2010 TRB Annual Meeting DVD
Papers related to winter maintenance

Evaluating Use of Small Unmanned Aircraft for Avalanche Control
Paper Number 10-0393
Edward D. McCormack, University of Washington (corresponding author)
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Abstract: The Washington State Department of Transportation's (WSDOT) snow avalanche control program reduces winter roadway closure times and hazards to motorists. The University of Washington (UW) and WSDOT evaluated small unmanned aircraft systems (UASs) as a tool to enhance this program. Because of military investment, UAS technology has dropped in cost while becoming increasingly capable and easier to operate. Commercially available UASs, which fly autonomously, can be operated off a roadway and can collect low cost, real-time aerial imagery while also carrying payloads. This project conducted a series of test flights involving both fixed and rotary wing (helicopter) UASs over a roadway in mountainous terrain. The flights demonstrated that UASs can conduct snow pack and terrain surveillance and can accurately drop explosive charges such as those used to trigger controlled avalanches. The rotary wing UAS was particular usable because of its ability to hover, which provided a stable camera platform, and because it required minimal area to land. The reliability of UASs is a concern, and their capabilities may be challenged by mountainous conditions. This problem may be reduced as UASs become either less expensive and more expendable or more reliable. A major barrier to use of UASs is the need to obtain approval to fly from the Federal Aviation Administration (FAA), the process of which can be time consuming and restrictive. The FAA is currently updating its plans to integrated UASs into the national airspace, and a number of technology-based solutions are being considered.

Comparison of Driving Behavior and Safety in Car-Following Platoons under Icy and Dry Surface Conditions
Paper Number 10-0504
Mitsuru Tanaka, McCormick Taylor Inc.
Prakash Ranjitkar, University of Auckland, New Zealand
Takashi Nakatsuji, Hokkaido University, Japan
From the abstract: In this study, we utilized rare car-following data on icy surface condition and compared the vehicle safety and car-following behavior on such a slippery surface to the normal dry asphalt surface condition. In order to evaluate the vehicle safety in the car-following conditions, we defined three safety indicators: potential collision index, impact speed, and expected impact speed. Our outcomes in these safety indicators showed a significant difference between the icy and dry surface conditions. We investigated further for what caused this difference even after considering a range of possible maximum deceleration rates and reaction times. We found that speed-spacing relationships were significantly different and drivers were creating much longer spacing to avoid rear-end collisions on the icy surface more than necessary. As a result, the icy surface showed significantly safer indicator values than the dry surface. At the same time, the result let us consider that drivers may have too much confidence and take very high rear-end collision risks on the dry surface.

Probabilistic Modeling of Inclement Weather Impacts on Traffic Volume
Paper Number 10-0646
David Samba, University of Virginia
Byungkyu (Brian) Park, University of Virginia
Abstract: Inclement weather may potentially create traffic flows and driving behaviors that differ from those behaviors observed under normal conditions. Depending on weather type, severity, and duration, roadways may not perform to their optimal capabilities and driver ability may be challenged. To this end, researchers have studied reductions in supply parameters (e.g., capacity and speeds) due to inclement weather conditions. Current studies have underrepresented the effect of inclement weather on demand parameters. This study proposes a probabilistic approach to determine the percent average reduction of traffic demand under both rain and snowfall conditions. This demand reduction is further differentiated by the time of day of inclemency and by the relative severity inclement weather. This research studied seven sites surrounding major central business districts in Virginia and Minnesota and found that (a) rain and snowfall have varying impacts on travel demand, (b) time of day is an important factor to consider because of the likelihood of discretionary and non essential trips occurring at specific hours of the day, and (c) snowfall, as expected, produces much bigger impact on traffic volume than rainfall.

Quantifying Mobility Benefits of Winter Road Maintenance: Simulation-Based Analysis
Paper Number 10-0715
Usama Shahdah, University of Waterloo, Canada
Liping Fu, University of Waterloo, Canada
From the abstract: This research is specifically concerned about the mobility benefit of winter road maintenance. A microscopic traffic simulation model is used to investigate the traffic patterns under adverse weather and road surface conditions. A segment of the Queen Elizabeth Way located in the Great Toronto Area, Ontario is used in the simulation study. Observed field traffic data from the study segment was used in the calibration of the simulation model. Different scenarios of traffic characteristics and road surface conditions as a result of weather events and maintenance operations are simulated and travel time is used as a performance measure for the effect of winter snow storms on the mobility of a highway section. The modeling results indicate that winter road maintenance aimed at achieving bare pavement conditions during heavy snowfall could reduce the total traffic delay of the highway by 5 to 36 percent, depending on the level of demand of the highway.

