Papers Related to Winter Maintenance from the 2017 TRB Annual Meeting

Contents

This compendium of papers related to winter maintenance from the 2017 Transportation Research Board Annual Meeting was prepared by the Clear Roads pooled fund project (#TPF-5(353)). It covers the following topic areas:

- Equipment and Facilities
- Information Systems and Technology
- Materials
- Performance Measurement
- Program Management
- Safety
- Snow Fences

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Equipment and Facilities

Field Test of Visibility Markers for Snow Maintenance Equipment
Paper number 17-02142, http://amonline.trb.org/63532-trb-1.3393340/t021-1.3405667/395-1.3405839/17-02142-1.3400060/17-02142-1.3405841

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Abstract: Due to the evolution of the use of private contractors in Ontario for highway snow removal a lack of consistency developed in the lighting and marking of maintenance vehicles. Due to safety concerns raised by operators of snow removal equipment, the Ministry of Transportation of Ontario (MTO) initiated the development of an updated standard for a lighting and marking system, to produce greater visibility/conspicuity of, and safety for, highway snow removal equipment and associated workers. The standard was developed through a multi-disciplinary value engineering study. This paper describes a series of tests that were carried out to assess the proposed lighting and marking system.

Tests involved selection of highly conspicuous elements, determination of the conspicuity of brake lights, turn signals and rotators, in the presence of other system elements and assessment of driver ability to determine closing speed with the proposed system. The final standard included: A fluorescent yellow-green/black checkerboard with Type III/IV sheeting, constant Amber + Flashing Blue LED light bars to each side and above the checkerboard, red and white retro-reflective tape on an airfoil above the checkerboard, upper and lower tail and brake lights and, amber and blue rotating beacons, one on the roof of the cab and the other two near the top left and top right corners of the back of the snow removal equipment. This design has now been accepted and published as a national guideline by the Transportation Association of Canada.

Fleet Replacement Methods Evaluation and Refinement

Paper number 17-04924, http://amonline.trb.org/63532-trb-1.3393340/t021-1.3405667/ahd60-1.3405669/17-04924-1.3400370/17-04924-1.3405670

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Abstract: This paper investigates the vehicle equipment replacement decision making methodologies available to the California Department of Transportation (Caltrans) and other similar vehicle fleet operations. The goal is to optimize the replacement timing of aging vehicle equipment to minimize total costs and maintain certain fleet characteristics; such as, fleet reliability and preparedness. In this paper, an overview and discussion of key factors for vehicle equipment replacement decision making and various Fleet Replacement Methods (FRM) utilized by Caltrans and other states' Department of Transportation (DOT) are presented. Aspects of more than 5 different FRMs in 3 different FRM categories are compared and summarized, and results are provided in the paper. An in depth analysis is presented focusing on the most applicable alternative to Caltrans' current FRM, i.e. a popular analytical technique called Life Cycle Cost Analysis (LCCA). The major tasks in this work include building a LCCA Model, utilizing Caltrans' fleet data, processing and visualizing fleet data, accurately modeling cost trends to predict future costs, evaluating the feasibility and constrains, and applying an enhanced method to optimize the model. The primary objective of this research is to develop a tailored FRM and facilitate the decision making process for replacing equipment within Caltrans' vehicle fleet.

Information Systems and Technology

WeatherEVANT: Real-Time Weather Related Event Visualization and Analytics Tool

Paper number 17-00114, http://amonline.trb.org/63532-trb-1.3393340/t021-1.3405667/653-1.3405736/17-00114-1.3399666/17-00114-1.3405743

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Abstract: Weather related events cause major disruptions to our overall transportation system. During the recent winter seasons, the east coast of the United States has struggled with heavy snowstorms, which has drawn attention to the efficiency of storm operations. In this paper, we describe a web-based tool called WeatherEVANT that was developed as a result of past research efforts conducted by the authors of this paper for the New Jersey Turnpike Authority (NJTA). The tool extracts the information residing in the snow operations database, which is updated frequently by NJTA maintenance operators, and provides various visualizations of this real-time data on its web-based interface integrated into GoogleMaps. WeatherEVANT also takes advantage of real-time data available from other sources including traffic cameras, weather reports, traffic data, and incident data among others. In that sense, it is a real-time data integration tool with extensive visualization and reporting capabilities. It can also automatically generate a variety of performance reports for the use by decision makers, such as salt usage, storm information, equipment usage, etc. One important salient feature of this tool is that it is being actively used by NJTA for the last two years, and improvements are implemented as a result of active feedback from its everyday users during the winter season.

