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Alberta Transportation

## Intersection Safety Device Program – Intersection Speed Camera Analysis

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Project Number: 60119668

Date: March 2014



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#### **Executive Summary**

Red Light Cameras (RLCs) are becoming more commonly deployed by jurisdictions who wish to attempt to reduce red-light running at signalized intersections. Various municipalities across the Province of Alberta have been using RLCs for many years. More recently, some Alberta jurisdictions already involved in RLC programs activated another function of RLCs known as "Speed on Green" (SOG) that enables an RLC to also act as an "Intersection Speed Camera" (ISC). The RLC program in Alberta was first initiated in 1999. However, the operation of RLCs as ISCs with dual SOG and "Red-Light" (RL) functions, also referred to as the ISD program, was not started until April 2009.

In order to examine the impacts of RLCs and ISCs on safety, Alberta Transportation initiated a study to evaluate these two Intersection Safety Devices (ISDs) across multiple jurisdictions within the Province. The first phase of the project was conducted to evaluate the safety effectiveness of RLCs, and this assessment is documented in the report titled "Intersection Safety Device Program – Red Light Camera Analysis", dated March 2014.

The current phase of the project evaluates the safety effectiveness of ISCs. For that purpose, data from multiple jurisdictions in the Province of Alberta were used to evaluate the various municipal ISC programs. A before-and-after study using an Empirical Bayes (EB) approach was used to evaluate the safety performance of ISCs. The study methodology is detailed in Appendix B.

This study was to answer three specific questions, as taken from the Request for Proposals (RFP). Based on the completed before-and-after study, after implementation of RLC programs and related publicity initiatives, the answers to the three questions are as follows:

1. How have ISCs impacted the total number of collisions at monitored intersections?

Based on the completed before-and-after study, it was found that there was a minimal increase (1.0%) in the total number of collisions.

2. How have ISCs impacted collision severity (fatal injury, and property-damage-only collisions) at monitored intersections?

The before-and-after study indicates an overall reduction in severe (fatal and injury) collisions at monitored intersections (32.3% reduction), with an increase in the number of PDO collisions (10.6% increase). This information is shown in **Table A** below.

Collision Category	Estimate of Percentage Change in Number of Collisions
Total Collisions	+1.0%
Property Damage Only (PDO) Collisions	+10.6%
Severe Collisions	-32.3%
Angle Collisions	-31.3%
Rear-End Collisions	+9.4%

#### Table A. Collision Analysis Aggregated Results (Four Municipalities)

3. How have ISCs impacted different collision impact types at monitored intersections?

The before-and-after study indicates that there is an overall reduction in angle collisions (31.3% reduction); however, the frequency of rear-end collisions was shown to increase after activation of the SOG function at monitored intersections (9.4% increase), as summarized in Table A.

In the first phase of this project, evaluating the effects of Red Light Cameras on intersection safety performance, it was noted that there can be a "spillover" or "halo" effect, with the presence of RLCs at some intersections within a jurisdiction influencing the behaviour of drivers and improving safety at non-RLC-equipped signalized intersections. That study assessed the magnitude of the "spillover" effect of RLCs and identified a rather significant "spillover" effect. The SOG programs are also expected to have the "spillover effect." This effect is observed when drivers' behaviour changes and this often requires the passage of a relatively long time after the initiation of a new safety program. Based on our past experience with the evaluation of safety programs in other jurisdictions it takes at least six years before the "spillover" effect can be seen in a jurisdiction. As follow-up work, it is suggested that further study in a couple of years could be undertaken to quantify the magnitude of the "spillover" effect for the SOG program.

The 4th of 5 questions in the RFP was as follows:

#### 4. How have ISCs impacted the number of speeding violations occurring at monitored intersections?

Study analyses and results are highly dependent on the available data input; in this study, the collected data with respect to ISC-based speeding violations was not sufficient to complete an assessment from an overall provincial perspective. In order to draw conclusions from a broader perspective, definition and control of uniform data collection processes is needed to obtain consistent and complete data from all of the individual participating municipalities.

