CSCE Annual Conference

Growing with youth – Croître avec les jeunes

Laval (Greater Laval)

June 12 – 15, 2019

TRANSFERRING ROAD SAFETY PLANNING MODELS ACROSS TIME: CASE STUDY ON CITY OF KELOWNA, BC

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Abstract: Macro-level collision prediction models (CPMs) have been identified as a reliable planning-level decision-support tool to facilitate road safety planning. This case study reports on the results of research updating macro-level collision prediction models (CPMs) for Kelowna. Two objectives of this research were to 1) develop a set of updated community-based macro-level CPMs, and 2) apply these updated models in macro-reactive road safety applications (i.e., identification, ranking and remediation of hazardous locations). Several models stratified by land use (i.e., urban or rural), independent variable class (i.e., exposure, socio-demographics, network or transportation demand management), and data derivation (i.e., measured or modelled) were updated using the data from 183 traffic analysis zones (TAZs) in Kelowna. Generalized linear modelling (GLM) technique with negative binomial error distribution was used. The updated CPM results were in good agreement with past research that developed the original Kelowna models. One new and significant result in updating the CPMs, due to the availability of new data, was that decreased total collisions in a zone (i.e., neighbourhood) were associated with an increase in the proportion of roundabouts, a result seen previously only in micro-level collision prediction models (i.e., looking at individual intersections). The updated CPMs were then applied to present-day Kelowna neighbourhoods, to identify and rank collision-prone zones (CPZs) using the same methods reported previously by Lovegrove & Sayed (2006). This research demonstrates that updated CPMs are practical tools for community planners and engineers and that roundabouts can significantly improve neighbourhood safety. It also demonstrates how little data is needed to identify, diagnose, and remedy collision-prone zones and neighbourhoods in a proactive manner.

INTRODUCTION

With the advancement in the concept of safety conscious planning transportation planners and engineers are now proactively considering safety in the transportation planning process to improve the overall safety of the transportation network. Macro-level collision prediction models (CPMs) have been identified as a reliable tool to inform safety conscious planning and have gained considerable attention in the past decade. They evaluate the road safety risk for the entire area (neighbourhood, region, and city) instead of individual facilities and goes well with transportation planning models. However, the success or failure of macro-level CPMs for one spatial environment depends on the quality of the dataset, appropriate functional model form, and time frame of model development and model application (Hadayeghi, 2009). Since the road parameters (road lane kilometres, speed limit), network design (the type of intersections, block size, connectivity), regional socio-demographic, and size of the geographical aggregation unit (traffic analysis zones) changes over time, updating macro-level CPMs becomes necessary. In addition, the updating process may identify new variables that improve model quality. This case study reports on the results of research updating Kelowna macro-level collision prediction models (CPMs) and applying them for macro-reactive applications.

DATA AND METHODS

The data for this research comes from the City of Kelowna, located in the Regional District of Central Okanagan in the province of British Columbia (BC), Canada. With a total area of 211.85 square kilometres and a population of 127,380 in 2016, Kelowna is the largest city in BC's Okanagan Valley (Statistics Canada, 2016). Moreover, Kelowna is anticipated to be home to 50,000 new residents by 2040, given its rapid urban growth and economic development.

In this research, all data used for the development of community-based macro-level CPMs were aggregated to TAZ level areal units. The use of TAZs as the aggregation unit in the model development process ensures proper synchronization between strategic community planning as well as road safety planning objectives (Wei & Lovegrove, 2013). Based on the 2014 dataset obtained from the City of Kelowna, there are 183 TAZs which were further classified into urban and rural zones based on visual examination in Google Maps.

A geographically referenced ICBC collision database for the years 2013-2015 was selected for the development of community-based macro-level CPMs. Most of the independent variables used in the model development were identified by Lovegrove (2007), divided into four themes including exposure (EXP), socio-demographic (SD), transportation demand management (TDM), and the road network (NET). In all, twenty-seven variables were set as independent candidate variables.

Generalized linear models with negative binomial (NB) error distribution were employed to develop macro-level CPMs. The NB regression is the most commonly used development method for the community-based macro-level CPMs. In this study, NB models were developed following the methodology described by Lovegrove & Sayed (2006). The following model form was used for the development of GLM models:

$$E(\Lambda) = a_o(Z)^{b_o}e^{\sum b_i X_i}$$

Where, $E(\Lambda)$ is the predicted collision frequency per TAZ, Z is the lead exposure variable (total lane kilometres or vehicle kilometre travelled), X_i are the explanatory variables and a_0, b_0, b_i are the model parameter estimates.

MODEL RESULTS

Model development was conducted in sixteen model groupings stratified by two land uses (131 urban traffic zones and 52 rural traffic zones), two exposure variable sources (modelled and measured), and four variable themes (exposure, SD, TDM and network). The statistical associations between the total collisions and independent variables were identified to be consistent across all model groups.