Implementation of Structural Control Measures for Avalanche Hazard Mitigation Along Transportation Corridors
Paper Number 10-0741 (a practice-ready paper)
Joshua Hewes, Northern Arizona University (corresponding author)
Rand Decker, Northern Arizona University
Scott Merry, Kleinfelder Inc.
Jamie M. Yount, Wyoming Department of Transportation
Abstract: Avalanche hazards along transportation corridors in the United States have traditionally been addressed through the use of forecast their potential and actively controlling them through explosive release while the roadway is closed. This approach reduces the threat of avalanches cascading onto the roadway and thus reduces danger to the traveling public. However, active control methods cannot always be implemented in a timely fashion, can be ineffective, and can have large associated economic impacts. An alternative to active control is passive, structural avalanche defenses. They are “passive” in that they do not require the efforts of winter maintenance personnel during winter storm periods. Structural defense measures include snow sails, snow supporting structures, and snow sheds. Despite their extensive use in Europe and their potential for effectively reducing avalanche hazards, there are very few examples to be found in the United States. The potential for negative impacts to the visual attributes of the landscape has been a significant reason for their lack of domestic use. This paper discusses several types of structural defense measures, criteria for their selection at a given site, and their relative effectiveness. Passive structural defense measures designed for implementation at the 151 Avalanche on US Route 89/191near Jackson, Wyoming are described. Details are given on important collaborations between landscape architects and engineers that led to successfully addressing National Environmental Policy Act (NEPA) requirements for retention of visual attributes at the 151 Avalanche site in the presence of snow support structures deployed for the purpose of avalanche hazard reduction.

Accident Prediction Models for Quantifying Safety Benefit of Winter Road Maintenance
Paper Number 10-0774
Taimur Usman, University of Waterloo, Canada (corresponding author)
Liping Fu, University of Waterloo, Canada
Luis Fernando Miranda-Moreno, McGill University, Canada
From the abstract: This research presents a modelling approach to investigate the association of the accident frequency during a snow-storm event with road surface conditions, visibility and other influencing factors controlling for traffic exposure. This methodology can be applied to the evaluation of different maintenance strategies using safety as a performance measure. As part of this approach, this research introduces a road surface condition index (RSI), similar to the commonly used friction measure, and uses this index as a representation of different road surface conditions. After the combination of different data sources, three event-based models including the Negative Binomial model (NB), the generalized NB model (GNB) and the zero inflated NB model (ZINB) are developed and compared for their capability to explain differences in accident frequency between individual snow storms. It was found that the GNB model best fits the data, and is most capable of capturing heterogeneity other than excess zeros. Among the main results, it was found that the RSI was statistically significant

influencing the accident occurrence. According to our proposed index, our results suggest that a 10% improvement in road surface condition would lead to nearly an 11% reduction in the expected number of accidents. This research is the first showing the empirical relationship between safety and road surface conditions at a disaggregate level (event-based), making it feasible to quantify the safety benefits of alternative maintenance goals and methods.

Quality in Spreading: Reducing Impact on Environment by Addressing Precision in Distribution of Ice Control Agent Spreading Technologies

Paper Number 10-0951

Lars Bolet, Aalborg University, Denmark (until January 2007, director of the Highway and Transportation Division in the former Danish county of Funen; corresponding author)
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Abstract: Traditional technologies in spreading ice control agents cause a considerable waste of salt. Measurements of spreading quality indicate that at least (almost) half the amount of ice control agents consumed do not have any effect on winter maintenance. The effect is illustrated by a scenario. Simple salinity measurements are used to find the distribution of salt across a road-section. The spreading quality is expressed as the standard deviation of the waste of salt due to imbalance between the lanes in the spreading patterns, while it is assumed that spreaders can be adjusted to eliminate systematic bias. The road authorities should focus on the spreading quality when ordering new spreaders, they should be aware of the stability in the spreaders adjustments, and they should introduce simple tests to verify that the adjustment, and thus the spreading quality, of each spreader is remained. Only this way it will be possible to reduce the enormous unnecessary impact on the environment. In addition, the costs will be reduced as well.