Development of Zonal-Specific Semivariograms for a Strategic RWIS Network Optimization—A Case Study

Paper number 17-02754, http://amonline.trb.org/63532-trb-1.3393340/t021-1.3405667/384-1.3405858/17-02754-1.3405109/17-02754-1.3405861

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Abstract: This paper presents a study aimed at developing zonal-specific semivariograms for zones with different climates using regionalized random variables for a strategic RWIS network implementation and optimization in a large region. Zonal semivariograms modeled in this study are explicitly compared with regional semivariograms to demonstrate the (dis)similarity in their underlying spatial structures. With two groups of semivariograms developed in terms of their weather characteristics, namely regional and zonal, large scale RWIS location and density optimizations are conducted to compare the outcomes and illustrate their distinct features. A case study based on the existing RWIS network in Ontario, Canada is used to show the application of the proposed method. The findings indicate that there are very different spatial autocorrelation patterns between regional and zonal-specific semivariograms, thereby emphasizing the need for a strategic zonal-specific RWIS implementation plan. The results of different planning scenarios for optimizing RWIS location and density also reveal that the optimal locations are insensitive to the underlying spatial structure (i.e. semivariogram) used to optimize the network but very sensitive to the optimal density, providing a very important yet useful decision making guidance for improved efficiency and effectiveness of overall winter road maintenance programs.

Prioritization Scheme for Proposed RWIS Sites: Montana Case Study

Paper number 17-02526, http://amonline.trb.org/63532-trb-1.3393340/t021-1.3405667/384-1.3405858/17-02526-1.3400074/17-02526-1.3405863

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Abstract: A model for prioritization of new proposed Environmental Sensor Station (ESS) sites is developed and presented in this paper. The model assesses the overall merit of a proposed ESS site as part of a Road Weather Information System (RWIS) using weather, traffic and safety data among other variables. Inputs to the overall merit model include weather index, traffic index, crash index, geographic coverage and opportunistic factors. The weather index at a proposed site is determined using multiple indicators of weather severity and variability. The crash index, another major input to the overall merit model, incorporates crash rate along the route and the percentage of weather related crashes over the analysis period. The traffic index, in turn, reflects the amount of travel on the highway network in the area surrounding the proposed ESS site. The fourth input to the merit model accounts for the ESS existing coverage in the area where the proposed site is located, while the fifth and last input is concerned with the availability and ease of access to power and communications. Model coefficients are represented by weights which reflect the contribution of each input (variable) to the overall merit of the ESS site. Those weights are user-specified and should be selected to reflect the agency preferences and priorities. The application of the proposed merit model is demonstrated using several selected sites in the state of Montana.

Materials

Agricultural By-Products Weaken the Snow/Ice Bond to Pavement and Improve Sunlight Absorbance and Longevity on Road

Paper number 17-05584, http://amonline.trb.org/63532-trb-1.3393340/t021-1.3405667/325-1.3405869/17-05584-1.3405114/17-05584-1.3405872

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Abstract: Agriculturally derived products, or agro-based products, are increasingly popular in snow and ice control operations. Agro-based products are either used alone or more commonly as additives or blended with traditional chloride-based products such as rock salt and salt brine. Agro-based products have been found to reduce the freezing point of water, improve the ice-melting capacity and reduce the corrosivity when blended with other winter maintenance products. More recently, manufacturers have claimed and anecdotal reports from practitioners suggest that agro-based products aid in weakening the bond between ice and road surface, improve the ability to prolong performance of deicers on the road surface, and attract and utilize sunlight light as an aid to ice prevention. The objective of this project was to investigate the effectiveness and functional mechanisms of three agro-based deicers in their ability to (a) weaken the ice bond to pavement (b) improve the product longevity on the road and (c) absorb more sunlight, through a laboratory investigation. This study found that agro-based products with higher viscosity and therefore slower grain boundary penetration resulted in more product remaining on the pavement surface than salt brine alone. The greater concentration of agro-based products remaining on the pavement surface aided in further weakening the bond strength between ice and pavement and reducing force required to plow the snow and ice off the pavement surface. Agro-based products tend to stay on the road surface longer than salt brine. Longevity of the product on the road surface depends on the amount of product wicked up or dissolved into the snow. Agro-based products tend to dissolve less into snow when compared to salt brine alone. Darker colored agro-based products produce more ice melt compared to salt brine alone.

