

INVESTIGATING SAFETY IMPACT OF BACKLIT PEDESTRIAN CROSSING SIGN USING DRIVER BEHAVIOR ANALYSIS

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Introduction and problem statement

The first traffic signs have been introduced at the end of 19th century. Over a century later these signs are still playing a major rule in traffic operation and safety performance of ground transportation network. The sheeting material of these signs has been evolved and tested constantly to evaluate retroreflectivity based on their use, type, pigments, film and micro-prisms. The objective is to ensure that road signs are visible, legible and reflecting an appropriate amount of light at the approach of road users. However these signs are still known to be a safety bottle neck especially under poor light condition. Only one quarter of the total driving occurs during night time however more than half of total collisions occur at dark [2].

Among all road facilities, intersections are known to be the most vulnerable with 45% of total collisions [2]. SCI is sitting at the top of the list with the highest collision rate accounting 8% of fatalities and 11% of total collisions with serious injuries [3]. Unfortunately pedestrians are the leading victims in the equation of nighttime SCI collisions. Only in Canada we have lost 2728 individuals between 1999 and 2011 [4]. Twenty-one percent of the cause for these collisions are known to be due to the environment surrounding the driver and “Inadequate and poorly maintained signs” is often cited as a contributing factor. According to one study, about 60% of SCI collisions are due to deliberate, intentional or unintentional in compliance to the command of the traffic signs [5]. Hence there isn’t any clear understanding about the balance between intentional vs unintentional violations. Nevertheless misperception or oversighting of the sign is a major contributing factor. The failure is due to the poor visibility or illegibility of signs or road/pavement marking alignments. Hereupon, the poorly visible signs may fail to meet the condition “to command drivers’ attention” required in the Manual for Uniform Traffic Control Devices [6]. Signs with enhanced conspicuity could be a proper substitute.

The illuminated signs (including LED and BLS) should be considered wherever reflectorized signs are not effective; for example, where background light sources or other uncontrollable distractions reduce visibility of the signs, at decision points on high speed/high volume facilities or where vehicle headlights may not adequately illuminate the signs and more over locations with hazardous pedestrian crossing. Currently there are available guidelines setting the standards for minimum performance requirements of LED signs (i.e. light intensity, flashing frequency, photometric parameters) [7] [6].

Proper installation of illuminated traffic signs and the impacts to drivers’ understanding has been investigated in the previous studies. That includes regulatory signs as well as warning signs (i.e. pedestrian crossing and school zones). The luminous Intensity of the flashing beacons and correlation with compliance as well as the sign face was among topics in the previous studies [8] [9].

As for the performance safety evaluation of flashing signs, there are two main streams in the previous studies; collision based and conflict based. Collision analysis is accounting and examining the actual accidents, while surrogate safety measures based on observation of actual driver interaction with the traffic signs are the basis of conflict analysis. Based on EB before-after studies, it appears that this kind of

treatments can reduce intersection-related collisions. However there is a lack of consistency between researches. For instance on two-way stop controlled intersections found a substantial change in stopping compliance after installation of the treatment, with minor changes in approaching speeds [10]. Hence the results either was either equivocal or not in agreement from report to report [8][11]. Lack of enough collision data is a major concern[12] [13] . Researchers have addressed the presence of underreporting in collisions too [10][14]. Additionally, while crash based analysis is “reactive” modeling approach in nature, the conflict-based safety assessment is a “proactive” one. This means that a significant number of crash events must occur before the problem is identified or a treatment performance measured. The availability of various quantitative analysis methods as well as the readily available computer traffic simulation models increased researchers’ confidence in conducting more reliable traffic safety studies using non-crash data [15][16][17].

