NON TRAFFIC VOLUME-BASED COLLISION-PREDICTION REGRESSION MODEL FOR INTERSECTIONS SAFETY[1]

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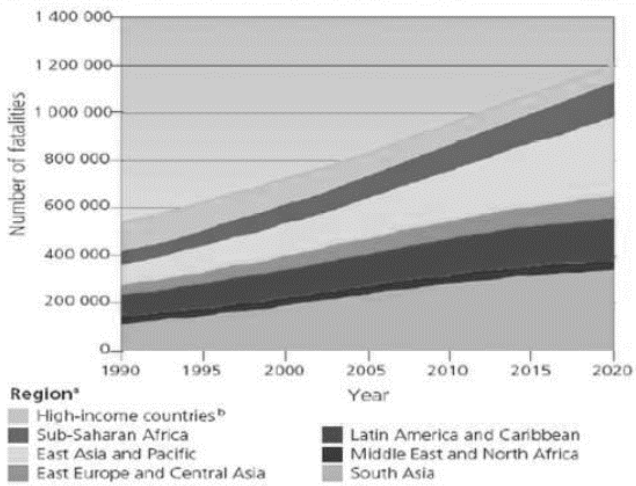
Introduction

The decade of "Action for Road Safety" started in 2010 when the number of people killed on the world's roads broke a record of 1.24 million(World Health Organization, 2013). As a volume comparison, this represents more than Bahrain's population that same year(Bahrain Open Data Portal, 2013). While the focus and trend shifted topromotingsustainability, encouraging non-motorized transport may not always meansafer roads; the report shows that 27% of global road traffic deaths are among pedestrians and cyclists. Walking and cycling needs to be safer, and protecting these road users from high-speed traffic is essential, although road traffic fatalities are predicted to increase by 17% by the year 2020 and the trend continues to increase.

Figure 1 number of road fatalities in world in 30 years (World Health Organization, 2013)



In Canada, the federal, provincial and territorial governments work to improve road safety in order to reduce the number of fatalities and serious injuries. However, in 2016, the number of motor vehicle fatalities was 1,898; up 2.0% from 2015 (1,860). The trend continued to improve in 2017 by 2.8%with 1,841 fatalities(Canada, 2018).Canadian road networks are relatively safe compared to other countries. The number of fatalities per 100,000 population and the number of fatalities per billion vehicle kilometres travelled were5.0 and 4.8 accordingly in 2017; the lowest on record.

Studying the history of the reported collisions is the most common approach to assess safety performance. These studies are all dependant from "Historical collision records." Conflict analysis and surrogate measures of safety performanceare alternative ways in safety analysis. Recently, there is a trend among researchers to use microscopic traffic simulationswith surrogate measures of safety performances. This is an analysis of high-risk vehicle interactions (or conflicts) rather than actual event (collision). This

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phenomenon can be described as “Observable situations in which two or more road users or vehicles approach each other in space and time to such an extent that there is a risk of collision if their movement remain unchanged”(Hauer, 2001).

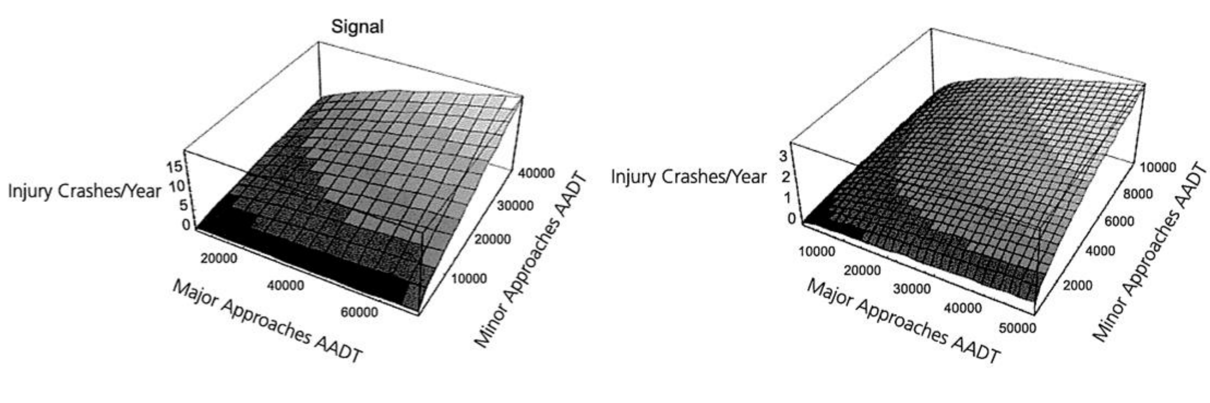
The focus of this research is to describe a methodological approach and to study a new or untested safety material without putting traffic at risk. Lack of collision data from deployment for untested safety treatment might prevent onesto conduct classic road safety analysis and evaluate their impact on road safety. This is an alternative approach to assess safety impact of a new treatment with observing, monitoring and recording collisions. It is also essential for traffic engineers to prevent future collisions and not cause them. The goal is to understand the ability of a new treatment in commanding drivers’ attention without putting them at risk.