Changes in Travel Behavior in Response to Weather Conditions: Do Type of Weather and Trip Purpose Matter?

Paper Number 10-0952

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Elke Amelie Moons, Hasselt University, Belgium
Lieve Creemers, Hasselt University, Belgium
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From the abstract: The main objectives of this paper are to test the hypothesis that the type of weather determines the likelihood of a change in travel behavior and to assay whether the changes in travel behavior due to weather conditions are dependent on the trip purpose. To this end, a stated adaptation study was conducted in Flanders (Dutch speaking region of Belgium). In total 586 respondents completed the survey, which was administered both on the Internet and via a traditional paper-and-pencil questionnaire. To ensure an optimal correspondence between the survey sample composition and the Flemish population, the observations in the sample are weighted. To test the main hypotheses Pearson chi-square independence tests will be performed. Both the results from the descriptive analysis and the independence tests confirm that the type of weather matters, and that the changes in travel behavior in response to these weather conditions are highly dependent on the trip purpose. This dependence of behavioral adjustments on trip purposes provides policy makers with a deeper understanding of how weather conditions affect traffic. Further generalizations of the findings are possible by shifting the scope towards revealed travel behavior. Triangulation of both stated and revealed travel behavior on the one hand, and traffic intensities on the other hand, is certainly a key challenge for further research.

High Wind Warning System to Prevent Overturning Truck Crashes in Wyoming

Paper Number 10-1034

Qiyue Dai, University of Wyoming
Rhonda Kae Young, University of Wyoming

Abstract: High wind conditions in Wyoming lead to frequent truck overturning crashes, particularly during the winter season. This paper develops a multiple logistic regression model that explores the relationship between the likelihood of overturning truck crashes and weather variables from a nearby Road Weather Information System (RWIS) at the time the crash occurred. Based on the results of the logistic model and historical truck crash data, a

high wind warning system is introduced for use by the Wyoming Department of Transportation (WYDOT) to improve truck safety along a hazardous corridor on Interstate 25.

Impact of Snowplowing and Traffic on Pavement Marking Retroreflectivity in New Hampshire
Paper Number 10-1364

Tobey Reynolds, New Hampshire Department of Transportation
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Abstract: Over the course of two winter seasons, the New Hampshire Department of Transportation collected data on pavement marking retroreflectivity, snowplow activity, and traffic volumes at twelve sites around the state to assess the retroreflective performance of the state's pavement markings in anticipation of future rulemaking on minimum levels of retroreflectivity for markings. All twelve sites were two-way, two-lane highways. At each site, they attempted to collect retroreflectivity data in the fall and spring and the number of times each line was hit by a snowplow. Each site was near a permanent count station, so winter traffic volume data was also available. Out of a possible 96 lines that could have been used for analysis, missing data limited the number of lines available for analysis to 64. The average retroreflectivity of the 64 lines in fall was 261 mcd/m2/lux (for both colors). The average retroreflectivity reading for the spring values was 92 mcd/m2/lux. There was an average of 242 plow hits on each line and the average winter ADT at each site was 7,734. The authors created a cumulative distribution of the retroreflectivity values that indicate that 13 percent of the white markings and 20 percent of the yellow markings would have retroreflectivity levels below 40 mcd/m2/lux, which is the minimum level recommended in an FHWA-sponsored research effort. The authors also performed regression analysis of the retroreflectivity data as a function of the snowplow hits and passing traffic volume. None of the regression relationships identified a significant relationship between the factors.

Cost-Benefits of Winter Road Maintenance Tools: A Renewed Perspective Based on Recent Research
Paper Number 10-1744

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From the abstract: This paper brings recent research results into one document to assist practitioners in understanding the current state of the practice related to specific items. The information presented here specifically focuses on the top ten winter maintenance practices, equipment and procedures as identified by practitioners, including anti-icing, deicing, front and underbody blades, Automatic Vehicle Location (AVL)/Global Positioning System (GPS), pavement temperature sensors, Road Weather Information System (RWIS), Maintenance Decision Support System (MDSS), carbide blades, air temperature sensors; and zero velocity spreaders. A review of the literature pertaining to these items indicated that, depending on the item of interest, significant data gaps may exist. This was less true for items such as RWIS, but more true of items such as temperature sensors and material placement systems. Overall, quantified costs and benefits related to many items are still needed. In addition, further investigation is necessary to quantify the dollar values of costs and benefits associated with many items considered intangible at present. The determination of such information would assist in the conduct of cost-benefit studies and decision-making.