The 5th question presented in the RFP was as follows:

#### 5. How have intersection speed cameras impacted the speed at which monitored vehicles travel?

Once again, the available/collected data with respect to ISC-based records of vehicle speeds passing through monitored intersections was not sufficient to complete an assessment from an overall provincial perspective



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# 1. Introduction

Red Light Cameras (RLCs) are becoming more commonly deployed by jurisdictions who wish to attempt to reduce red-light running at signalized intersections. Various municipalities across the Province of Alberta have been using RLCs for many years. More recently, some Alberta jurisdictions already involved in RLC programs activated another function of RLCs known as "Speed on Green" (SOG) that enables an RLC to also act as an "Intersection Speed Camera" (ISC). An ISC is an Intersection Safety Device (ISD) that aims at reducing the number of speed violations by detecting and taking photographs of speeding vehicles going through the green signal, as the basis for issuing speeding tickets, thereby reducing associated collisions and casualties. The ISC also serves as a tool to measure the speed of crossing vehicles at intersections for both data collection and speed limit enforcement purposes.

The RLC program in Alberta was first initiated in 1999. However, the operation of RLCs as ISCs with dual SOG and "Red-Light" (RL) functions, also referred to as the ISD program, was not started until April 2009. In this report the terms SOG and RL describe different functional operations of the same camera/device, and the terms ISC and RLC are used interchangeably to refer to the camera/device itself. Both ISCs and RLCs are considered ISDs.

In order to examine the impacts of RLCs and ISCs on safety, Alberta Transportation initiated a study to evaluate ISDs across multiple jurisdictions within the Province. The first phase of the project was conducted to evaluate the safety effectiveness of RLCs, and this assessment is documented in the report titled "Intersection Safety Device Program – Red Light Cameras", dated January 2014.

The final phase of the project aims at evaluating the safety effectiveness of ISCs and finding answers to the following questions presented in the Terms of Reference and AECOM's work plan:

- 1. How have ISCs impacted collision severity (fatal injury, and property-damage-only collisions) at monitored intersections?
- 2. How have ISCs impacted the total number of collisions at monitored intersections?
- 3. How have ISCs impacted different collision impact types at monitored intersections?

To achieve the study objectives, the following analyses were conducted:

- Before-and-after analyses to study the impact of ISCs on collision severity. Since the total number of collisions includes both severe and property-damage-only (PDO) collisions, the answer to the second question (impact of ISCs on the total number of collisions) lies within the answer to the first question; and,
- Before-and-after analyses to study the impact of ISCs on angle and rear-end collision impact types.

This report summarizes the methodology used to evaluate the effectiveness of ISCs, results of the collision evaluation, and final conclusions. The rest of this document is structured as follows:

- Section 2 provides a summary of the methodology used for the evaluation of safety impacts of the ISCs;
- Section 3 includes the results of the safety evaluations of ISCs; and,
- Section 4 concludes the report with a summary of findings and discussions of results.

We note that the 4th of 5 questions in the RFP was as follows:

4. How have ISCs impacted the number of speeding violations occurring at monitored intersections?

Study analyses and results are highly dependent on the available data input; in this study, the collected data with respect to ISC-based speeding violations was not sufficient to complete an assessment from an overall provincial



perspective. In order to draw conclusions from a broader perspective, definition and control of uniform data collection processes is needed to obtain consistent and complete data from all of the individual participating municipalities.

The 5th question presented in the RFP was as follows:

5. How have intersection speed cameras impacted the speed at which monitored vehicles travel?

Once again, the available/collected data with respect to ISC-based records of vehicle speeds passing through monitored intersections was not sufficient to complete an assessment from an overall provincial perspective.

## AECOM

# 2. Study Approach

## 2.1 Background

A before-and-after study using an Empirical Bayes (EB) approach was used to evaluate the safety performance of ISCs. The methodology used to evaluate the safety impacts of ISCs is similar to the methodology used in the first phase of the project to evaluate the safety performance of RLCs.

Applying the same methodology concept to the current study phase, the safety performance of an ISC-equipped intersection was evaluated by determining the difference between:

- The expected collision frequency for a given collision type that would have occurred in the "After Period"<sup>1</sup> had the SOG function not been activated and,
- The actual number of collisions observed in the "After Period".

The "Before Period" for an ISC-equipped intersection was considered as the period from the date of RLC installation to the date the SOG function was activated and the "After Period" was considered as the period after the date of SOG activation, when the RLC also operated as an ISC. The date of activation for the SOG function varied from one intersection to another for each jurisdiction. The defined "Before Period" and/or "After Period" used for analysis purposes are different from one municipality to another and even from one monitored intersection to another within each municipality.

