City of Toronto

SAFETY IMPACTS AND REGULATIONS OF ELECTRONIC STATIC ROADSIDE ADVERTISING SIGNS TECHNICAL MEMORANDUM #2B – BEFORE/AFTER COLLISION ANALYSIS AT MID-BLOCK LOCATIONS

FINAL REPORT

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Project No: B000203-3

17/09/2013

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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 2b), a before/after collision analysis of the impact of electronic static advertising signs at mid-block locations along expressways and arterial roads. The methodology used is the "comparison-group safety effectiveness evaluation method" outlined in the AASHTO Highway Safety Manual (HSM), 1st Edition. In the sections that follow, this memorandum discusses the treatment and comparison sites analyzed, explains the analysis methodology and presents the results. In addition, Sections 3.3 and 4.2 discuss the results of an analysis of the collision data separated by natural light conditions, to determine if these signs have any different impacts on road safety during darkness.

2 Treatment and Comparison Sites

2.1 Treatment Sites

The City identified seven electronic static advertising signs along the F. G. Gardiner Expressway and three signs along Highway 27, which were all installed between 2009 and 2010, for analysis. It should be noted that Highway 27 is deemed a major arterial road under the City's official road classification system. The location of the ten signs is presented in Table 1. This table also provides the side of the highway on which the sign is installed and its orientation (direction that the sign is facing).

Table 1: Electronic Static Roadside Advertising Sign

Location	Road Side	Orientation
0 Oakville Sub Gardiner Expressway and Park Lawn Rd	South	West & East
2150 Lakeshore Boulevard West Gardiner Expressway and Park Lawn Rd	South	West & East
1635 The Queensway Gardiner Expressway westbound exit for Highway 27	North	East
2 Wickman Road (400 Evans Avenue) Gardiner Expressway and Wickman Road	South	East
10 Wickman Road Gardiner Expressway and Wickman Road	North	West & East
29 Algie Avenue Gardiner Expressway and Algie Avenue	North	West & East
16 Arnold Street Gardiner Expressway and Arnold Street	West	West & East
10 Marmac Drive Highway 27 and Marmac Drive	East	North
15 City View Drive Highway 27 and Dixon Road	East	North & South
CN Rail Highway 27 and 350 m North of Vulcan Street	West	North & South

Figure 1 and Figure 2 show example signs located along the F.G. Gardiner Expressway and Highway 27, respectively.

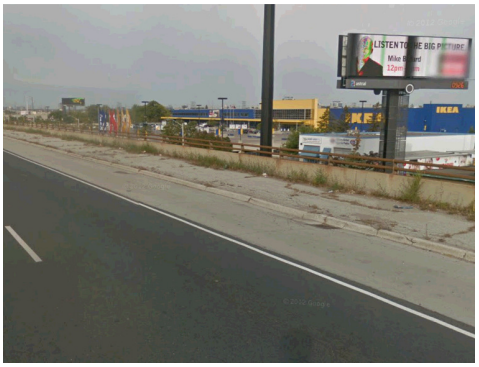

Figure 1: Electronic static roadside advertising sign – Gardiner Expressway

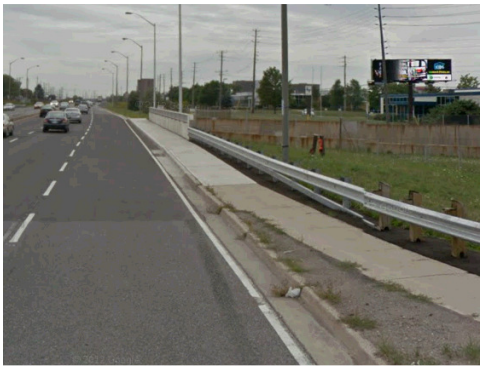

Figure 2: Electronic static roadside advertising sign – Highway 27

Figure 3 shows the location of the studied signs along the F.G. Gardiner Expressway, and Figure 4 shows the location of the studied signs along Highway 27.