Laboratory and Field Evaluation of Sodium Propionate for Snow and Ice Control

Paper number 17-01094, http://amonline.trb.org/63532-trb-1.3393340/t021-1.3405667/325-1.3405869/17-01094-1.3400157/17-01094-1.3405885

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Abstract: To provide the driving public with a safe road surface during winter, large amounts of anti-icing and deicing chemicals (deicers) are used. Since there are growing concerns about the impact of chloride-based deicers on motor vehicles, highway infrastructures, maintenance equipment and the environment, the development of alternative deicers and additives serves the public interest. To find a material that can be feasibly used as a deicer, the performance of sodium propionate (SP), which is commonly used as a food additive, was evaluated through a series of laboratory and field tests. Freezing point, metal corrosion, ice melting performance, toxic constituents, and damage to plants were tested in the laboratory, and a field test was conducted to evaluate SP's deicing performance. SP was found to conform to the standard for toxic substances of deicer in Japan, to achieve more rapid deicing than sodium chloride (NaCl), and to cause almost no corrosion of metal. To reduce costs while taking advantage of SP, the mixing of NaCl and SP, which exhibits performances intermediate between those of NaCl and SP, is considered to be a solution. A mixture of 80% NaCl and 20% SP shows freezing point and ice melting performance equivalent to those of NaCl, mitigates the concentration of chloride ions and the inhibitory effects of NaCl on plants, and is still 80% less corrosive to metal than NaCl is. Considering SP's high solubility in water and the field test results, it is recommended that SP be used as a pre-wetting material.

Sustainable Traction with Winter Sand

Paper number 17-01664, http://amonline.trb.org/63532-trb-1.3393340/t021-1.3405667/325-1.3405869/17-01664-1.3405115/17-01664-1.3405881

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Abstract: This research presents the findings from a field study aiming at comparing the performance of sanding treatments using pre-wet sand versus conventional dry sand for friction enhancement of road surfaces under severe winter conditions. The research was motivated by the question of whether or not application of pre-wet sand at a lower rate could achieve the similar level of service as the conventional dry sand. Field tests were conducted on two sections of a provincial highway in Southwest Ontario in the winter season 2015/2016. The research utilised three different approaches, namely, comparative analysis, visual assessment and statistical modeling to analyze the field test data. The results shows that treatments with pre-wet sand at a rate of 485 Kg/2-Ln-Km had a comparable friction level to those of conventional dry sand applied at 570 Kg/2-Ln-Km while at the same time achieving a 20% reduction in sand usage.

Effect of Pre-wetting Brines and Mixing on the Ice Melting Rate of Salt at Cold Temperature Measured by a New Tracer Dilution Method

Paper number 17-01728, http://amonline.trb.org/63532-trb-1.3393340/t021-1.3405667/453-1.3405792/17-01728-1.3399993/17-01728-1.3405795

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Abstract: A novel test method has been developed to measure the ice melting rate of deicers. Ice melting rates of 60 grams of salt blended with 100 grams of NaCl, $CaCl_2$, and/or $MgCl_2$ brines were determined by measuring the change in concentration of Cl^- and Mg^{+2} or Ca^{+2} in the ice melt as "tracers." The method is substantially more precise than the SHRP H205.1 standard and has the further advantage of measuring both ice melting and salt dissolution rates simultaneously. Brines were pre-equilibrated with ice at -19.3°C (-2.7°F) and blended with solid salt to determine the effect of different pre-wetting brines on the ice melting rate of the solid salt component-only. The equilibrium ice melting capacity of NaCl was measured to be 3.59 grams ice melted per gram NaCl dissolved, which agreed well with the theoretical value of 3.53 calculated from the NaCl freezing point curve. Under a condition of no mixing, solid salt yielded 0.87% of its total available ice melting capacity after 60 minutes when wetted with NaCl brine and 9.70% when wetted with $CaCl_2$ brine. Mixing raised the yield of ice melt to 27.1% and 50.5%, respectively, for wetting with NaCl and $CaCl_2$ brines after 60 minutes. $CaCl_2$ brine was slightly more effective than $MgCl_2$ brine at enhancing the ice melting rate of salt. A "hot mix" of 7 parts 23.3% NaCl brine to 3 parts of a commercial brine containing 17.5% $MgCl_2$ and an agricultural performance enhancer resulted in a lower ice melting rate of wetted salt than a hot mix made from 7 parts 23.3% NaCl and 3 parts of a 30.3% $MgCl_2$ brine with no agricultural additive. The test method promises to be a useful tool to permit a more precise optimization of pre-wetting brine composition, concentration, and brine to salt ratio at different temperatures. It may also permit better determination of the cost effectiveness of different pre-wetting strategies and provide deeper insights into the mechanism of chemical ice melting.