The methodology for the ISC program evaluation was developed to extract the safety effects of activation of the SOG function from the safety effects of the RL function of cameras/devices by using the EB method. This is a rigorous statistical approach for a before-and-after road safety study. The analyses assess the ISC program effects on both collision severity (severe, and PDO collisions) and collision impact types (rear-end and angle collisions).

In the first phase of this project, evaluating the effects of Red Light Cameras on intersection safety performance, it was noted that some road authorities question whether RLCs affect safety performance only at the specific intersections at which RLCs are installed, or, if their presence at some intersections within a jurisdiction can influence the behaviour of drivers and therefore generally improve safety at other signalized intersections within the jurisdiction which are not equipped with RLCs. This type of behavioural influence is referred to as a "spillover" or "halo" effect. That study assessed the magnitude of the "spillover" effect of RLCs and identified a rather significant "spillover" effect, with an additional 10.7% reduction in the total expected number of collisions at non-RLC equipped signalized intersections due to the "spillover" effect.

The SOG programs are also expected to have the "spillover effect." This effect is observed when drivers' behaviour changes and this often requires the passage of a relatively long time after the initiation of a new safety program. Based on our past experience with the evaluation of safety programs in other jurisdictions it takes at least six years before the "spillover" effect can be seen in a jurisdiction. It should be noted that the following are factors affecting the potential magnitude of the "spillover" effect and that how fast this effect will appear:

- a public outreach program to increase public awareness about the SOG program,
- the maturity of the SOG program,
- the number of cameras in a jurisdiction, and,
- the spatial distribution of cameras.

<sup>1. &</sup>quot;After Period" refers to the period after the SOG function was activated at the RLC-equipped intersections.



As follow-up work, it is suggested that further study in a couple of years could be undertaken to quantify the magnitude of the "spillover" effect for the SOG program.

#### 2.2 Data Analysis and Processing

The data used in this study included the data collected at all RLC-equipped signalized intersections with and without the SOG function activated. The following information was required to complete the study:

- Intersection description (major roadway / minor roadway);
- RLC installation date;
- Activation date for the SOG function (as applicable);
- Intersection geometry (four-legged or three-legged);
- Major and minor Average Annual Daily Traffic (AADT) of intersecting roadways; and
- Observed collision frequencies categorized by severity and impact type for the period between the RLC program start dates to the end of December 2012.

The jurisdictions from which the above data were obtained included:

- City of Calgary
- City of Fort Saskatchewan
- City of St. Albert
- Strathcona County
- City of Edmonton (for Safety Performance Function (SPF) development only), and
- City of Red Deer (for SPF development only).

**Table 1** presents a summary of data from the participating municipalities that were used in this study.

Municipality	RLC Program Start Dates*	No. of RLC-Equipped Sites	ISC Program Start Dates**	No. of ISC-Equipped Sites
Calgary	2001 – 2004	42	2009 – 2012	36
Edmonton	1999 – 2005	19	-	-
Red Deer	2000 - 2005	7	-	-
Fort Saskatchewan	2008	2	2009	2
Strathcona County	1998 – 2005	6	2009	6
St. Albert	2001	4	2009	2

Table 1.	Summary of Data Collection	on Periods and Equipped Sites
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\* The start date of RLC Program varied from one intersection to another within the jurisdiction

\*\* The date of activation for the SOG function varied from one intersection to another within the jurisdiction.

The data obtained for the RLC-equipped intersections prior to the activation of the SOG function were used in developing and calibrating Safety Performance Functions or SPFs. As discussed in the next section, SPFs developed in this study are a function of entering AADT at intersections. Therefore, AADTs for all years in the study period are required to conduct a before-and-after study using the EB method. One of the challenges with the data in both phase 1 and phase 2 of this study was the lack of availability of AADT for all years during the study period (1999 to 2012). As a result, in both phase 1 and phase 2 of the study, the missing AADTs were estimated using the available traffic count information, either by use of a trending analysis (based on least square methodology) or by applying an average annual growth rate (assumed to be equal to 2% per annum).