Positive associations were identified between total collision frequency and explanatory variables including vehicle kilometres travelled (VKT), total lane kilometres (TLKM), zonal vehicular congestion (VC), population density (POPD), employment density (EMPD), signalized intersection density (SIGD), intersection density (INTD), the proportion of arterial lane kilometres (ALKP), and proportion of arterial-local intersections (IALP). The association with vehicle kilometre travelled (VKT), total lane kilometres (TLKM), and vehicular congestion (VC) appeared to confirm the intuitive expectations of higher probability of collisions with increased travel and road kilometres. The positive association with signal density (SIGD) is reasonable as signalized intersections have high-speed, high-volume traffic, and left-turn conflict, which presents high collision risk. Moreover, the increased crashes with an increase in the proportion of arterial-local intersections (IALP) in rural zones is also rational and can be related to one of the two issues:

a) usual nature of rural intersections, which are often screened by foliage, rolling hills, or other rural features,
b) unexpected conflicts at the intersections between the low-speed traffic on local roads and high-speed through traffic on rural arterials.

The increased collisions with increased intersection density (INTD) agreed with the results from the previous studies (Lovegrove & Sayed, 2006; Wei & Lovegrove, 2013). This association suggest that closer attention is needed when planning neo-traditional communities with grid street patterns that may encourage higher intersection densities. The association of increased collisions with the increased population density (POPD) and employment density (EMPD) seemed intuitive as well because greater population and employment densities lead to more commuters, more exposure, and more collisions. Similar associations were observed by Lovegrove & Sayed (2006).

Several models revealed the inverse association between total collisions and neighbourhood core size (CORE), the proportion of roundabouts (IRBP), proportion of local lane kilometres (LLKP), and the unemployment rate (UNEMPP). The decreased collisions with the increase in local lane kilometres (LLKP) is intuitive as local lane roads are low speed and low volume roads that indicate low collision risk. However, the association with an increased rate of unemployment is difficult to explain but intuitively fewer residents with jobs on average results in fewer commuters, less exposure, and fewer collisions. Though decreased collisions at roundabouts have been seen previously in micro-level CPMs (i.e., looking at individual intersections), decreased collisions with the increase in the proportion of roundabouts (IRBP) is observed for the first time in macro-level CPMs. This association is rational as roundabouts reduce vehicular speeds, and conflict points at intersections by eliminating left turns thereby reducing collision risks and severity.

MACRO-REACTIVE APPLICATIONS

The developed NB CPMs were applied to identify, rank, diagnose, and remedy collision-prone zones (CPZs) in Kelowna. Empirical Bayes (EB) method was employed for the identification of collision-prone zones (CPZs). Two ranking criteria, namely potential collision reduction (PCR) and collision risk ratio (CRR), were utilized to rank the identified CPZs. Further, trigger variables, over-represented collision patterns, land use, and road maps provided clues to possible road safety problems for each CPZ. Most of the urban CPZs were identified along Highway 97, which can be attributed to the high-speed high-volume traffic on the highway and the predominance of signalized intersections. For rural CPZs, a high proportion of arterial-local intersections was identified as a primary trigger variable due to the conflict between the traffic to/from the local roads and the high-speed through traffic on the arterials. Based on the different road safety problems identified in top-ranked urban and rural CPZs, converting signalized intersection to roundabouts in urban zones, traffic calming local roads in urban and rural zones, converting arterial local intersections to restricted right-in/right-out intersections with no left turns, transit service improvements, and improved land use mix were identified as potential remedies to check collisions.

Moreover, a series of macro-level collision modification factors (CMFs) was developed to examine the impact of planning level explanatory variables on the safety of a traffic analysis zone using sensitivity analysis. Conceptually, sensitivity analysis provides similar information to the conventional collision modification factors (CMFs) which are used to estimate the change in collision frequency because of network design or operational change. The CMF for an explanatory variable indicates percentage change in collision frequency with one-unit change in the value of a variable. The CMFs were not developed for the exposure variable, as the relationship between collisions and lead exposure variable (VKT or TLKM) is nonlinear, and one single CMF value for a total collision model cannot be reported.

One interesting observation was made regarding the proportion of roundabouts: CMFs for the network model indicated that 10%, 20%, 30% increase in proportion of roundabouts in an 80 m grid pattern neighbourhood (with 20 intersections) by converting signalized intersections to roundabout results in 26-

60%, 45-85%, and 60-90% fewer collisions in the neighbourhood respectively. This indicates that roundabouts can be considered as a potential countermeasure in urban CPZs where collisions are triggered by high intersection density. Though no CMF was obtained for rural zones, roundabouts can still be implemented as a traffic calming measure in rural zones to remove the conflict of the low-speed local traffic with high-speed shortcutting traffic or high-speed through traffic on connected collectors or arterials.

CONCLUSIONS

The collision prediction modelling results indicate that it is possible to quantify statistical associations between community-level collision frequency and community traits. The research also demonstrates that updated CPMs are practical tools for community planners and engineers and that roundabouts can significantly improve neighbourhood safety. It also demonstrates how little data is needed to identify, diagnose, and remedy collision-prone zones and neighbourhoods in a proactive manner.

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