City of Toronto

SAFETY IMPACTS AND REGULATIONS OF ELECTRONIC STATIC ROADSIDE ADVERTISING SIGNS TECHNICAL MEMORANDUM #2C – BEFORE/AFTER COLLISION ANALYSIS AT SIGNALIZED INTERSECTION

FINAL REPORT

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1 Introduction

Like many other industries, the outdoor advertising industry is embracing and applying new technologies. As technology continues to advance, the industry is taking advantage of electronic signs, some of which are Static Electronic Signs (SES). SES are electronic, or digital signs that use an LED display and have the ability to automatically change the message shown on the sign at regular intervals. The ability to show multiple advertisement copies on a single sign, along with their brightness, high-resolution capacities and attention-grabbing potential is appealing to the outdoor advertising industry. These signs are usually controlled remotely and some can even display full-motion videos. For the purpose of this study, only electronic signs showing static copies are being considered, and video advertising signs are not included.

The advertising industry is, by nature, seeking people's attention and roadside SES can be highly conspicuous and compete for drivers' attention. While studies have proven that electronic advertising displays have impacts on driver distraction, the actual effects of this sign technology on collision experience have been difficult to prove conclusively. As a result, many government agencies are adopting guidelines or regulations for SES in response to an ever-increasing number of installation requests. The objective of these guidelines is to control aspects of the placement and operation of these signs, such as brightness, message duration, and message change intervals, which can have impacts on the surrounding environment and traffic.

In order to gain a better understanding of the safety impacts of SES the City directed CIMA to undertake a 3-part review of electronic static advertising signs, which included the following components:

1) Review of current research literature;
2) Before/after collision analysis of existing electronic signs, including:
   a) Transit shelter scrolling advertising signs
   b) Electronic signs at mid-block locations (expressways and arterial roads)
   c) Electronic signs at signalized intersections;
3) Review of best practice guidelines and regulations in other jurisdictions.

This technical memo addresses component 2c), a before/after collision analysis of the impact of electronic static advertising signs at signalized intersections. The methodology used is similar to the "comparison-group safety effectiveness evaluation method" outlined in the AASHTO Highway Safety Manual (HSM), 1st Edition, but also incorporates the use of Safety Performance Functions. In the sections that follow, this memorandum discusses the treatment and comparison sites analyzed, explains the analysis methodology step-by-step and presents the results.

2 Treatment and Comparison Sites

CIMA was retained by the City to evaluate the impacts of an electronic sign installed in 2007 at the north-east corner of Sheppard Avenue East and Victoria Park Avenue intersection (Figure 1). No other sign existed at this location before the installation of this SES.

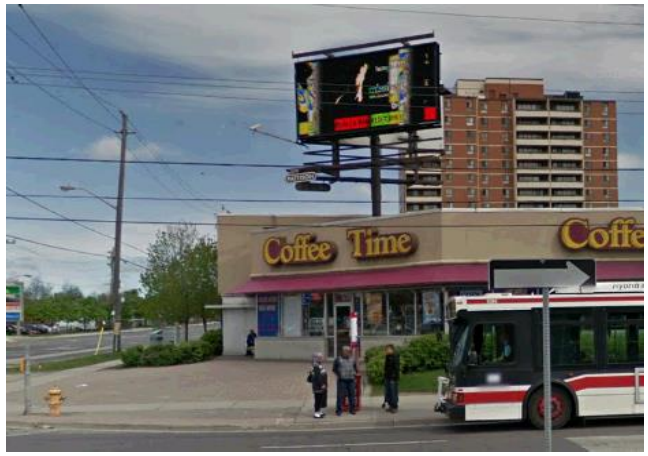

Figure 1: Electronic Static Sign - Sheppard Ave E and Victoria Park Ave Intersection

The sign is made of two digital panels, one facing north-west and the other one facing south-west. Because of its orientation, the sign is visible from three of the four intersection approaches: south, west and north approaches. Therefore, a total of three approaches are affected by the sign and considered as treatment sites (Figure 2).