Improving Road Weather Hazard Products with Vehicle Probe Data: Vehicle Data Translator Quality Checking Procedures
Paper Number 10-1768 (a practice-ready paper)

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Elena Schuler, National Center for Atmospheric Research
Gerry Wiener, National Center for Atmospheric Research
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Paul A. Pisano, Federal Highway Administration
Ben McKeever, Research and Innovative Technology Administration
Abstract: One of the goals of the Research and Innovative Technology Administration's IntelliDriveSM initiative is for the public and private organizations that collect, process, and generate weather products to utilize vehicle sensor data to improve weather and road condition hazard products. It is possible that some users will not be able to—or not want to—contend with the complexities associated with vehicle data, such as data quality, representativeness, and format. With funding and support from the U.S. Department of Transportation's (USDOT) Research and Innovative Technology Administration (RITA) IntelliDriveSM initiative and direction from the Federal Highway Administration's (FHWA) Road Weather Management Program, the National Center for Atmospheric Research (NCAR) is conducting research to develop a Vehicle Data Translator (VDT) to address these vehicle-based data challenges. This paper first describes the VDT quality-check (QCh) concept and then examines QCh pass rates for temperature and pressure data collected from 11 specially-equipped vehicles operating in the Detroit Testbed in April 2009. Results show that temperature pass rates are higher than pressure. Additionally, pass rates are affected by vehicle type, vehicle speed, ambient temperature, and precipitation occurrence for both temperature and pressure.

Using a Driving Simulator to Determine Most Effective Installation Locations for Illuminated Delineators on Expressways Under Snowstorm Conditions
Paper Number 10-1798
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Akira Kawamura, Kitami Institute of Technology, Japan
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Abstract: This study investigated how the location of illuminated delineators affected the following, for drivers running under snowstorm conditions: driver subjective mental workload (SMWL), fluctuation of vehicle lateral position, and variation of driving speed. The experiment was conducted on a driving simulator. Thirty-six participants, aged 22 to 77 years, participated. The participants were exposed to four delineation conditions as the main independent variables: (1) no illuminated delineators (no delineation), (2) illuminated delineators at the shoulder (left-side delineation), (3) illuminated delineators at the median strip (right-side delineation), and (4) illuminated delineators on the left and right sides (both-sides delineation). The subjects drove in the simulator on a 4-km section of a four-lane expressway under snow-induced low-visibility for each run. SMWL was lower (i.e., less mental workload) for "both-sides delineation" than for "left-side delineation" or "right-side delineation." Fluctuation of vehicle lateral position and variation of driving speed were significantly better for both-sides delineation than for any of the other three delineation conditions.

Snow and Ice Accumulation on Vehicles
Paper Number 10-2315
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Abstract: During the winter months in regions with significant snowfall, snow and ice accumulates on the tops of vehicles, which can then dislodge during travel. These chunks of snow and ice may strike other vehicles, creating a safety issue that results in property damage or injury to other motorists. The research objectives of this study included quantifying the scope of the problem, identifying potential solutions and developing a recommended action plan for highway safety stakeholders. ATRI conducted a thorough scan of existing literature, snow/ice removal products and regulatory actions relating to snow and ice safety issues. Stakeholder interviews and surveys were also conducted to better understand the technical and institutional challenges and potential solutions. The comprehensive review and synthesis of available research and information yielded little to no data on the scope of snow and ice accumulation on vehicles. The research findings discretely document the myriad safety, financial, technical and institutional challenges associated with effectively addressing or mitigating the safety concerns associated with snow and ice falling from vehicles. To offer a comprehensive set of solutions, a list of actions for the short-, mid- and long-term are recommended in the research. Short-term actions include a public outreach and education campaign targeting operators of all vehicle types. A mid-term action is to further explore the feasibility of locating snow removal devices at public weigh stations and ports of entry. The recommended long-term action plan involves

investigation of potential vehicle-based solutions which would prevent or impede snow and ice accumulation on vehicles.