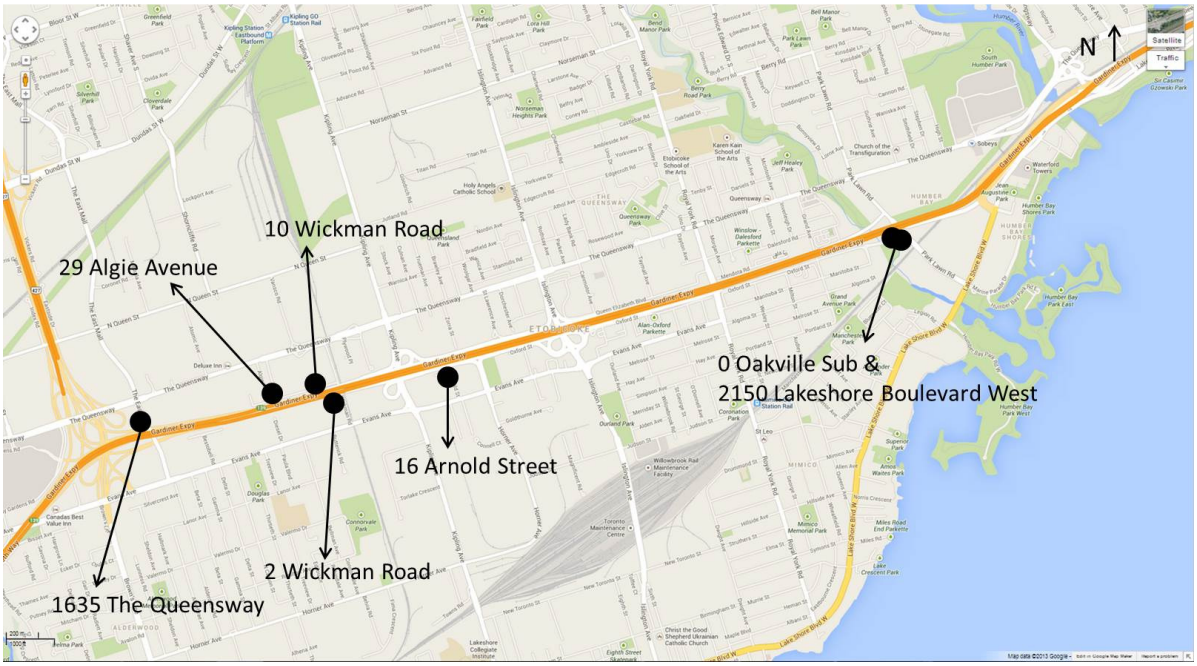

Figure 3: Location of Signs along the F.G. Gardiner Expressway

Figure 4: Location of Signs along Highway 27

Each of the above electronic signs has a specific influence zone that can be defined as the area in which drivers heading towards the sign face can potentially see the sign and consequently be distracted by it (Figure 5). To determine the influence zone, the furthest distance from the sign at which the sign face is visible to oncoming drivers, was assessed through field visits conducted on June 14 and 15, 2013. Therefore, for this analysis, the influence zone for each sign was considered the treatment site.

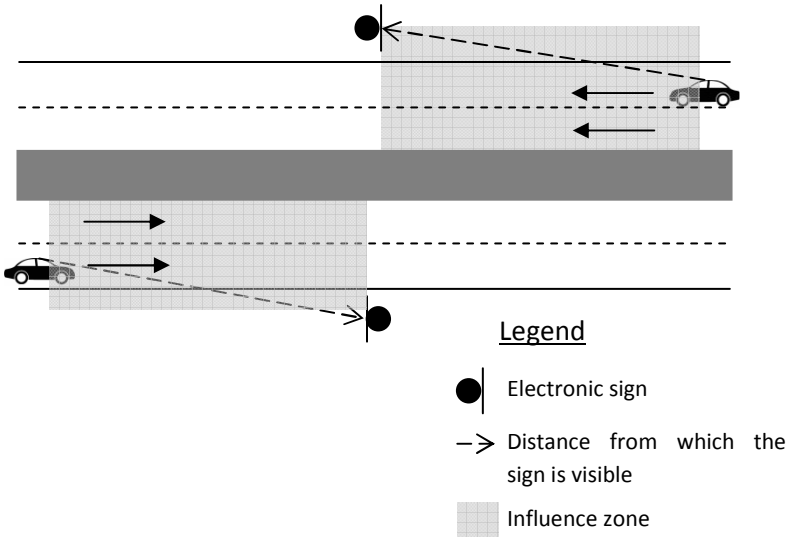

Figure 5: Influence Zone

Because some of the above signs were located close to each other, the influence zones of some signs were overlapping. Therefore, these sites were grouped and considered as one treatment site, as shown in Table 2. Considering the direction of travel and the grouping of sites, in total eight treatment sites were selected. Table 2 shows the eight treatment sites selected and the start and end of each influence zone.