Modeling Salt Usage During Snow Storms: An Application of Hierarchical Linear Models with Varying Dispersion

Paper number 17-05221, http://amonline.trb.org/63532-trb-1.3393340/t005-1.3409009/419-1.3409356/17-05221-1.3400024/17-05221-1.3409360

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Abstract: Snow can cause dangerous driving conditions by reducing the pavement friction and covering the road surface markings. Salt is widely used by highway maintenance managers in the U.S. for reducing the impact of snow or ice on traffic. To develop long-term plans especially for the next winter season, it is essential to know what are the factors affecting salt usage and to determine sufficient amount of salt needed in each depot location. This can be done by estimating statistically robust models for salt usage prediction. In this study, historical data regarding storm characteristics and salt usage of New Jersey Turnpike (NJT) and Golden State Parkway (GSP) are used to estimate those models. The

linear models, the hierarchical linear (HL) models and the hierarchical linear models with varying dispersion (HLVD) are developed to predict the salt usage of these highways. Results show that districts with higher average snow depth, longer storm duration and lower average temperature are associated with greater salt usage. The HLVD models are found to have the best predictive performance by including random parameters to account for unobserved spatial heterogeneity and by including fixed effects in the dispersion term. In addition, by estimating case-specific dispersion based on storm characteristics, the HLVD models could be used appropriately to estimate the upper bounds of salt usage, which are not extremely large and could satisfy the salt demand in most cases. The findings of this paper can provide highway authorities with valuable insights into the use of statistical models for more efficient inventory management of salt and other maintenance materials.

Thermodynamics of Deicing Chemicals

Paper number 17-00413, http://amonline.trb.org/63532-trb-1.3393340/t021-1.3405667/325-1.3405869/17-00413-1.3405116/17-00413-1.3405887

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Abstract: The use of deicing chemicals is an important tool to keep roads free from snow and ice. To judge the performance of different deicing chemicals, testing them either in a laboratory or in the field is a common practice. Such tests are, however, time consuming and not always accurate. Another potential method, as we describe in this paper, is to use existing thermodynamic theory combined with an activity model for aqueous solutions to calculate properties relevant for winter maintenance. We looked at three common chloride salts, NaCl, $MgCl_2$ and $CaCl_2$, and used the extended UNIQUAC model to acquire the water activity for solutions of the three salts and mixes thereof. With the activity we could find the most stable state (solid, liquid as solution or vapor) of water at different temperatures. Two examples of applications for winter maintenance are presented, one predicting whether a road dries up after applying chemicals and the other calculating the ice melting capacity and freezing point of the salt solutions. The first example showed that, if the aim is to get a dry road after a deicing measure, mixing chloride salts would be disadvantageous. The second example showed that additives to NaCl increased ice melting capacity, particularly at low temperatures. It also showed that additives lowered the freezing point of the resulting solution, albeit only moderately for realistic amounts of additives. All in all, theoretical predictions of deicing chemical behavior showed good promise to become a useful tool for all actors in road winter maintenance.

Measuring Ice Melting Capacity Using Calorimetry

Paper number 17-00115, http://amonline.trb.org/63532-trb-1.3393340/t021-1.3405667/453-1.3405792/17-00115-1.3399995/17-00115-1.3405799

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Abstract: The ability to melt snow and ice is an important feature of any deicing chemical or product. This is called “melting capacity”, and is defined as grams of melted ice per grams of deicer. A product’s

melting capacity is important with regard to its applicability for use in snow and ice control. The standard procedures in the US for measuring melting capacity are SHRP H-205.1 for solid chemicals and H-205.2 for liquid chemicals. However, these test methods have proven to be inadequate with respect to their accuracy for research purposes. There is a growing need for developing improved procedures, as an increasing number of deicing products are currently being released on the market. This paper describes how calorimetry, which is measurements of heat changes that occur during a process, may be used to measure melting capacity. A calorimeter was therefore custom made for this paper's research purposes. It required a minimum of mechanical handling and had high temperature control precision excluding the most extreme causes for measurement errors in previously developed test methods. Liquid NaCl was tested and compared with the calculated melting capacity. The calorimeter produced accurate results. Tests were also performed using $MgCl_2$; the results demonstrated that $MgCl_2$ has a higher melting capacity than NaCl.