Using critical traffic conflicts computed in simulation models as a surrogate safety measure is presented for assessing safety at un-signalized intersection with a backlit Light-emitting diode (LED)STOP sign.In this study, thetraffic flows were computed using camera footage fromfour consecutive intersections. The extracted data was used in a calibration process of microsimulation model for validation. The number of critical conflicts at the intersections has been extracted and correlated to presumable collisions. Thresholds for Time toCollision (TTC) and Post Encroachment Time (PET) was assumed 1.5” and 5”, respectively. A regression model was then utilized to predict collisions on the basis of the critical conflicts. Unlike the conventional regression models, this method is using conflict as the dependent variable.Previous studies conducted by the authors have used volume-based regression models in order to benchmark all findings. (Giahi Foomani, Li, & Alecsandru, 2016)

Research Background

Among road network facilities, roadway intersections are known to account for 45% of total collisions (DOT, 2014). Among control devices at intersections, the ones operated through STOP signs represent the most vulnerable facilities that exhibit the highest collision rate leading to fatal or serious injuries (Hauer & Persaud, 1996). Twenty-one percent of collisions are known to be caused by the environment surrounding the driver (DOT, 2014), while “Inadequate and poorly maintained signs” is often cited as a contributing factor. About 8% of fatalities and 11.1% of total collisions occur at STOP-controlled intersection.As for collisions with injuries, the safety comparison between two identical four-leg intersections is displayed in figure 2.As per below, the STOP-controlled intersections (SCI) have relatively high risk than signalized intersection comparing to their throughputs. In Canada, 2,728 individuals have lost their lives at these facilities between 1999 and 2011 (National Collision Database Online, 2014).

Figure 2Predicted injury crashes at signalized vs STOP-controlled four-leg intersection(AASHTO, 2010)



Intersections are known as one of the main cause of traffic safety hazards due to a conflict risk among motorist and non-motorist travellers. From a traffic operation perspective, intersections are sources of traffic delays, capacity constraints and interruptions in traffic flow. However, they are an unavoidable necessity for a traffic network point of view.Proper signage and road alignment are part of the requirement of a well-designed intersection.The STOP signs should be visible from a sufficient distance to command drivers' attention well before entering the intersection.The American Association of State Highway and Transportation Officials (AASHTO) recommends Minimum Required Stopping Sight Distance (MRSSD) from the conflict line (for instance,stop line at intersection) to be calculated to define variables like signage size and speed limit of the link (AASHTO, 2004).

The safety performance function of two-way STOP-controlled intersections has been estimated in different studies (Persaud, Retting, Garder, & Lord, 2001; Retting, Persaud, Hauer, Vallurapalli, & Mucsi, 1997). According to the Federal Highway Administration (FHWA), accuracy, completeness, validity, timeliness, coverage and accessibility are data quality measures in traffic operation and safety data (DOT-FHWA, 2004). The impact of data quality has been investigated in different studies (Essa & Sayed, 2015; Foomani, Alecsandru, & Khodabakhshi, 2013; Ibrahim, Sayed, & Ismail, 2012).