Table 2: List of Treatment Sites

Location	Influenced Direction	Influence Zone	
		From	To
0 Oakville Sub Gardiner Expressway and Park Lawn Rd 2150 Lakeshore Boulevard West Gardiner Expressway and Park Lawn Rd	Eastbound	670 m east of Gardiner & Islington interchange	2480 m east of Gardiner & Islington interchange
0 Oakville Sub Gardiner Expressway and Park Lawn Rd 2150 Lakeshore Boulevard West Gardiner Expressway and Park Lawn Rd	Westbound	2830m west of Gardiner & Jameson interchange	4570 m west of Gardiner & Jameson interchange

Location	Influenced Direction	Influence Zone	
		From	To
1635 The Queensway Gardiner Expressway westbound exit for Highway 27 2 Wickman Road (400 Evans Avenue) Gardiner Expressway and Wickman Road 10 Wickman Road Gardiner Expressway and Wickman Road 29 Algie Avenue Gardiner Expressway and Algie Avenue 16 Arnold Street Gardiner Expressway and Arnold Street	Eastbound	350m east of Gardiner/Hwy 427 interchange	260 m east of Gardiner & Kipling interchange
1635 The Queensway Gardiner Expressway westbound exit for Highway 27 2 Wickman Road (400 Evans Avenue) Gardiner Expressway and Wickman Road 10 Wickman Road Gardiner Expressway and Wickman Road 29 Algie Avenue Gardiner Expressway and Algie Avenue 16 Arnold Street Gardiner Expressway and Arnold Street	Westbound	Gardiner & Islington interchange	1650 m west of Gardiner & Kipling interchange
10 Marmac Drive Highway 27 and Marmac Drive	Southbound	490 m north of Belfield Rd	170 m south of Belfield Rd
15 City View Drive Highway 27 and Dixon Road	Northbound	500 m south of Dixon Rd	390 m north of Dixon Rd
CN Rail Highway 27 and 350 m North of Vulcan Street	Northbound	102 m south of Belfield Rd	770 m north of Belfield Rd
CN Rail Highway 27 and 350 m North of Vulcan Street	Southbound	315 m south of Rexdale Road	1350 m south of Rexdale Rd

To determine the frequency of collisions that occurred within each influence zone, the collision data obtained from the City were analyzed to determine the direction of travel of the driver at-fault and mapped using Geographical Information System (GIS) software so that only collisions involving vehicles heading towards the sign face and within the influence zone were included in the analysis. In assessing the direction of travel of the at-fault driver, two collision fields were reviewed: “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.

The before and after periods were determined based on the installation year of signs. Table 3 summarizes the study period considered for each treatment site and the number of collisions in the corresponding before and after periods.

Collisions at interchanges on the Gardiner Expressway and at the signalized intersections at both ends of the arterial road sections on Highway 27, were excluded from the analysis. It was determined that the electronic signs being studied were remote enough from these locations that they were unlikely related.

Table 3: Study Period and Collision Frequency of Treatment Sites

Sign IDs	Direction	Study Period								Number of Collisions	
		2006	2007	2008	2009	2010	2011	2012	2013	Before Period	After Period
0 Oakville Sub 2150 Lakeshore Boulevard West	EB	Before period				Installation	After period			257	170
	WB									180	89
1635 The Queensway 2 Wickman Road (400 Evans Avenue) 10 Wickman Road 29 Algie Avenue 16 Arnold Street	EB	Before period			Installation		After period			230	118
	WB									318	276
10 Marmac Drive	SB		Before period			Installation	After period			12	6
15 City View Drive	NB		Before period			Installation	After period			12	3
CN Rail	NB		Before period			Installation	After period			35	15
CN Rail	SB		Before period			Installation	After period			2	4

Collision data for the period between 2006 and 2013 were provided for all sites located on the Gardiner Expressway. The 2013 collisions used are associated with the months of January, February, and March only. The installation of the electronic static roadside advertising signs took place in 2010 for all treatment sites, with the exception of the signs between Highway 427 and Kipling Avenue, for which the installation occurred between 2009 and 2010.

