediction error at the root-mean-squared error of 16.6%.

**Transit Information Utilization During an Extreme Weather Event: An Analysis of Smartphone App Data**

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*Abstract:* Extreme weather events such as heavy snow can severely disrupt urban transportation systems. When this occurs, travelers often seek information about the status of transportation services. This study aims to assess information utilization during an extreme weather event by analyzing data from a smartphone application ("app") called Transit, which provides real-time transit and shared mobility information in many cities. This research focuses on a snowstorm that hit the northeastern USA in January 2016 and severely disrupted transit and shared mobility services. An analysis of Transit app data is conducted in four parts for New York City, Philadelphia, and Washington, D.C. First, hourly app utilization during the snowstorm is compared to mean hourly app utilization prior to the storm. Second, the rate of app usage is calculated by dividing hourly utilization during the storm by the mean hourly volume before the storm. Third, an ordinary least squares regression model of hourly app usage was estimated for each city. Last, a feature within the app used to request Uber vehicles was examined. The results of the first three analyses reveal that overall app usage decreased during the snowstorm in all three cities; after the storm, New York experienced a significant increase in overall app use during the first Monday commuting period. The analysis of Uber data reveals that app users continued to search for ridehailing services during the snowstorm, despite travel bans. These findings are important for transportation operators and app developers to understand how travelers use information during extreme weather events.