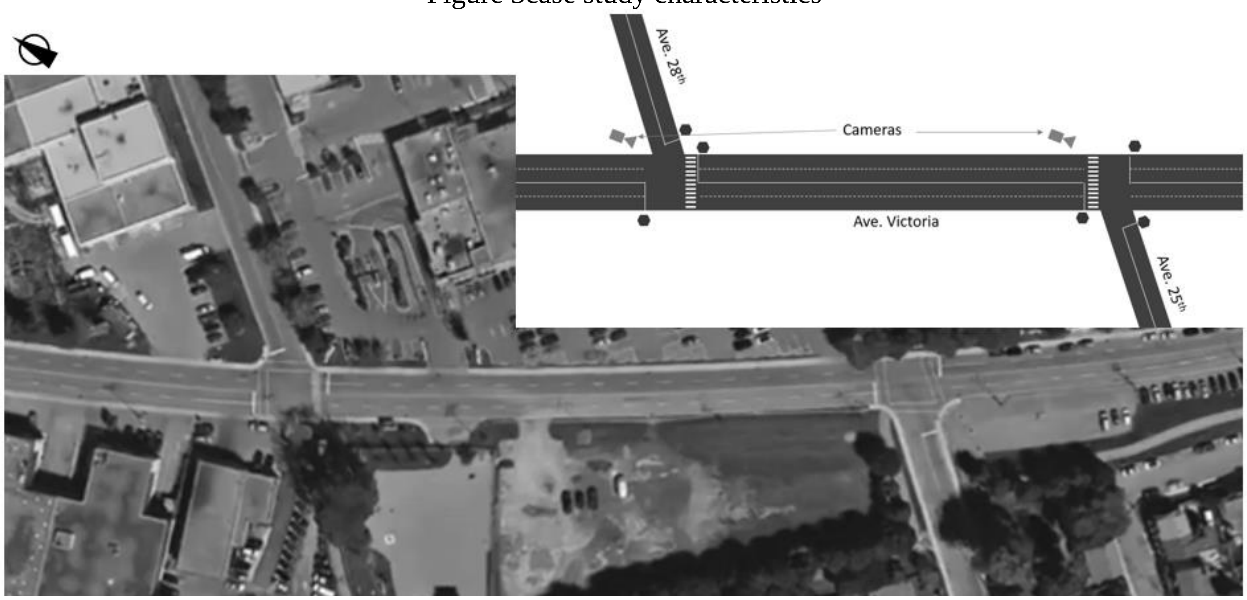
This study is choosing not to use the traditional road safety analysis due to numerous problems associated with accident data; accidents are rare to happen, not all accidents are reported, a new treatment might put traffic at risk for long-term analysis.Traffic simulation models have been used widely to conduct objective methods in conflict analysis using computers.Although the early modeling techniques were ineffective to replicate real world scenarios, eventually, the advancement in computational power and numerical simulations allowed for more modeling opportunities. Gettman and Head investigatedthese limitations in different microscopic traffic simulation software packs. They have also provided some detailed guidelines for calibration of simulation model, extracting the required data, and presenting the results (Gettman & Head, 2003). Sayed has developed one of the earliest tools using traffic conflicts with TTC as the critical traffic event in simulating driver behavior (Sayed, 2008). Surrogate Safety Assessment Model (SSAM) is a common tool for objective conflict analysis developed by FHWA. Major microsimulation software vendors can provide safety parameters required for SSAM modeling. For example,vehicle trajectory file is an output option for traffic simulation models. Many researchers have refined surrogate safety assessment modeling, and have also revealed their operating limits (intersection, road segment, roundabout, etc.) (Al-Ghandour, Schroeder, Williams, & Rasdorf, 2011)(Zhang, Liu, Wang, Bai, & Chen, 2013)(Wang & Stamatiadis, 2013)(Saunier, 2014)(Tao, Foomani, & Alecsandru, 2015). Two elements of PET and TTC has been used in this study.

PET is used as the primary proxy safety indicator in some studies(Pirdavani, Brijs, Bellemans, & Wets, 2010). The simulation model used was Paramicsand parameters such as speed and traffic volume wereused for the calibration. The methodology consisted of four loop detectors placed at each approach of a 4-leg intersection with 4 conflict zones inside the intersection. The findings of this study showed a significant correlation between the selected parameters and PET. Pirdavani's approach was used more recently (Deepak & Vedagiri, 2014) at a T-intersection in Mumbai, India. Similarly, the PET measure was used as the proxy conflict indicator. The collected real-world data was used to calibrate another microscopic simulation model, namely VISSIM. The authors choose to use image processing to detect the conflict. In another attempt, El-Basyouny and Sayed have tried to determine the relationships between collisions and conflicts for SCI and they compared volume-based to conflict-based SPF(El-basyouny & Sayed, 2011). They found a significant relationship between collisions and conflicts upon adjusting for measurement errors compared traditional statistical models.Other studieshave evaluated the limitation of conflict analysis using microsimulation for SCI by calibrating AIMSUN. They suggestthat a conflict-based model is a better fit compared to their previous attempt using multiple linear regression model(Caliendo & Guida, 2012). This study has been developed later (Lorion & Persaud, 2015) in a three-pronged investigation to develop collision prediction models based on traffic volume and two surrogate safety measures (conflicts and delay). The authors included 133 two-way SCI (78 three leg and 55 four leg) in greater Toronto region. Vehicular traffic at each site was modeled with Synchro to estimate the intersection delay, and microscopic simulations were conducted with VISSIM. The delay at intersection includes both left turn maneuver delay as well as delay at entering (delay from the upstream intersection). The promising results of this study add more value to microsimulation surrogate safety measures in developing collision prediction models compared to the traditional collision volume modeling approach. Lorion and Persaud results both from the delay and conflict-based collision prediction models were shown to be reliable for the types of intersection analyzed (i.e. three and four leg intersection, respectively).