Performance Measurement

Development of a Model-Based Performance Measurement Tool for Winter Road Maintenance Management

Paper number 17-03099, http://amonline.trb.org/63532-trb-1.3393340/t021-1.3405667/325-1.3405869/17-03099-1.3400154/17-03099-1.3405877

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Abstract: Performance measurement of winter road maintenance programs have long been plagued with challenges of large spatial and temporal variation of winter events, wide variety of winter maintenance methods, and complex relationships between maintenance inputs, outputs and outcomes. This paper introduces a model based framework to address these challenges, which is demonstrated through a case study using data from the province of Ontario, Canada. The framework has been implemented in a web-based dashboard application that can be used as a decision support tool for evaluating the performance of a winter road maintenance program. The application integrates various highly disaggregated data pertaining to winter events, road traffic, collisions, and winter road maintenance activities. Various performance statistics and model estimates can be viewed at different levels of spatial and temporal aggregations supporting the needs of different tiers of management.

Integrating Crowdsourced Probe Vehicle Traffic Speeds into Winter Operations Performance Measures

Paper number 17-00161, http://amonline.trb.org/63532-trb-1.3393340/t021-1.3405667/653-1.3405736/17-00161-1.3404617/17-00161-1.3405741

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Abstract: Winter weather has a large impact on both mobility and safety nationwide. Transportation agencies rely on weather forecasts to make decisions before and during a storm but often lack quantitative tools for real-time monitoring of the storm's impact on traffic. Crowdsourced probe vehicle data provide an outcome oriented measure that can be used to calculate the impact on traffic of storms in near-real time as well as in after action review. This paper presents a series of performance measures relating winter storm parameters to the impact on traffic. Eight storms from the 2015-2016 winter season in Indiana that vary in duration and severity as well as impact on traffic are used for a case study. Performance measures, including time to recovery after the storm, duration-normalized impact on traffic, and material usage oriented measurements are proposed.

Snow Removal Performance Metrics: Past, Present and Future

Paper number 17-05301, http://amonline.trb.org/63532-trb-1.3393340/t021-1.3405667/453-1.3405792/17-05301-1.3399992/17-05301-1.3405793

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Abstract: Snow/ice maintenance operation is one of the most critical functions of state transportation agencies and municipalities in cold regions. The use of snow removal performance metrics is of increasing interest to transportation practitioners and academics. In this paper, a comprehensive literature review and a survey were conducted to gather information on performance metrics used by different transportation agencies in winter highway maintenance activities. The performance goals for snow/ice control were identified in the survey, with average rankings as follows (in descending order): Safety, Mobility, Economy, Essential Functions, Environment, Infrastructure, and Livability. The survey results were also tabulated and analyzed to identify best practices and future trends in the agencies. The key themes of the analysis were: Restoring safety and mobility consistently remains a priority of nearly all agencies. At present, time to established level of service is the most commonly used metric of different agencies. Due to their relatively high effectiveness, reliability and timeliness, more agencies are moving toward outcome-based and severity index-based performance metrics. Performance measurement by geographic area was also investigated, but no clear trend was found.

Pilot Test of a Thermal Infrared Video System for Performance Measurement of Roadway Snow and Ice Control

Paper number 17-00649, http://amonline.trb.org/63532-trb-1.3393340/t021-1.3405667/653-1.3405736/17-00649-1.3404616/17-00649-1.3405739