2.2 Comparison Sites

11 comparison sites were included in this study, as shown in Table 4. Five are located along the Gardiner Expressway and six are along Highway 27. The before and after periods used for the comparison sites were as follows:

Road	Before Period	After Period
F. G. Gardiner Expressway	Jan. 2006 – Dec. 2010	Jan. 2011 – Mar. 2013
Highway 27	Jan. 2007 – Dec. 2010	Jan. 2011 – Mar. 2013

Similar to the treatment sites, the collisions obtained for 2013 were not for the full year but rather for a period of three months (January to March). Table 4 summarizes the comparison sites included in this study and the number of collisions in the before and after periods.

Table 4: Collision Frequency of Comparison Sites

Road	From	To	Direction	Number of Collisions	
				Before Period	After Period
Gardiner	2480 m east of Islington	Jameson	EB	591	311
Gardiner	Jameson	2830 west of Jameson	WB	250	125
Gardiner	Bathurst	Spadina	EB	179	125
Gardiner	Yonge	Cherry	EB	166	103
Gardiner	Cherry	Yonge	WB	103	67
Hwy 27	Queen's Plate Dr	Humber College Blvd	NB	20	13
Hwy 27	Humber College Blvd	Queen's Plate Dr	SB	7	5
Hwy 27	Finch Ave	Carrier Dr	NB	4	2
Hwy 27	Carrier Dr	Finch Ave	SB	1	6
Hwy 27	Albion Rd	Royalcrest Rd	NB	5	5
Hwy 27	Royalcrest Rd	Albion Rd	SB	6	3

Figure 6 shows the comparison sites on the F.G. Gardiner Expressway, and Figure 7 shows the comparison sites on Highway 27.