Impact of Inclement Weather on Dilemma Zone Boundaries
Paper Number 10-2356
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Nathaniel Burnett, University of Nebraska, Lincoln
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Abstract: Adverse or inclement weather events, such as snowfall, impact the traffic efficiency, traffic safety, and trip distribution. Inclement weather is reported to be the prime causal factor for fatal two vehicle crashes. Weather-based signal control strategies have the potential to enhance both the operational efficiency and the safety at a signalized intersection. This paper reports on an empirical study to model the impacts of inclement weather (snow and rain) on driver decision making at the onset of yellow at a high speed signalized intersection. In this research, the data were collected for a variety of weather conditions at a high speed intersection at Noblesville, Indiana. The impact of inclement weather on probability of stopping was assessed by developing binary discrete choice models for different weather conditions. The model parameters for snow and rain condition were found to be statistically significantly different from normal day in more than 90% of the cases. The impact of snow on dilemma zone boundaries was more pronounced than rain.

Comparison of Alternative Models for Road Surface Condition Classification
Paper Number 10-2789
Feng Feng, University of Waterloo, Canada
Liping Fu, University of Waterloo, Canada
Max S. Perchanok, Ontario Ministry of Transportation, Canada
From the abstract: In this research, with the help of a classification tree, several nested logistic regression models based on continuous friction measurement were developed for automatic classification of multiple winter road surface conditions. New variables from probability density pattern, like variance and skewness, and from spectral density pattern of continuous friction measurement were included in the classification models in addition to mean friction level. As these new variables can reflect spatial distribution patterns of snow cover along the maintenance route, including them into the classifier can improve the power of the models. The performance of the nested logit models were partially compared to the naïve Bayesian classifier which was solely based on mean friction.

Using Vehicle Probe Data to Diagnose Road Weather Conditions: Results from Detroit Intellidrive Field Study
Paper Number 10-3060 (a practice-ready paper)
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Tara Jensen, National Center for Atmospheric Research
Christian Johansen, National Center for Atmospheric Research
William Mahoney III, National Center for Atmospheric Research
Paul Pisano, Federal Highway Administration
Benjamin McKeever, Research and Innovative Technology Administration
Abstract: Over the past two years, the USDOT/Research and Innovative Technology Administration funded an IntelliDriveSM vehicle probe data collection testbed in the Northwest Detroit area (the Detroit Testbed). The purpose of the testbed was to provide the infrastructure for both public and private organizations to collect, process, and generate a robust observation dataset for multiple purposes (e.g., crash avoidance, automated toll services, weather diagnostics). During April 2009, a weather specific field study was performed over an 11-day period. The resulting dataset was processed by a Vehicle Data Translator (VDT), which parsed, quality controlled, and combined these data (with ancillary weather data) in the generation of road-weather specific algorithms. This paper briefly describes the VDT concept and then examines the accuracy of the quality-controlled temperature and pressure data (for several different stratifications) collected from 11 specially-equipped vehicles operated during the study time period. Results show that the vehicles accurately measure the temperature (compared with a nearby fixed

weather station; KDTW), but are not as accurate at measuring the barometric pressure. In addition, stratification by speed, vehicle type, time of day, and occurrence of precipitation do not affect the accuracy of the temperature and barometric pressure measurements.

Resistance of Portland Cement Pervious Concrete to Deicing Chemicals
Paper Number 10-3145

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Abstract: In the present study, the damaging impact of deicing chemicals on Portland Cement Pervious Concrete (PCPC) materials was investigated. Two concrete mixes were used (with and without latex modification) and subjected to three deicing chemicals (sodium chloride, calcium chloride, and calcium-magnesium acetate) under a freezing-thawing or drying-wetting condition. Two different deicing chemical application methods (saturated and drained) were employed. The impact of deicing chemicals on the concrete was evaluated based on the concrete mass and strength losses. The results indicated that among the deicing chemicals studied, the calcium chloride solution caused the most damage while the calcium-magnesium acetate caused the least. The saturated scaling test method as followed by ASTM C672 provided much higher mass loss of tested concrete samples when compared with a modified more realistic drained test method.