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Abstract: Real-time performance measurement can provide quality control for productivity improvement and efficient use of resources. Visual roadway snow and ice control (RSIC) performance

measurement is common when assessing the state of road surface (snow-covered, icy, bare, etc.), but is generally a subjective assessment made by RSIC operators and/or supervisors. The objective of this project was to pilot-test an objective method for processing real-time thermal imagery comparing roadway conditions in front of, and behind, an active RSIC vehicle. Two cameras were mounted on a plow truck, one forward-facing and one backward-facing, and test imagery was collected in the winters of 2014, 2015, and 2016. Differences in the temperature of the road surface created by the RSIC pass were quantified with a tool developed in MATLAB®. The tool imports the dual thermal video recordings and extracts still images every second. Analysis zones are captured and re-oriented and the difference in image intensity (a representation of temperature change) between the two images is calculated on a pixel-by-pixel basis. The tool was successfully applied to a RSIC service run and the average difference between the front and rear images on a reconnaissance (no plowing or spreading) and plowing pass across 4 minutes (240 frames at one per second) of imagery was calculated at 6.6 and 14.5, respectively (statistically significant at p = .01). While thermal video is well matched to RSIC evaluation, there are a number of challenges that make it impossible to implement this performance measure at a full scale for real-time feedback.

A Simple Snow Transport Estimation Based on Closed-Circuit Television Road Images

Paper number 17-06049, http://amonline.trb.org/63532-trb-1.3393340/t021-1.3405667/653-1.3405736/17-06049-1.3404615/17-06049-1.3405737

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Abstract: Snowdrifts on roads create serious safety problems in Hokkaido, Japan. Snow transport is commonly used to assess hazardous conditions resulting from snowdrifts on road; however, it is difficult for a model to estimate snow transport based on meteorological data, because snow conditions on the road space are complex. The present study objective was to improve the reliability of the differential weighted intensity of power spectrum (DWIPS), which was proposed by Nagata et al. as a way of estimating snow transport based on road images recorded by CCTV cameras along the road. The principle merit of DWIPS is that it enables snow transport to be estimated based on onsite images within the spatial area of the road. The present study used images from five CCTV cameras and meteorological data during the six winters from 2010 to 2015 in Northern Hokkaido. Snow transport estimated by the DWIPS model was compared with that estimated by the Hokkaido model under various blowing snow conditions. The comparison found that the snow transport determined by the DWIPS model better reflected the actual snow particle conditions on the road space than the Hokkaido model did, because the DWIPS model included the onsite conditions. It might be concluded that the DWIPS model has great potential for measurement of snow transport along the road.

Program Management

Dynamic Predictive Strategies for Urban Snowplow Routing

Paper number 17-06813, http://amonline.trb.org/63532-trb-1.3393340/t027-1.3402384/827-1.3402649/17-06813-1.3402650/17-06813-1.3402651

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Abstract: Snowplow operation is widely applied in snow season to remove snow/ice away from pavement surface to remove the snow impact on traffic and to achieve mobility and safety benefits. This paper proposes an optimization model to design a snowplow routing plan for a large urban network in a dynamic setting using predicted weather and traffic information. Different from traditional snowplow routing problem, which is formulated in a static manner and aims to minimize cost, our goal is to reduce snow impact on traffic and operation cost and to increase the benefit from plowing. To achieve the goal, we propose a formulation by taking advantage of the predictive weather and traffic information according to the assumption that the benefits associated with plowing depend on the real-time snow accumulation, the interaction between reduced capacity and traffic volume, and average travel time. A cluster-first, route-second heuristic approach is adopted to solve the problem. To evaluate the model and algorithm, an experiment is implemented with a locally calibrated network in the Chicago area. The snow accumulation effect before and after snowplow operation is emulated with a mesoscopic simulation tool. The simulation results confirm the proposed model with the ability to generate snowplow routing plan and to improve traffic performance after plowing. By comparing the results of our model and other static models, the method proposed results in lower average travel time and higher travel time reliability than the benchmark snowplow routing algorithm.

Operational Winter Severity Indices in Canada—From Concept to Practice

Paper number 17-03338, http://amonline.trb.org/63532-trb-1.3393340/t021-1.3405667/325-1.3405869/17-03338-1.3400153/17-03338-1.3405875