Design of the study

Among potential SCI in the greater Montreal area, a section of Victoria Avenue, (East-West arterial) under the jurisdiction of borough of Lachine has been selected. The approaches of SCI had similar physical and operational characteristics in term of geometry, traffic flow, driver population mix and various transportation modes. While the test bed location was accessible for researcher to do the daily visits, proximity of nearby road-side structures has been also considered in order to safely attach, mount and install data collection equipment. The section under study includes a four-leg intersection on two-lane bidirectional road, crossing 18th Avenue Figure 1 Site location and characteristics. The posted speed limit is 40 km/h. The intersection is equipped with four pedestal-mounted retro-reflective sheeting STOP sign, regulatory sign (ARRÊT) P-010. The west approach has also a ped-crossing sign (P-270-2). On the east approach, a ped-crossing sign has been mounted under the STOP sign with 1Hz flashing backlit LEDs embedded behind the sign-face. This is a solar powered device equipped with photocell and it was used to replace a standard ped-crossing sign for the purpose of this study. All signs follow MUTCD standard under section 2B-05/4L.05 of MUTCD and flashing sign requirements under 2A.07 [6].



Figure 1 Site location and characteristics

In total 60 hours night-time video data was recorded in three data collection sessions after 30 days warmup period. As for data collection, four safety factors has been measured; drivers’ compliance to the traffic control devices at SCI, approaching vehicle speed, traffic volume, speed variances, drivers’ reaction point and finally, drivers’ interaction with the pedestrians crossing the SCI. A hybrid data collection method [16]

has been deployed with digital video cameras and high definition radars to measure per-vehicle speed data. The data comprises per motorist speed, correlative speed, headway, encroachment time, trajectory, maneuver, and traffic volume. A pole mounting unit attached a radar and cameras to a telescopic mast as shown in figure 2b.



Figure 2a picture annotation, 2b Data collection station

The drivers' compliance and interaction has been captured deploying a semi-automated method instead of traditional observers' judgment proposed in previous studies[16]. Then the video footage has been overlaid on a marked and annotated transparent picture (figure 2a) to account number of frames for judgment on compliance using formula 1. ITE manual of transportation engineering studies suggests full stop (0-1 km/h), rolled through (1- 5±1 km/h) and blew through the stop sign (more than 5 km/h) [9] however the presence of opposing traffic or pedestrian was also considered. For instance for a vehicle with a length " l " and speed " s ", the total number of frames in which the object crosses a virtual line can be calculated as follow:

$$\#frames = \frac{l(m)}{s(m/s)} resolution\ rate\ (fps)$$

Equation 1

The total sample size comprises of 2311 approaching vehicles with different reaction depending on presence of opposing traffic or type of the sign. The results has been summarized bellow:

	Full - stop	Roll - through	Blow-through	Grand Total
Eastbound traffic (Exposed to BLS)	499	552	75	1126
Without opposing traffic/pedestrian	133	278	37	448
With opposing traffic/pedestrian	366	274	38	678
Westbound traffic (exposed to standard per-crossing sign)	533	452	200	1185
Without opposing traffic/pedestrian	157	186	93	436
With opposing traffic/pedestrian	376	266	107	749
Grand Total	1032	1004	275	2311

Table 1 approaching vehicle and behavior at the SCI

Summary of findings

Some recent studies have considered speed and compliance, as the two major surrogate collision measures to evaluate treatments efficiency at SCI [10] [17] [18]. This study is based on those factors with an insight into SCI dynamics of interaction between travelers. In a simple word, the collision risk is higher whenever a driver doesn't comply with the sign in the presence of another opposing vehicle or crossing pedestrian. Another technique used in this study was calibration of microsimulation and conflict analysis. Hence the results include analysis of; speed, compliance and conflicts.

Speed

Two HD radar devices have been installed on the road side, fifty meters down the stream of east/west bound. In addition to radars, two cameras were facing the street and recording the approaching traffic. With the same video annotation technique described earlier, the decision point of each driver (based on the brake lights) has been marked. With this method, the speed and brake distance (front bumper – stop line) has been captured (figure 3).