Variation in Impact of Cold Temperature and Snowfall and Their Interaction on Traffic Volumes
Paper Number 10-3182

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Satish Sharma, University of Regina

Abstract: Presented in this paper is a detailed investigation of highway traffic variations with severity of cold, amount of snow and various combinations of cold and snow intensities. Separate analysis for starting, middle and ending months of winter seasons is conducted to understand the variations in traffic-weather relationships within the winter season. The study is based on hourly traffic flow data from 350 permanent traffic counter sites located on the provincial highway system of Alberta, Canada, and weather data obtained from nearby Environment Canada weather stations, during the period of 1995-2005. Multiple regression analysis is used in the modeling process. The model parameters include three sets of variables: amount of snowfall as a quantitative variable, categorized cold as a dummy variable and an interaction variable formed by the product of the above variables. The developed models closely fit the real data with R-square values greater 0.99. The study results indicate that the association of highway traffic flow with cold and snow varies with day of week, hour of day and severity of weather conditions. A reduction of 1% to 2% in traffic volume for each centimeter snowfall is observed when the mean temperatures are above 0°. For the days with zero precipitation, reductions in traffic volume due to mild and severe cold are 1% and 31%, respectively. An additional reduction of 0.5% to 3% per each centimeter of snowfall results when snowfall occurs during severe cold conditions. Study results show lesser impact of adverse weather conditions on highway traffic volumes during severe winter months and the months thereafter as compared to starting months.

Evaluation of Freeway Travel Time Variability and Reliability Under Adverse Weather with TRANSMIT Data
Paper Number 10-3214

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Kiran Kumar Kolluri, New Jersey Institute of Technology

Abstract: In addition to delay, the variability and reliability of travel time has been of concern to motorists on their daily travel, especially during peak periods. Traffic congestion has caused many detrimental effects including higher fuel consumption, more vehicle emissions, increased accidents, as well as greater tension due to uncertain travel time. The objective of this study is to examine freeway travel time variability and reliability under different traffic and weather conditions with the use of TRANSMIT data collected by roadside readers deployed on a 40-mile segment of the Interstate I-287 in New Jersey. Travel time variability and reliability measures including mean travel

time, the 95th percentile travel time, travel time index, buffer index, and planning time index are investigated under various circumstances, such as adverse weather.

Direct and Indirect Effects of Adverse Weather and Maintenance Operations on Traffic Crashes
Paper Number 10-4040

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Abstract: This study explored the various contributions of road attributes, weather, maintenance activities, and other circumstances surrounding the crash involvement during adverse weather conditions. This study especially analyzed the direct and indirect casual effects of weather and maintenance operations on crash probabilities through changing road surface conditions and traffic flow characteristics. The structure of the influence of adverse weather and maintenance operations on safety was first hypothesized. Multiple Classification Analysis (MCA) was applied to give estimates to three models. The results produced from these three models were used to reveal the complex relationships and to understand the effects. Results indicate plowing activities indirectly reduce injury probability by 24.2% and PDO [property damage only] probability by 23% through improving road surface conditions. Similarly chemical application reduces injury by 33.3% and PDO by 17.8%, but it is not the same case for sanding operations.

Weather-Responsive Traffic Management: Deployment of Real-Time Traffic Estimation and Prediction Systems
Paper Number 10-4094

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Abstract: Traffic Estimation and Prediction Systems (or TrEPS) are real-time systems that interact continuously with loop detectors, roadside sensors and vehicle probes, and provide real-time estimates of traffic conditions, network flow patterns and routing information. TrEPS can be used by traffic managers and operators for evaluating and implementing transportation advisory, control and treatment strategies, including those that mitigate weather impacts. Since TrEPS are capable of predicting where and when drivers travel on the road network, they enable dynamic control and traffic management systems to anticipate problems before they occur, rather than simply reacting to existing conditions. This paper reviews existing applications of weather-responsive advisory and control strategies and proposes a high level framework of deploying real-time traffic estimation and prediction systems for weather responsive traffic management that recognizes modern technological developments including weather and traffic data sensing/forecasting. Recognizing the deficiency in current practice, we develop traffic estimation and prediction models at the corridor and network levels that account for traffic response to inclement weather with presence of advisory and control strategies and incorporate these models in existing TrEPS.