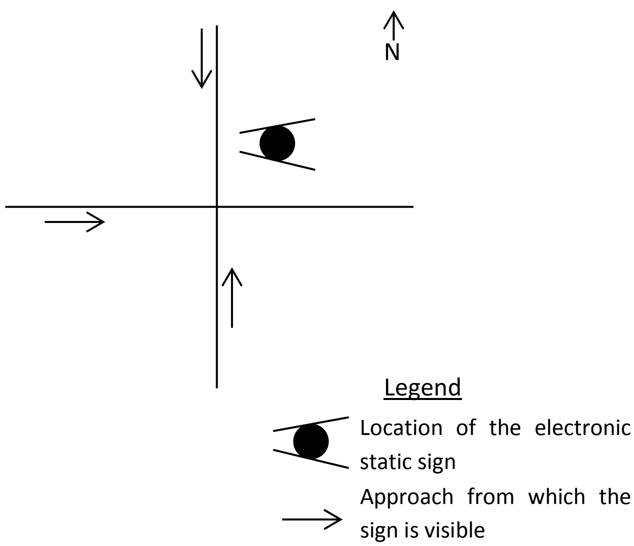

Figure 2: Approaches Impacted by the Electronic Static Sign

It is assumed that all other factors that might impact road safety (e.g. exposure, driver behaviour, driver population, City's road safety programs, traffic regulations, etc.) have equally affected all four approaches of the intersection. This is an ideal scenario for considering the remaining east approach of the same intersection, not impacted by electronic static sign, as a comparison site for conducting a before/after study using a comparison group. To increase the size of our comparison group and better account for the different conditions between the before and after period, another signalized intersection was included to the comparison group. The intersection has similar characteristics and no electronic sign was installed between the before and after period. This results in a total of 3 treatment sites from 3 approaches and 5 comparison sites for analysis. It should be noted that the proposed methodology is consistent with the City's 2004 study evaluating the traffic safety impacts of digital video advertising signs[1]. The treatment and comparison sites are located at two intersections: Sheppard Ave E and Victoria Park, and Sheppard Ave E and Warden Ave. Locations of these two intersections are shown in Figure 3.

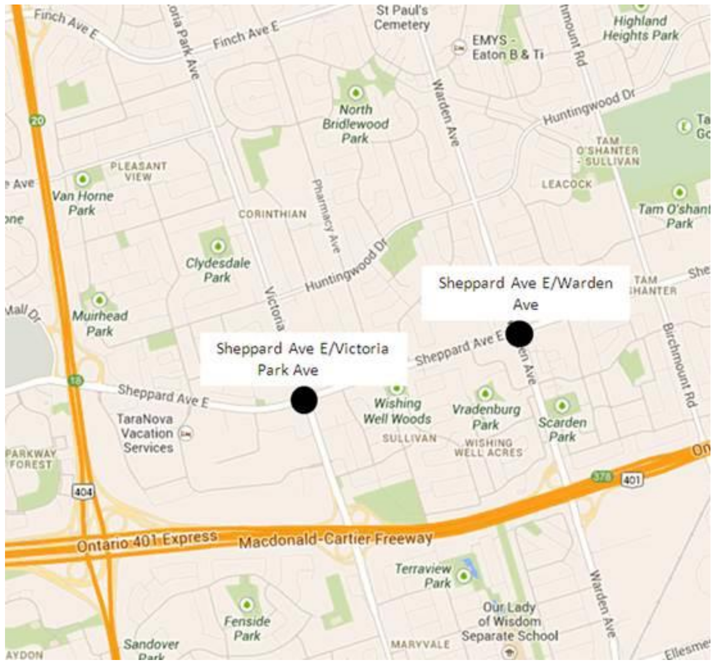

Figure 3: Location of the Study Intersections

The before and after periods considered in this study were identical for all sites. The before period was from January 2004 to December 2006 and the after period from January 2008 to December 2010. Table 1 and Table 2 summarize the vehicle and pedestrian volumes and number of collisions in the before and after periods, for each treatment and comparison approach.

Table 1: Treatment Sites

Intersection	Approach	Traffic Volume (8-hour Count)			Observed Number of Collisions	
		Pedestrian	Major	Minor	Before	After
Sheppard Ave E and Victoria Park	South	4,481	19,526	18,030	71	83
	North	4,481	19,526	18,030	64	77
	West	4,481	19,526	18,030	63	68

[1] Smiley, A., Persaud, B., Bahar, G., Mollett, C., Lyon, C., Smahel, T., & Kelman, W. L. (2005). Traffic safety evaluation of video advertising signs.Transportation Research Record: Journal of the Transportation Research Board, 1937(1), 105-112.