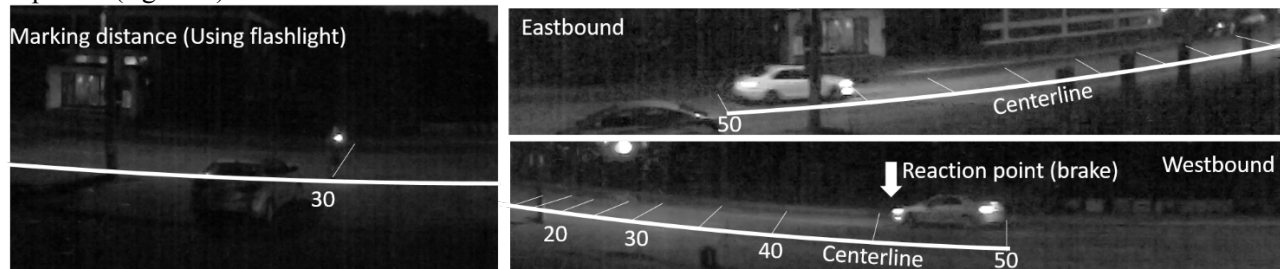


Figure 3 transformation from the screen coordinates to real-world coordinates (left). Marking the decision points (Right)

The distribution diagram of the braking points is presented on the figure 4. The average speed on the west approach has been slightly reduced for almost 2 km/h in comparison to the opposite direction (23.38km/h). Another findings was the distribution of the speed has changed. More uniform speed distribution when drivers approaching to BLS. Less variability on the eastbound (STD ~3.9 compare to ~5.1). That implies, drivers approaching the BLS sign were responding faster to the sign compare to the opposite direction while they were approaching gently in a more even pattern.

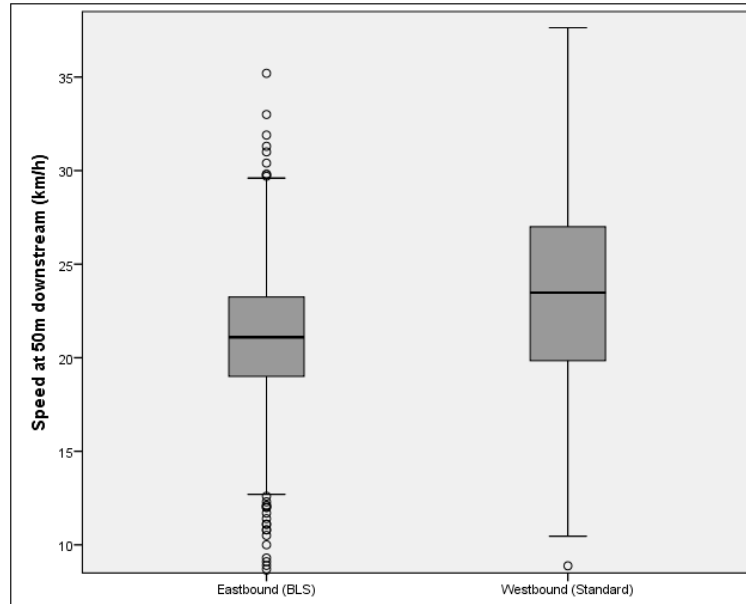


Figure 4 boxplot speed comparison

Compliance

The main goal of the statistical modeling was to determine if, after controlling for external variables (weather, light, geometry,...) and with or without presence of opposing traffic or pedestrian crossing, the distribution over the three degrees of stopping compliance was different between BLS and Standard. The weather, light and geometry was the same at the time of test and therefore these variable had no statistically significant effect on stopping compliance and was dropped. The multinomial logistic regression model (MNL) was selected.

The response variable had one of the three outcomes (full-stop, roll-through and blow-through) which is non-continues without natural ordering. The explanatory variable can be selected as approaching to BLS vs approaching to standard Ped-crossing. This is also categorical (non-continues). The correlation between response variable to the explanatory variable is examined with MNL. Making full-stop is the desired response variable. Hence all the other categories has been selected to be the reference category in the analysis.

In order to better understand the covariance B on table 2, one can say that when opposing traffic was present, the odds that a driver at BLS make a blow-through instead of full-stop is 0.364 to odds for a driver at Standard sign. The odd ratio is $\exp^{(B)}$. Based on the results, we can see that the ratio of roll-through has been increased (especially on no-opposing traffic case), however this is a true assumption that the difference could represent those drivers that were going to blow through at the SCI if BLS wasn't there.