Aside from estimating the missing AADTs and given the available data for use in the study, the study team proceeded with extensive data cleaning and data quality checks. The data cleaning tasks included the following major sub-tasks:

- Remove collision records for which the "collision location" field had been coded as something other than Code "2" (Code "2" collisions are those that report the collision location as either "intersection-related" or "at-intersection");
- Fix all inconsistencies with street names. There were some inconsistencies/variations in the way names of intersection streets were reported and input in the collision database for most of the municipalities. In addition, there were reported street names which were incomplete with errors in names spelling. This task was required in order to complete the following task.
- Create a new field in the collision database (for all participating municipalities). This new field is called "intersection name", and was created by combining the names of the intersecting roadways in a defined format: "Street A-Street B". Street names were required to be consistent (as noted in the previous bullet) in order to complete this task, and provide a unique name in the database for any given intersection.

### 2.3 Development of SPFs

For the purpose of this study, SPFs were developed and used to estimate what the collision frequency would have been had the ISC program not been implemented in the participating municipalities. SPFs provide a benchmark to compare the observed number of collisions at SOG-activated intersections to the expected number of collisions at the same intersections had the SOG function not been activated, during the "After Period". The SPFs are mathematical models to estimate the yearly number of collisions on a road facility at intersection, mid-block road sections, etc., as a function of variables such as traffic volume, number of lanes, area type, etc. on that facility. A number of SPFs have already been developed by researchers and other municipalities elsewhere to estimate collision frequencies on different road facilities. The SPFs that were developed in this study are a function of the "entering AADT volumes" at each intersection, as further discussed below.

The expected collision frequency of an RLC-equipped intersection in the "After Period" without the SOG functionality was estimated by utilizing the SPFs developed based on the data from the RLC-equipped signalized intersections. SPF development also used the data obtained at current SOG-activated intersections from the "Before Period", when the SOG function was not activated at the intersections. SPFs were developed using the collision, traffic volume, and intersection geometry data associated with these intersections.

In this study, SPFs for severe (i.e., fatal and injury), PDO, rear-end, and angle collisions were developed. Because all intersections in this study were four-legged intersections, SPFs were developed only for four-legged signalized intersection types. The methodology followed to develop SPFs is outlined in **Appendix A**.

The SPFs were used for evaluating the safety performance of SOG-activated RLC-equipped intersections. The SPFs were applied to the EB analysis method to account for changes in (traffic) volumes and the regression-to-the-mean (RTM) phenomenon<sup>2</sup>.

**Table 2** summarizes the resulting SPF model form and its parameters for signalized intersections for severe, PDO, angle, and rear-end collision categories.

<sup>&</sup>lt;sup>2</sup> "Regression to the mean" is a statistical phenomenon and a tendency to select locations with high collision histories for applying safety treatments (e.g. installation of cameras). However, if the selection is made based on short-term high prevalence of collisions, a lower collision rate would be expected in subsequent years even if no treatment had been implemented.

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Туре	SPF Model Form	α	b	с	k	X <sup>2</sup> <sub>mean</sub>
Severe	$E(Y) = \alpha \times F_{tot}^b$	5.2858 X 10 <sup>-4</sup>	0.83349	-	0.562	1.112
PDO	$E(Y) = \alpha \times F^b_{maj} \times F^c_{min}$	3.4072 X 10 <sup>-4</sup>	0.31316	0.7751	0.191	1.064
Angle	$E(Y) = \alpha \times \left(\frac{F_{maj}}{Ftot}\right)^b \times \left(\frac{F_{min}}{Ftot}\right)^c$	1.2276 X 10 <sup>2</sup>	3.01373	2.29841	0.529	1.062
Rear-end	$E(Y) = \alpha \times F_{maj}^b \times F_{min}^c$	1.18 X 10 <sup>-7</sup>	0.68825	1.0630	0.518	1.726
<ul> <li>In the second column from the left, Ftot, Fmaj and Fmin denote total entering AADT, total entering AADT for the major and total entering AADT for minor roads respectively.</li> <li>'α', 'b', and 'c' are model parameters (presented in third, fourth, and fifth columns respectively) determined by AECOM through model development / calibration tasks using historic collision and traffic data.</li> <li>E(Y) is the mean annual expected collision frequency for that intersection.</li> <li>The two last columns are the dispersion parameter (denoted by 'k') and mean Pearson's Chi-Square (X)<sup>2</sup> as two statistical meansures to assess the geodeness of fit of the SPE model. A more statistically reliable model is represented by a smaller model</li> </ul>						

#### Table 2. Safety Performance Functions (SPFs)

decrease) on the number of predicted collisions.

All parameters are significant at a 95% confidence level, and present intuitive signs with an expected effect (increase or

dispersion parameter and a mean Pearson's Chi-square value that is closer to 1.0000.