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Abstract: Public agencies are under increasing scrutiny to use their resources effectively and to demonstrate their effectiveness through performance measures. A variety of measures have been developed for winter maintenance operations, but the measures only provide meaningful information when they are normalized to the weather conditions that vary significantly from year to year and place to place. One method of normalizing is to use a measure the severity of winter weather conditions as they relate to winter maintenance activities. The challenge is to develop a WSI that explains temporal and spatial variations in winter road maintenance activities across varied geographic areas. In this paper, a methodology for developing a province-wide and simple-to-use winter severity index (WSI) is described using a case study approach on the provincial highway system of Ontario, Canada. This

methodology combines the use of expert knowledge and mathematical optimization to develop a WSI that assigns daily weather scores for each day based on weather triggers and an adjustment factor. These daily scores are aggregated to the 14- day period and are then correlated to maintenance activities. The WSI for Ontario provincial highways has a strong fit with maintenance measured as equipment-hours. Correlation of WSI values with equipment-hours at this temporal aggregation level vary from moderate to very high for each of the 20 maintenance areas across Ontario. When spatially aggregated to the provincial fit improves further to between 0.959 and 0.989 over seven seasons. This study demonstrates the utility of a province-wide WSI and describes how a WSI can be developed for road authorities.

Safety

A Reduction in Nonfatal-Injury Motor Vehicle Crashes with Anti-Icing Technology

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Abstract: Although there are several published papers and studies that find adverse weather conditions contribute to motor vehicle crashes and have an overall negative effect on highway safety, there do not appear to have been results published for an entire network, such as a state highway system, demonstrating the positive effects of winter maintenance anti-icing policies on safety. Following a decision in 2005/2006, the Connecticut Department of Transportation (CTDOT) converted from deicing to anti-icing policies. In this paper, aggregated motor vehicle crashes with nonfatal injuries are analyzed graphically to determine if winter weather safety was affected by CTDOT's switch from deicing using a sand and salt mix to anti-icing procedures including a switch to all salt. A survey of the states surrounding Connecticut provided evidence that CTDOT applies winter deicer chemical types and quantities in a similar manner to its neighboring states. This Connecticut study concludes that crashes with nonfatal injuries during winter seasons, in all kinds of weather and road conditions, declined by 19.2 percent between seven winters with sand-salt (7:2) mix (1999/2000-2005/2006) and seven winters of salt-only (2006/2007-2012/2013); and also that the same type of crashes that occurred when roads were snow/slush or ice covered declined by 33.5 percent. Also, there was an immediate additional reduction in nonfatal crashes with injuries after CTDOT converted to anti-icing in 2006/2007. Even considering the value of the increase in safety technology employed by modern vehicles, it appears that anti-icing likely reduces the amount of time that roads are slippery, thus prompting a reduction in serious crashes.

Snow Fences

Investigating Safety-Effectiveness of Wyoming Snow Fence Implementations Along a Rural Mountainous Freeway

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Abstract: Blowing and drifting snow is a problematic and dangerous aspect of interstate travel in the state of Wyoming. The control of snow and maintenance of roadways is an essential and significant task for many state and local agencies. Many significant roadway factors, such as vehicle control, surface conditions, and visibility, can be effected by the presence of hazardous winter weather conditions. In areas such as the inspected 19-mile section of Interstate 80, snow fences have become a common and practical method for mitigating the problem faced with large quantities of snow near or on the traveled way. Wyoming is a state that deals with a high amount of adverse weather related crashes during the winter season. Snow fence implementations have historically indicated a slight decrease in such crashes using a naïve before-after analysis. In this study, the safety effectiveness of snow fence implementations was investigated using a more rigorous quantitative-based approaches such as a before/after analysis with Empirical Bayes (EB) utilizing Wyoming-specific Safety Performance Functions (SPFs), as well as odds ratio. Crash modification factors (CMFs) were estimated for various crash types and severity levels. The results from this paper indicate that the implementation of snow fences contributes to a significant increase in safety effectiveness for interstate use during the winter. Specifically, it was found that during adverse weather conditions, snow fences decrease total crashes, and fatal and injury crashes by about 25% and 62%, respectively.

Snow Fences for Reducing the Impacts of Snow Drifts on Highways: A Renewed Perspective

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Abstract: In northern climates, snow fences are usually established in and/or beyond right-of-way to eliminate blowing and drifting snow on roadways and thus improve road safety. In order to make snow fences more effective on highways and provide guidelines for the departments of transportation siting them, this work reviews both the literature and survey responses from practitioners in northern states. This review combines information obtained from both resources to detail several aspects of snow fences, including the history, design protocols, siting policies, benefits, challenges, and numerical modeling of snow fences. Particular attention is paid to living snow fences as an alternative to the traditional structural snow fence. The survey results show that almost all of the responding agency have launched

snow fence programs in their districts, with a various design and siting protocols according to the specific conditions.