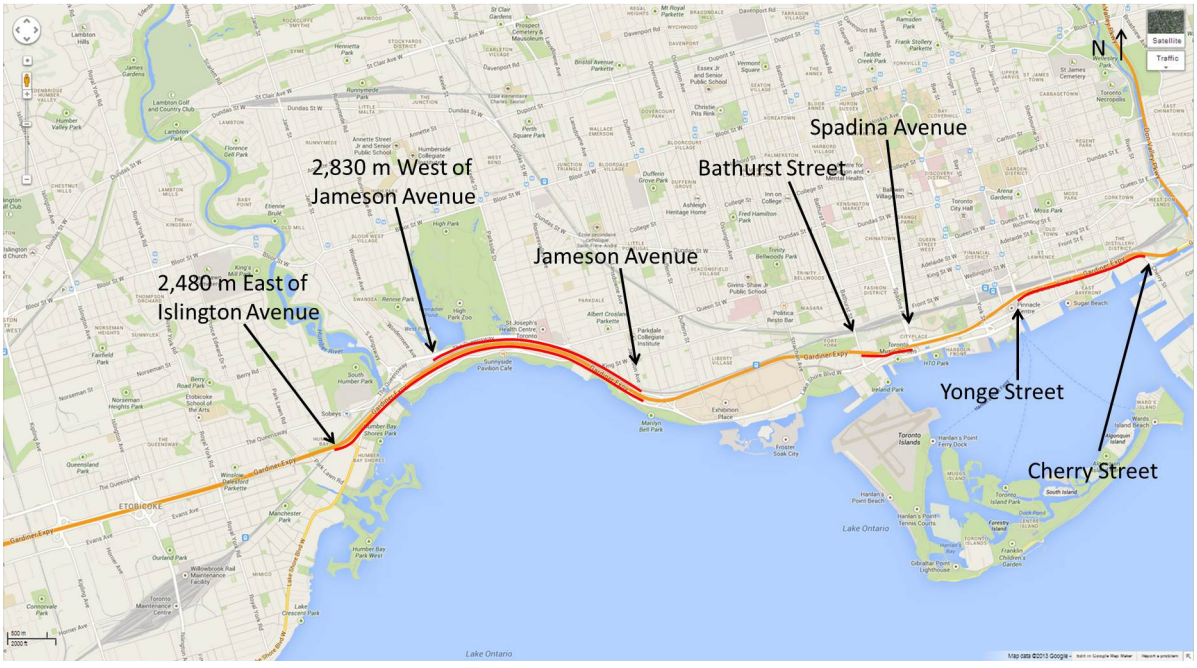

Figure 6: Comparison Sites on the F.G. Gardiner Expressway

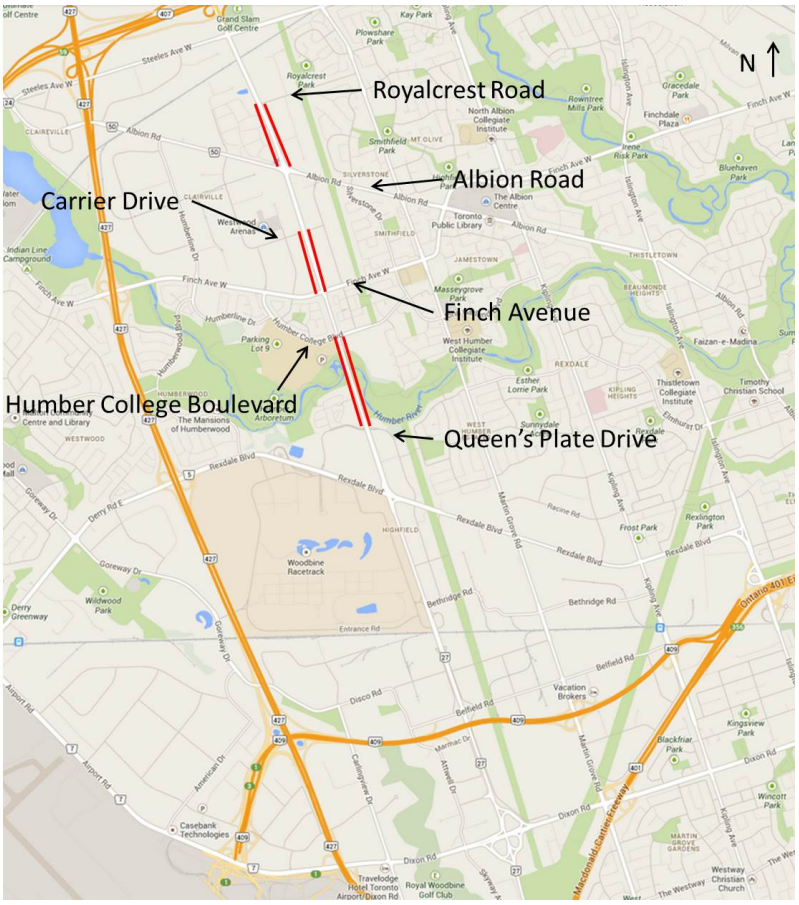

Figure 7: Comparison Sites on Highway 27

3 Study Approach

To evaluate the safety impacts of the SES, a before/after study with comparison groups was conducted. In before/after studies with comparison groups, the observed collisions frequencies in the after period is compared with the predicted collision frequencies in the same period if the treatment had not been implemented. The predicted frequencies in the after period are estimated using the observed number of collisions at the treated sites, as well as the collision frequencies observed at the comparison sites. By doing so, the changes in collision frequency from the before period to the after period associated with the exposure effect (traffic volume) and the trend effect (e.g. traffic composition, drivers composition, law enforcement and weather condition) are taken into account[1].

The notation used to refer to the number of collisions that occurred in the before and after periods at the treatment and comparison sites are shown in Table 5.

[1] Transportation Safety Council. BEFORE-AND-AFTER STUDY TECHNICAL BRIEF. 2009.

Table 5: Collision Notations

Period	Treatment Site	Comparison Site
Before	*K*	*M*
After	*L*	*N*

A before/after study with comparison group is composed of two main steps. The calculation of the changes in collisions between the before and after conditions is first performed; then, a statistical test is conducted to evaluate whether the change in collision frequency is statistically different. These two steps are further explained below.

3.1 Calculation of the Change in Collision Frequencies

The procedure for estimating the change in collision frequencies is summarized in Table 6.