Table 2: Comparison Sites

Intersection	Approach	Traffic Volume (8-hour Count)			Observed Number of Collisions	
		Pedestrian	Major	Minor	Before	After
Sheppard Ave E and Victoria Park	East	1,259	20,597	3,292	64	53
Sheppard Ave E and Warden Ave	South	3,275	20,292	17,767	84	82
Sheppard Ave E and Warden Ave	North	3,275	20,292	17,767	73	55
Sheppard Ave E and Warden Ave	West	3,275	20,292	17,767	59	72
Sheppard Ave E and Warden Ave	East	3,275	20,292	17,767	56	71

To determine the frequency of collisions that occurred on each approach, two fields from the Motor Vehicle Accident (MVA) reports were used: “Apparent Driver Action” and “Initial Direction of Travel”. If a driver had an attribute different than “Driving Properly” for the collision field “Apparent Driver Action”, it was identified as the at-fault driver and its direction of travel was used.

For each of these sites, the following data was provided by the City:

- Intersection type (type of traffic control and road classification);
- 8-hour pedestrian volumes and 8-hour vehicle volumes (obtained from the City's 2013 Signalized Intersections and Arterial Roadways Network Screening study);
- Collision data for each intersection and the mid-block sections of each intersection approach for 3 years before and 3 years after the installation date; and
- Current Safety Performance Functions (SPFs) for signalized intersections.

A review of the collisions on the mid-block sections of each approach of each intersection was undertaken to determine if any were related to the signalized intersection or the scrolling signs and, therefore, need to be included in the analysis.

A field visit was conducted on June 14, 2013, to verify the information provided by the City and identify the approaches or directions from which the sign was visible.

3 Study Approach

To evaluate the safety impacts of the electronic static sign, a "before/after comparison-group using Safety Performance Functions" study was conducted. In before/after studies, an estimate of collision frequencies in the after period is compared with a prediction of the collision frequencies in the same period if the treatment had not been implemented.

The before/after study with comparison group methodology also uses SPFs to take into account the non-linear effects of changes in traffic volume on collision frequency. Table 3 provides the symbols used for the observed number of collisions in accordance with the HSM notation.

Table 3: HSM Symbols Used for the Before/After Study

	Before Treatment	After Treatment
Treatment Site	$N_{observed\ T,B,i}$	$N_{observed\ T,A,i}$
Comparison Group	$N_{observed\ C,B,j}$	$N_{observed\ C,A,j}$

The subscript i denotes sites, i=1,…,n, where n is the number of treatment sites and the subscript j denotes sites, j=1,…,m, where m is the number of comparison sites.

Step 1 – Predict the Number of Collisions

The first step is to estimate the predicted collision frequencies using the applicable SPFs for each treatment and comparison site, and for both the before and the after period. The predicted number of collisions is calculated for four different groups. The HSM symbol notation for predicted collisions is shown in Table 4.

Table 4: Predicted Number of Collisions

	Before Treatment	After Treatment
Treatment Site	$N_{predicted\ T,B,i}$	$N_{predicted\ T,A,i}$
Comparison Group	$N_{predicted\ C,B,j}$	$N_{predicted\ C,A,j}$

For this analysis, each treatment and comparison site corresponds to an intersection approach or direction. However, because SPFs can only predict the total number of collisions at an intersection, the number of predicted collisions associated with each approach needs to be estimated. To estimate the number of collisions for each approach, collision distributions at intersections (proportion of at-fault collisions associated with each approach) must be applied to the number of predicted collisions for each intersection. As a result, the following three proportions are to be estimated:

- Proportion of collisions at each approach for the comparison and treatment sites in the before period,$P_{B,d}$;
- Proportion of collisions at each approach for the comparison sites in the after period ,$P_{C,A,d}$;
- Proportion of collisions at each approach for the treatment sites in the after period, $P_{T,A,d}$.

The subscript d denotes the approach direction (eastbound, westbound, southbound and northbound).

The City has recently updated its SPFs for signalized intersections, based on 2007-2011 data, for their network screening. Table 5 present the SPF parameters for both Property Damage Only (PDO) and Fatal/Injury collisions for 4-legged Arterial/Arterial (Group 3) signalized intersections. The functional form of the SPF for this group is:

$$(N_{predicted})_{intersection}\ (Collision/Year) = \exp^{(intercept)}(MajVOL)^{B1}(MinVOL)\exp^{(B3*PEDVAR)} \qquad \text{Equation 1}$$

Where,

MajVOL = 8 hour traffic count on major road;

MinVOL = 8 hour traffic count on minor road;

PEDVAR = equal to 1 if 8 hour pedestrian volume at intersection is greater than 1000; 0 otherwise;

intercept, B1, B2, B3, B4, B5 are estimated parameters; and

k = the overdispersion parameter estimated during SPF calibration.