As a numerical example, and based on information provided in Table 2, for a signalized intersection with total entering AADT (F<sub>tot</sub>) of 25,000, the mean annual expected number of severe collisions is calculated at 2.4476 (roughly equivalent to two or three collisions per year), as follows:

Mean annual expected severe collision frequency:  $E(Y) = 5.2858 \times 10^{-4} \times (25,000)^{0.83349} = 2.4476$ 

Through this example it is shown that the development of SPFs provides a means to approximate expected numbers of collisions, the benchmark used for comparison to the observed number of collisions in the "After Period". The results of the comparison are discussed in Section 3.

The performance of the above SPFs over a range of total AADT values entering intersections was also evaluated using CUmulative REsidual (CURE) plots. The CURE plots illustrate how well the model fits the observed collision data. In the CURE plots, the cumulative residuals (the difference between the observed and predicted values for each intersection) are plotted versus Total AADT. Graphs of the 95% confidence limits are also plotted. The plots can show if there is bias in the model. For example, if there is no bias in the model, the plot of cumulative residuals moves up and down around the x-axis with a random pattern, and ideally it should stay inside of the graphs of 95% confidence limits.

**Figure 1** illustrates CURE plots for the models developed for a range of total AADT values. The indication is that the fit is good for SPF models that were developed for the severe, PDO, angle, and rear-end collisions at signalized intersections (Figures 1-A, 1-B, 1-C, and 1-D).

The SPFs were developed to evaluate the impact of the SOG-activation at the RLC-equipped intersections, using a before-and-after study process, as described in detail in **Appendix B**. These SPFs were developed using the data from RLC-equipped locations in order to assist in separating the safety effects of SOG activation of the cameras from the safety effects of their RL-capturing functionality.





# 3. Before-and-After Analysis Results

The before-and-after analyses were conducted for 46 intersections located in four municipalities: Calgary, Fort Saskatchewan, St. Albert, and Strathcona County. The results of the study are presented in the following subsections.

### 3.1 Before-and-After Results for Collision Severity and Total Collisions

Table 3 presents the aggregated results of the before-and-after analyses with respect to collision severity.

Item/Measure	Equation	PDO Collisions	Severe Collisions
EB Estimate of Collisions Expected in After Period without SOG activation	π	1,759	508
Observed Collisions in After Period	λ	1,946	344
Estimate of Percent Change in Collision Frequency	$\left(100 \times \frac{\lambda}{\pi}\right) - 100$	10.6%	-32.3%
Estimate of Index of Effectiveness	$ heta = rac{\lambda}{\pi}$	1.11	0.68
Lower Bound of the 95% Confidence Interval	$\theta - 1.96\sqrt{(var(\theta))}$	1.015	0.597
Upper Bound of the 95% Confidence Interval	$\theta + 1.96\sqrt{(var(\theta))}$	1.195	0.755

#### Table 3. Aggregated Results of Before and After Collision Analysis (Collision Severity)

As can be seen in Table 3, the results of the before-and-after analyses for collision severity show:

- A 10.6% statistically significant increase in PDO collision frequency, and
- A 32.3% statistically significant reduction in severe collision frequencies.

As shown in Table 3, the total collisions (severe and PDO) in the after period was 2,290 collisions (1,946 PDO collisions plus 344 severe collisions). The expected total number of collisions had the SOG function not been activated would have been 2,267 (1,759 PDO collisions plus 508 severe collisions). Comparison of the observed and estimated collisions shows that the ISC has not had a notable impact on the total number of collisions. Based on the completed before-and-after study, it was found that there was only a minimal increase (1.0%) in total number of collisions, from 2,267 to 2,290 collisions.

## 3.2 Before-and-After Results for Collision Impact Type

**Table 4** presents the aggregated results of the before-and-after analyses for collision impact types.

#### Table 4. Aggregated Results of Before and After Collision Analysis (Collision Impact Types)

Item/Measure	Equation	Angle Collisions	<b>Rear-end Collisions</b>
EB Estimate of Collisions Expected in After Period without ISC activation	Π	214	1,272
Observed Collisions in After Period	λ	147	1,392
Estimate of Percent Change in Collision Frequency	$\left(100 \times \frac{\lambda}{\pi}\right) - 100$	-31.3%	9.4%
Estimate of Index of Effectiveness	$\theta = \frac{\lambda}{\pi}$	0.69	1.09
Lower Bound of the 95% Confidence Interval	$\theta - 1.96\sqrt{(var(\theta))}$	0.551	1.023
Upper Bound of the 95% Confidence Interval	$\theta + 1.96\sqrt{(var(\theta))}$	0.816	1.165