Table 6: Estimation of the Change in Collision Frequencies

Variable	Equation
1. Estimate the expected number of collisions in the 'after' period:	$\hat{\lambda} = L$
2. Calculate the ratio of the expected collision counts for the treatment and comparison groups:	$\hat{r}_C = \hat{r}_T = \left(\frac{N}{M}\right) \Big/ \left(1 + \frac{1}{M}\right)$
3. Predict the expected number of collisions in the 'after' period had the treatment not been applied:	$\hat{\pi} = \hat{r}_T K$
4. Calculate variance of $\hat{\lambda}$:	$\hat{Var}\left(\hat{\lambda}\right) = L$
5. Calculate $\hat{Var}\left(\hat{r}_T\right)/\hat{r}_T^2$:	$\hat{Var}\left(\hat{r}_T\right)/\hat{r}_T^2 \approx \frac{1}{M} + \frac{1}{N} + \hat{Var}(\omega)$
6. Calculate variance of $\hat{\pi}$:	$\hat{Var}\left(\hat{\pi}\right) = \hat{\pi}^2\left(1/K + \hat{Var}\left(\hat{r}_T\right)/\hat{r}_T^2\right)$
7. Estimate $\hat{\theta}$:	$\hat{\theta} = \left(\hat{\lambda}/\hat{\pi}\right) \Big/ \left(1 + Var\left(\hat{\pi}\right)/\hat{\pi}^2\right)$
8. Estimate variance of $\hat{\theta}$:	$\hat{Var}\left(\hat{\theta}\right) = \hat{\theta}^2 \times \left[\left(\hat{Var}\left(\hat{\lambda}\right)/\hat{\lambda}^2\right) + \left(\hat{Var}\left(\hat{\pi}\right)/\hat{\pi}^2\right)\right]$
9. Calculate change in collision frequencies:	$\hat{E} = 100 \times \left(\hat{\theta} - 1\right)$

Variable	Equation
10. Calculate Variance of *E*:	$\hat{Var}\left(\hat{E}\right) = 100^2 \times \hat{Var}\left(\hat{\theta}\right)$

3.2 Statistical Assessment

In order to determine whether the change in safety is different between the before and after period, it is appropriate to use Student's two-tailed T-test. In this case, the null hypothesis is that there is no difference in the average collisions frequencies in the after period with the predicted collision frequencies in the same period if the treatment had not been implemented. This is represented mathematically as follows.

$H_o: \hat{\lambda} = \hat{\pi}$ Equation 1

$H_1: \hat{\lambda} \neq \hat{\pi}$ Equation 2

Then, the *t* statistic can be calculated and compared to the Student's *t* table value with (*n*-2) degree of freedom where *n* is number of observations in the treatment group. If the calculated value of *t* exceeds that for the 5% level (*t*=0.05), the null hypothesis is rejected. In other words, it can be concluded that the change in collision frequency is statistically different between the before and after periods with a confidence level of 95%. Otherwise, if the calculated *t* statistic is smaller than the table value at the 5% level (*t*=0.05), there is no statistical change in collision frequency.

3.3 Natural Light Conditions Analysis

In order to determine if there is any safety impact from the SES relating specifically to the natural lighting conditions (daylight vs dark), the same type of before/after methodology was carried out but using the following collision data subsets:

- Collisions that occurred during daylight conditions; and,
- Collisions that occurred during dark conditions.

The same treatment and comparison sites were used for the natural light conditions analysis. To determine whether the collisions occurred during daylight or dark conditions, the collision field "LIGHT" was used.

4 Results of the Before and After Analysis

This section presents the results of the before and after analysis that evaluates the overall impact of the SES on collision experience, which used all collisions that occurred within the study period. This section also includes the results of the natural light conditions analysis.

4.1 Overall Safety Impact

The results of the before/after study are summarized in Table 7 and Table 8. Table 7 provides the yearly average collision frequencies in the before and after periods for both the treatment and comparison sites. Table 8 presents the overall safety effectiveness of installing electronic static roadside advertising signs along Highway 27 and the Gardiner Expressway.