Table 5: SPF Parameters for Group 3 Signalized Intersections

	Intercept	B1	B2	B3	K
PDO	-8.3934	0.5241	0.6651	0.2756	0.1405
Fatal/Injury	-8.2937	0.4668	0.5892	0.1310	0.0812

Once the predicted total number of collisions is calculated for each group of sites, the number of predicted collisions for each approach can be calculated for both the treatment and comparison sites. This can be performed by multiplying the number of predicted collisions at an intersection by the appropriate proportion of collisions for each direction, as follows:

$(N_{predicted\ T,B,i})_{approach} = (N_{predicted,T,B,i})_{intersection} \times P_{B,d}$ Equation 2

$(N_{predicted\ C,B,j})_{approach} = (N_{predicted,C,B,j})_{intersection} \times P_{B,d}$ Equation 3

$(N_{predicted\ T,A,i})_{approach} = (N_{predicted,T,A,i})_{intersection} \times P_{T,A,d}$ Equation 4

$(N_{predicted\ C,A,j})_{approach} = (N_{predicted\ C,A,j})_{intersection} \times P_{C,A,d}$ Equation 5

Step 2 – Calculate Adjustment Factors

The adjustment factors are calculated to take into account the differences in traffic volumes and number of years between the treatment and comparison sites during the before and after period. The equation to calculate the adjustment factors during the before period is as follows:

$$Adj_{i,j,B} = \frac{N^{i}_{predicted,T,B}}{N^{j}_{predicted C,B}} \times \frac{Y_{B,T,i}}{Y_{B,C,j}}$$ Equation 6

Where,

$Y_{B,T,i}$ = duration (years) of the before period for each treatment site i; and,

$Y_{B,T,j}$ = duration (years) of the before period for each comparison site j.

The equation to calculate the adjustment factors during the after period is as follows:

$$Adj_{i,j,A} = \frac{N^{i}_{predicted T,A}}{N^{j}_{predicted C,A}} \times \frac{Y_{A,T,i}}{Y_{A,C,j}}$$ Equation 7

Where,

$Y_{A,T,i}$ = duration (years) of the after period for each treatment site i; and,

$Y_{A,T,j}$ = duration (years) of the after period for each comparison site j.

Step 3 - Calculate the Expected Collision Frequency at Each Comparison Site

In this step, an expected average collision frequency at each comparison site is calculated by multiplying the previously calculated adjustment factors (Step 2) by the observed number of collisions in the before and after periods. The equation to estimate the expected number of collisions in the before period is as follows:

$$N^{j}_{expected,C,B} = N^{j}_{observed,C,B} \times Adj_{i,j,B}$$ Equation 8

The equation to estimate the expected number of collisions in the after period is as follows:

$$N^{j}_{expected,C,A} = N^{j}_{observed,C,A} \times Adj_{i,j,A}$$ Equation 9

Step 4 - Calculate the Total Comparison-Group Expected Average Frequency

After calculating the expected collision frequency at each comparison site, the total comparison-group number of expected collisions in the before and after periods is evaluated. This is performed by summing the number of expected collisions at comparison sites in the before and after period, as shown by the following equations.

$$N^{j}_{expected,C,B,total} = \sum_{j=1}^{m} N^{j}_{expected,C,B}$$ Equation 10

$$N^{j}_{expected,C,A,total} = \sum_{j=1}^{m} N^{j}_{expected,C,A}$$ Equation 11

Step 5 - Calculate the Expected Collision Frequency for a Treatment Site

In this step, the expected collision frequency for each treatment site in the after period, had no treatment been implemented, is calculated. This is performed by multiplying the number of observed collisions at each treatment site in the before period by a comparison ratio. The comparison ratio is the ratio of the comparison-group expected collision frequency in the after period ($N_{expected,C,A,total}$) to the comparison-group expected average collision in the before period ($N_{expected,C,B,total}$), as shown by the following equation:

$$r_{i,C} = \frac{N^{j}_{expected,C,A,total}}{N^{j}_{expected,C,B,total}}$$ Equation 12

