Abstract

In countries with severe winters such like Canada, winter road maintenance (WRM) operations, such as plowing, salting and sanding, play an indispensible role in maintaining good road surface conditions and keeping roads safe. WRM is, however, also costly, both monetarily and environmentally. The substantial direct and indirect costs associated with WRM have stimulated significant interest in quantifying the safety and mobility benefits of winter road maintenance, such that systematic cost-benefit assessment can be performed. A number of studies have been initiated in the past decade to identify the links between winter road safety and factors related to weather, road, and maintenance operations. However, most of these studies have focused on the effects of adverse weather on road safety. Limited efforts have been devoted to the problem of quantifying the safety benefits of winter road maintenance under specific road weather conditions. Moreover, the joint effects of and complex interactions between road driving conditions, traffic and maintenance and their impact on traffic safety have rarely been studied.

This research aims to determine the effect of WRM on road safety during snow storm events and develop models that can be used to quantify the safety benefit of alternative winter road maintenance policies, strategies and practices. Two integral aspects of collision risk were investigated, namely, collision frequency and severity. Collision frequency models were developed using winter storm collision data compiled for six winter seasons (2000 to 2006) for a total of 31 highway routes across Ontario. A comprehensive measure, namely, road surface condition index (RSI), was proposed to represent the road surface conditions during a variety of snow events. RSI was used as a surrogate measure to capture the effects of WRM. Other factors related to weather, traffic and road features were also accounted for in the analysis. Problems associated with data aggregation were also investigated. For this purpose, two different datasets were formed, namely, event-based data (EBD) which aggregates data by snow storm events and hourly based data (HBD) which includes hourly records of collision counts and other related factors. These two data sets of different aggregation levels were then used to investigate the effects of data aggregation and correlation (within – event) as well as to develop models for different purposes of benefit analyses. For EBD, Negative Binomial models and Generalized Negative Binomial models were calibrated whereas for HBD, Generalized Negative Binomial models and multilevel Poisson Lognormal models were calibrated. Generalized Negative Binomial models were found to best fit the data for both datasets. It was found that addition

of site specific variables improves model fit. RSI and exposure were found significant for all the models and datasets. Weather factors such as visibility, wind speed, precipitation, and air temperature were also found to have statistically significant effects on collision frequency. All the models were consistent in terms of effects of different variables. The EBD models are useful to quantify the effect of different maintenance service standards and policies with limited information on the details of the weather events and traffic. On the other hand, HBD models have a higher level of reliability capable of providing more accurate estimates on road accidents. As a result, they are useful for determining the effects of different treatment operations. Several examples were employed to demonstrate the application of the developed models, such as quantifying the benefits of alternative maintenance operations and evaluating the effects of different service standards using safety as a performance measure.

To enable a comprehensive risk analysis, collisions under both all-weather conditions and snow storm conditions over the six winter seasons were analyzed to identify the relationship between collision severity and various factors related to road weather and surface conditions, road characteristics, traffic, and vehicles etc., on collision severity. A multilevel modeling framework was introduced to capture the inherent hierarchy between collisions, vehicles and persons involved within the collision data. For each collision data set, three alternative severity models, namely, multinomial models, ordered logit models and binary logit models, were calibrated and compared. It was found that multilevel multinomial logit models were best fit to the data. Moreover issues related to different levels of aggregation were also discussed and results from occupant based data were found to be more reasonable and in line with general literature. Different individual, vehicle, environment and accident location factors were found to have a statistically significant effect on the injury severity levels. Contributing factors at the individual and vehicle levels include driver condition, driver sex, driver age, position in vehicle, use of safety device such as seat belt, vehicle type, vehicle age and vehicle condition. Roadway and environment factors include number of lanes, speed limit, road alignment, RSI/road surface condition, wind speed, and visibility. Other factors include light, and traffic volume. Two case studies were conducted to demonstrate the application of the developed models in conjunction with the accident frequency models for cost benefit analysis.

This research was the first to investigate the direct link between road surface conditions and collisions at an operational level. It has been shown that the developed models are capable of evaluating alternative winter road maintenance policies and operations and assessing the safety benefit of a particular winter road maintenance strategy or decision. This research is also the first to conduct an in-depth analysis on the problem of winter road safety at a disaggregate level that captures detailed temporal variation (e.g., hourly and by storm event)) within small spatial aggregation units (road sections corresponding to actual patrol routes). The safety models developed from this research could be easily incorporated into a decision support tool for conducting what-if analysis of alternative winter road maintenance policies and methods. Moreover these models could provide a mechanism to estimate road safety level based on road surface as well as weather and traffic conditions and therefore could potentially be used for generating safety related information for travelers as part of a winter traffic management scheme. Directions for future work are also provided at the end of this document.