Table 7: Collision Average in 'Before' and 'After' Periods

Period	Treatment Group Collision Frequency per Year	Comparison Group Collision Frequency per Year
Before	312.3	336.6
After	302.7	340.0

Table 8: Safety Effectiveness Results

Parameter	Values
Expected number of accidents in the 'after' period	302.67
Ratio of the expected collision counts for the treatment and comparison groups	1.01
Expected collision frequency in the 'after' period had the treatment not been applied	314.49
Change in collision frequencies	11.82
Percentage change in collision frequencies	4%
Significant (at 5% confidence level)	No

The results show that there was a 4% decrease in the number of collisions after installing electronic static roadside advertising signs and that the reduction is statistically insignificant at the 95% confidence level. In other words, there is not enough evidence to suggest that these signs have any impact on safety.

4.2 Natural Light Conditions Analysis

Daylight Conditions

The results of the before/after study using collisions that occurred under daylight conditions are summarized in Table 9 and Table 10. Table 9 provides the yearly average number of collisions that occurred under daylight conditions in the before and after periods for both the treatment and comparison sites. Table 10 presents the overall safety effectiveness of installing SES under daylight conditions along Highway 27 and the Gardiner Expressway.

Table 9: Collision Average in 'Before' and 'After' Periods – Daylight Conditions

Period	Treatment Group Collision Frequency per Year	Comparison Group Collision Frequency per Year
Before	220.7	230.1
After	220.4	241.8

Table 10: Safety Effectiveness Results – Daylight Conditions

Parameter	Values
Expected number of accidents in the 'after' period	220.44
Ratio of the expected collision counts for the treatment and comparison groups	1.05
Expected collision frequency in the 'after' period had the treatment not been applied	230.88
Change in collision frequencies	10.43
Percentage change in collision frequencies	5%
Significant (at 5% confidence level)	No

The results show that under daylight conditions there was a 5% decrease in the number of collisions after installing electronic static roadside advertising signs and that the reduction is statistically insignificant at the 95% confidence level. In other words, there is not enough evidence to suggest that these signs have any impact on safety.

Dark Conditions

The results of the before/after study using collisions that occurred under dark conditions are summarized in Table 11 and Table 12. Table 11 provides the yearly average number of collisions that occurred under dark conditions in the before and after periods for both the treatment and comparison sites. Table 12 presents the overall safety effectiveness of installing SES under dark conditions along Highway 27 and the Gardiner Expressway.

Table 11: Collision Average in 'Before' and 'After' Periods – Dark Conditions

Period	Treatment Group Collision Frequency per Year	Comparison Group Collision Frequency per Year
Before	99.3	116.5
After	84.4	102.2

Table 12: Safety Effectiveness Results – Dark Conditions

Parameters	Values
Expected number of accidents in the 'after' period	84.44
Ratio of the expected collision counts for the treatment and comparison groups	0.87
Expected collision frequency in the 'after' period had the treatment not been applied	86.35
Change in collision frequencies	1.90
Percentage change in collision frequencies	4%
Significant (at 5% confidence level)	No

The results show that under dark conditions there was a 4% decrease in the number of collisions after installing SES and that the reduction is statistically insignificant at the 95% confidence level. In other words, there is not enough evidence to suggest that these signs have any impact on road safety.

5 Conclusions

A before/after study with comparison group was performed to evaluate impacts of SES on collisions. A total of ten sites where SES were installed in 2010 and 2011 along the Gardiner Expressway and Highway 27 were identified by the City for study. The before period corresponded to three or four years, while the after period corresponded to two years and three months (from January 2011 to March 2013). Treatment sites consisted of the "influence zone" upstream of a sign, which is the area between the furthest point where the sign is visible to drivers to the location of the sign. A few of the signs that were installed close together were grouped as one treatment site. As a result, the treatment group included 8 sites. Besides the treatment sites, a total of eleven comparison sites, five along the Gardiner Expressway and six along Highway 27, were used for this before/after analysis.

The results of the before/after study show that there is not enough evidence to suggest that the electronic static roadside advertising signs have any impacts on road safety along the adjacent mid-block sections of Highway 27 and Gardiner Expressway, with 95% confidence.

Additionally, the safety impacts from the SES relating specifically to the natural light conditions (daylight vs dark conditions) were assessed. It was found that the collision frequency under daylight and dark conditions is not statistically different before and after installing SES.