Then, to obtain the expected collision frequency for each treatment site in the after period, the following equation is used:

$$N_{expected,T,A,i} = N_{observed,T,B,i} \times r_{i,C}$$ Equation 13

Step 6 - Calculate the Safety Effectiveness for Each Treatment Site

With both the expected collision frequency of treatment sites and the expected collision frequency had no treatment been implemented calculated, the safety effectiveness at each treatment site, expressed as an odds ratio, OR_i, can be estimated. The odds ratio is obtained from the following equation:

$$OR_i = \frac{N_{observed,T,A,i}}{N_{expected,T,A,i}}$$ Equation 14

Step 7 - Calculate the Overall Safety Effectiveness

The overall safety effectiveness of a treatment takes into account the safety impact observed at each treatment site and provides an indication of whether the treatment has resulted in an increase or decrease in collision frequency. The overall safety effectiveness is calculated as follows:

$$\text{Safety Effectiveness} = 100 \times (1 - R)$$ Equation 15

Where,

R = weighted average log odds ratio across all n treatment sites

The weighted average log odds ratio is calculated using the following equation:

$$R = \frac{\sum w_i \ln(OR_i)}{\sum w_i}$$ Equation 16

Where:

$$w_i = \frac{1}{\frac{1}{N_{observed,T,B,i}} + \frac{1}{N_{observed,T,A,i}} + \frac{1}{N_{expected,C,B,j}} + \frac{1}{N_{Expected,C,A,j}}}$$

Equation 17

Step 8 – Assess the Statistical Significance

The last step is to determine whether the safety impact measured is statistically significant. This is obtained by calculating the standard error, SE (Safety Effectiveness), as follows:

$$SE(SafetyEffectiveness) = 100\frac{OR}{\sqrt{\sum_n w_i}}$$

The ratio of the standard error over the safety effectiveness can then be compared to different statistical values. Depending on the value of this ratio, one of the following two conclusions can be drawn:

- If Abs[SafetyEffectiveness/SE(SafetyEffectiveness)] < 2.0, the treatment effect is not significant at the 95 percent confidence level
- If Abs[SafetyEffectiveness/SE(SafetyEffectiveness)] ≥ 2.0, the treatment effect is significant at the 95 percent confidence level

4 Results of the Before and After Analysis

The results obtained for the before/after study with comparison-group are summarized in Table 6 and Table 7. Table 6 provides the results related to the safety effectiveness at each treatment site, and Table 7 presents the overall safety effectiveness of installing an electronic static sign at the intersection of Sheppard Ave East and Victoria Park Avenue .

Table 6: Safety Effectiveness at Individual Treatment Site

Approach	Predicted Collision in the After Period	Expected Collision Frequency in After Period Without Treatment	Observed Collision Frequency in After Period	Odds Ratio	Log Odds Ratio	Standard Error of Log Odds Ratio
South	39.9	80.3	83	1.03	0.03	0.18
North	37.0	74.5	77	1.03	0.03	0.19
West	32.7	65.8	68	1.03	0.03	0.19

Table 7: Overall Safety Effectiveness and Its Precision

Description	Result
Weighted Average Log Odds Ratio (R)	0.03
Overall Effectiveness (OR)	1.03
Safety Effectiveness	3.3% increase
Standard Error (SE)	10.99
Safety Effectiveness / SE	0.3
Significant (at 95% confidence level)	No - To be significant the Safety Effectiveness / SE must be greater than 2.0

The results show that there was a 3.3% increase in the number of collisions after installing the electronic sign and that the increase is statistically insignificant at the 95% confidence level. In other words, there is not enough evidence to suggest that this sign has any impact on safety.

This before/after study analyzed the impact of an electronic static sign at only one intersection, which constitutes a small sample size. Despite the sample size, the results are still statistically valid but should be treated with caution.

5 Conclusion

The City was interested in evaluating the impacts of electronic static advertising signs at signalized intersections on road safety. A before/after study was conducted using comparison groups and Safety Performance Functions, following methods outlined in the AASHTO Highway Safety Manual.

An electronic static sign made of two panels was installed in 2007 at the intersection of Sheppard Ave E and Victoria Park Ave. The sign is visible from three of the four intersection approaches. Therefore, three approaches are affected by the sign and considered as treatment sites. Three years of before data, from January 2004 to December 2006, and 3 years of after data, from January 2008 to December 2010, were used. To increase the sample size and better account for the different conditions between the before and after period, another signalized intersection with similar characteristics but where no electronic sign was installed, was considered as comparison site. This resulted in a total of 3 treatment sites and 5 comparison sites for analysis

The results of the before and after study shows that there is not enough evidence to suggest that this electronic static sign has had any impact on road safety at the signalized intersection with 95% confidence. Due to the fact that this study analyzed the impact of an electronic static sign at only one intersection, the results of the study should be treated with caution.