Parameter Estimates (without opposing traffic)								
1 ^a	B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
							Lower Bound	Upper Bound
Roll-through	Intercept	.176	2.625	1	.105			
	[BLS]	.561	13.760	1	.000	1.753	1.303	2.358
	[Standard]	0 ^b	.	0	.	.	.	.
Blow-through	Intercept	-.517	15.589	1	.000			
	[BLS]	-.762	11.234	1	.001	0.467	.299	.729
	[Standard]	0 ^b	.	0	.	.	.	.
Parameter Estimates (with opposing traffic)								
1 ^a	B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
							Lower Bound	Upper Bound
Roll-through	Intercept	-.343	18.354	1	.000			
	[BLS]	.054	.227	1	.634	1.055	.845	1.318
	[Standard]	0 ^b	.	0	.	.	.	.
Blow-through	Intercept	-1.254	130.927	1	.000			
	[BLS]	-1.011	24.891	1	.000	0.364	.245	.541
	[Standard]	0 ^b	.	0	.	.	.	.

a. The reference category is: Full-stop.

b. This parameter is set to zero because it is redundant.

Table 2 Parameter Estimates (with and without opposing traffic)

Conflicts

Over the past three decades traffic simulators have been improved with multiple calibration efforts by adjusting the parameters of the behavioral models to the observed driving behavior in different studies[15][19][20]. In this study VISSIM network was been assembled and traffic flow and driving behavior characteristics has been set to values using a two-step calibration method to obtain realistic results[20]. However VISSIM has no function to simulate the compliance to stop line. That means all vehicle making a full stop! By introducing dummy connections between links on the intersections we tried to introduce this driving behaviour (full stop, rolled through, and blew through) in the network. The data captured from video analysis was used to feed the simulation.

The output trajectories then were utilized in SSAM (surrogate safe analysis model) and three type of conflicts; crossing, rear-end and lane changing was detected by selecting the right objective method and setting appropriate threshold. The selected objectives was time to collision (TTC) and post encroachment time (PET). TTC is the expected time for two road users (at least one motorized) to collide if they remain at their present speed and direction. PET is the time lapse between ends of encroachment of a vehicle and the time that another vehicle (or road user) subsequently arrives and occupied the same spot. Based on literature, on a two lane SCI, over 85% of the conflict percentile are happening with $TTC \leq 2.5$ Sec and $PET \leq 4$ Sec. Zero values were removed as these conflicts are caused by errors in the simulation as well as

irrelevant conflicts outside of a 50 meter radius of the intersection and north/south bound conflicts. In figure 5 the locations of the conflicts were determined from datasets and overlaid on google map to show the spatial distribution of the conflicts on a heat maps.



Figure 5 heat-map overlay of collisions from microsimulation

The hotspots on the west approach (BLS equipped) are more likely to be rear-end conflicts while the conflicts concentration on the westbound is more likely crossing. ~25000 random vehicle fed into the simulation model (distribution was based on hourly volume recorded by radar in the experiment). 765 conflicts has been recorded which east side of CSI center point accounts for more than 57% of conflicts. The conflicts type (crossing, Rear-end and lane-change) has not been investigated and remained unanswered as the next task for this study.

Conclusion

This paper discussed the effectiveness of BLS ped-crossing signs and benchmarked it to standard BLS. The tests were conducted under low light ambience on a two-lane urban arterial. Speed data were collected, processed, disaggregated and evaluated. A noble approach has been selected to observe drivers' interactions between drivers and the traffic control signs. Instead of traditional compliance assessment, a video processing method was deployed. BLS had a positive impact to driver behavior both on speed as well as compliance. This study concludes that there is a measurable correlation between drivers' compliance and type of treatment used as the control devices at SCI.

Other surrogate safety measures including conflict analysis has been addressed in this study however a validation between on-site observed conflicts and conflicts from simulation could enhance calibration of the model. Finally, and more importantly, cross-sectional on-road field tests are needed to observe the effect of other regulatory and warning signs at different facilities and under different road conditions over time. The next step in this study will examine hot spots with potential to reduce the run-off-the-road crashes including locations with sharp horizontal alignments.

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