As a result, there are at least 3 reasons for justifying this paper: the first is motivated by the need to quantify safety effect on the expected number of crashes for a new and un-tested treatment without putting the travelers at risk; secondly, given the range of the above mentioned surrogate safety assessment models, conflict analysis, using microsimulation, is highly recognized and is areliable tool where accident data is unavailable or incomplete; last but not least, the opportunity which is unique to the testbed that the same travellers are exposed to two different types of LED signs under the same road conditions. This will reduce the impact of many independent variables which might affect frequency of conflicts such as pavement surface condition, lighting, weather and diverse driver behaviour (acceleration, deceleration).

Testbed characteristics:
The two T-intersections in the picture below are located in Lachine-Montreal-Quebec as displayed in figure 3. Mixed traffic of motorized and non-motorized was considered in the study. The major road is a two way, two lane link in parallel to highway 20 which makes it an attractive alternative route during rush hours. The two, two-way, one lane minor collectors are not perpendicular to the major link with almost identical properties in term of traffic volume, alignments and geometry.

Figure 3case study characteristics



All approaches are equipped with STOP signs. The two STOP signs on the westbound approaches on the Victoria intersection and 28th Ave are equipped with flashing LEDs. On the westbound approach of Victoria and 28ththe 6 LEDs are embedded at each corner of the sign-face. The other sign is equipped with a backlit LED film behind the signage. They both have consistent flashing rate of 60 times per minute (1 hertz). All the other remaining signs are standard retro-reflective sheeting signs. All approaches have been included in the study.Four GoPro Hero 3 video cameras were used, set to record 720p video at 30 frames per seconds, each pair recording east and westbound on the main link as shown on figure 3. The camera is capable of recording up to 10 hours of video with backup battery pack. The LED signs are standard shape, solar powered and have been installed for 2 months to pass the warm-up phase as suggested or before-and-after analysis(Gates, Carlson, & Hawkins, 2004).

Findings from the study

The network was assembled and simulated for previous study conducted by the authors and presented in 52nd CTRF annual conference. The process of calibration of the microsimulation (VISSIM)using traffic flow and driving behavior characteristics has also been demonstrated using a two-step calibration method to reproduce realistic results(Alecsandru, Lauziere, & Foomani, 53AD). The calibration operation is the capability of the presentation of the values observed and measured in the field with values produced by the simulation.

Total traffic entering each intersection, for every approach, turning (left, right), straight-on maneuvers, vehicle type, lane changes, and the peak hourly traffic volume VHP has been used in the calibrated model as well as assignment of traffic.

The goodness-of-fit measures between simulation and measure based on GEH scale was less than 5 on all time intervals.

$$GEH = \sqrt{2(M-C)^2 / M+C}$$

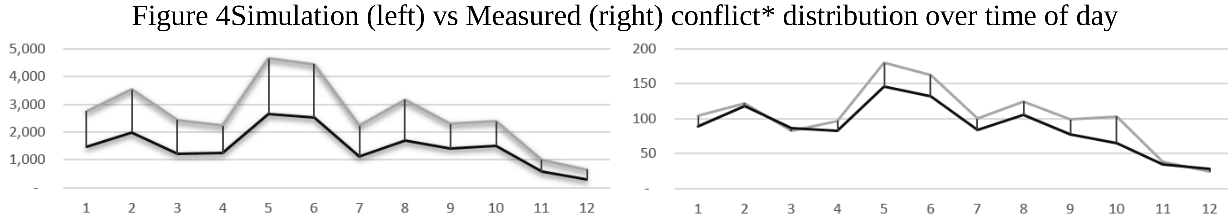
M and *C* are denoting simulated and measured hourly traffic volume.

The sampling data provided 2311 events of conflicts enriching simulation calibration. According to literature, on a two-lane SCI, over 85% of the conflict percentile is happening with 0<TTC≤2.5 Sec and 0<PET≤4 Sec(Park & Lord, 2010). Zero values were removed as these conflicts were caused by errors in the simulation, irrelevant conflicts outside of a 50-meter radius of the intersection and north/south bound conflicts since they were not impacted by the treatment. Unfortunately, it does not appear that the severity can be investigated with PET and TTC hence the magnitude of conflicts-collision is not included in the purpose of this paper. The conflict types can only be categorized based on the trajectories as |conflict angle| less than 30^ rear-end, crossing conflict >85^ or otherwise lane changing.

Table 1 Conflict (0<TTC≤2.5, 0<PET≤4 Sec) for each intersection

		Time														
		11h00	12h00	13h00	14h00	15h00	16h00	17h00	18h00	19h00	20h00	21h00	22h00	23h00		
	Total conflicts	12h00	13h00	14h00	15h00	16h00	17h00	18h00	19h00	20h00	21h00	22h00	23h00	24h00	Measured	Simulation
LED sign (WB	Observation	104	122	82	97	180	163	100	125	99	103	38	24	15	1,252	
28th Ave.)	Simulation	1,478	1,987	1,210	1,244	2,666	2,510	1,120	1,710	1,395	1,515	570	275	222		16,424
Backlit sign (WB	Observation	89	118	86	83	146	132	84	105	78	65	35	28	10	1,059	
25th Ave.)	Simulation	1,280	1,549	1,227	987	1,986	1,932	1,117	1,469	895	879	425	376	135		12,977
														Total	2,311	29,401

Figure 4Simulation (left) vs Measured (right) conflict* distribution over time of day



** Gray westbound on Victoria and 28th Ave, black westbound on Victoria and 25th Ave.*

In order to estimate the expected number of collisions on each intersection, we need to a conflict-based collision prediction model and test to determine the strength of this relationship. Unfortunately, the authors did not have a traditional traffic volume-based crash prediction due to insufficient collision data.

To estimate the frequency of collision at each intersection, Generalized Linear Regression Model (GLM) were used. The assumption was the number of accidents $Y_t$occurs at the time interval *t* at each intersection during the observation time are Negative Binomial (NB) random variable with:

$$E\{Y_t\} = \lambda_t \quad and \quad VAR\{Y_t\} = \lambda_t(1+\lambda_t/\varphi) \ and \qquad \lambda_t = \exp(x_t^T \beta)$$

Where φ is overdispersion variable $x_t$is a vector of k covariates and β is a vector of k (unknow) parameters.
More in-depth discussion is literature (Caliendo, Guida, & Parisi, 2007).
The log-liklihood function under the leading model is maximized to get the estimate for $\hat{\varphi}$ and $\hat{\beta}$ of the unknown parameters $\beta$and φ. Taking to consideration of maximum likelihood estimate:

$$\hat{\lambda}_t = \exp\left(x_t^T \hat{\beta}\right)$$

The total number of conflicts per hour (*C*) generated by the simulation model after calibration considered as the potential covariate. A dummy variable (Du) introduced to unbiased rush hours' time intervals to take into account the occurrence of a much higher number of collisions during the evening peak hours.

$$Collisions = \ e^{\beta_0+\beta_1 Du}(\mathrm{C})^{\beta_2}$$

The result from Likelihood ration test (LRT) shows that covariates Du and C in model are significant with the R-squared over 95%. The estimates for collisions for intersection equipped with backlit sign and LED STOP sign consequently showed 18.72 vs 24.14 consequently.

Conclusion and Remarks

A microsimulation model was calibrated and employed to predict the number of collision at two signalized intersections using conflicts countsas covariates. These two intersection were equipped with two different type of treatment (LED and backlit). A significant relationship was found between collisions and conflicts uponadjusting for measurement error and introducing a dummy variable. This was to reinforce the idea that a well calibrated model can be used after validation of the conformity between variables from observation and Simulation. The intent was to not expose traffic for a long period of time to the risk from an untested treatment.
Conflict is a closely correlated variable to traffic volume however the reason that conflict might fit better to actual collision. "The likelihood of collision will increase with increasing number of conflicts", this statement seems more factual and related than "Increase in volume will increase collision". A congested traffic condition is a good example that violate the second statement.
In this example the number of conflicts during day time between the two intersections was more uniform than night. One way to explain this difference is, better perception of the traffic commend from the backlit signage at night. The challenge still remain to reflect these difference in microsimulation model.

Acknowledgement

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