As can be seen in Table 4, the results of the before and after analyses for collision impact types show:

- A 31.3% <u>statistically significant reduction</u> in angle collision frequencies (i.e., 147 observed collisions vs. 214 estimated collisions), and
- A 9.4% <u>statistically significant increase</u> in rear-end collision frequency (i.e., 1,392 observed collisions vs. 1,272 estimated collisions).



# 4. Conclusions and Discussions

A before-and-after study using the EB approach was conducted to evaluate the safety impacts of ISCs. The results of the before-and-after study show that the ISCs have a statistically significant impact on the frequency of severe, PDO, angle, and rear end collisions. The study also showed that the total number of severe and angle collisions have decreased while the number of PDO and rear-end collisions has increased.

The analysis shows that a shift in the severity of collisions has occurred after the introduction of ISCs, where the reduction in the number of severe collisions is approximately the same as the increase in the number of PDO collisions. With respect to collision impact types, there is a statistically significant decrease in angle collisions and some increase in rear-end collisions after the activation of the SOG function in the RLC cameras. A decrease in both severe and angle collisions and an increase in both PDO and rear-end collisions is consistent with the generally accepted assumption that angle collisions are typically associated with more severe collision outcomes, while the outcome of rear-end collisions is typically less severe in comparison.



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# **Appendix A**

Methodology to Develop Safety Performance Functions



#### Appendix A. Methodology to Develop Safety Performance Functions

The SPF models were developed using a Full Bayes approach and Markov Chain Monte Carlo (MCMC) simulation techniques assuming a negative binomial error structure (2, 3). The BayesX software package (4) was used as a tool in the development of the SPFs. For each of the dependent variables (i.e., frequency of collision severity levels and frequency of collision impact types described before), SPFs with different model forms were calibrated. The candidate SPF model forms considered in this study were those that most often had appeared in the literature for signalized intersections with similar traffic and environment characteristics. These SPF model forms were evaluated using various criteria. The first criterion was the presence of a counter-intuitive sign for variable coefficients (' $\alpha$ ', 'b', and 'c'), which immediately resulted in the rejection of the model. The second criterion was the statistical significance of the coefficients. Only models for which all coefficients were statistically significant at a 95% confidence level were accepted. The over-dispersion parameter ('k') was also used as an overall goodness-of-fit measure. A lower value of the over-dispersion parameter ('k') represents a better fit of the model. Finally, the fourth criterion was the mean Pearson's Chi-Square (X)<sup>2</sup> statistical measure. This measure is calculated using the following equations, where  $d_f$  represents the degrees of freedom of the model:

$$X^{2} = \sum_{i=1}^{n} \sum_{t=1}^{T} \frac{[Y_{it} - E(Y)]^{2}}{Var(Y)}$$
(A-1)

$$X^2_{mean} = \frac{X^2}{df} \tag{A-2}$$

where,  $Y_{it}$  denotes observed collision frequency for intersection i in year t,

E(Y) denotes the expected value of collision frequency corresponding to  $Y_{it}$  obtained from the SPF model, Var(Y) represents the variance of collision frequency,

*n* is the number of intersections, and

T is the study period.

A value of  $X^2_{mean}$  closer to 1 indicates a better goodness-of-fit of the model.

The third and fourth criteria were jointly used to assess the overall goodness-of-fit of the model. In this assignment, if the first two criteria for goodness-of-fit were satisfied (i.e., the signs for the model coefficients were all intuitive and coefficients were statistically significant) then the SPF model form with the smallest over-dispersion parameter ('k')\_and  $X^2_{mean}$  statistics closer to 1 was selected.



# **Appendix B**

Detailed Algorithm to Evaluate Safety Performance of ISC Programs



# Appendix B. Detailed Algorithm to Evaluate Safety Performance of ISC Programs

This appendix presents the algorithm used to evaluate the safety performance of ISC programs. The evaluation of an ISC program involves finding the expected number of collisions in the "After Period" and comparing it with the observed number of collisions in the "After Period". The Empirical Bayes (EB) approach was utilized to estimate this quantity.

The first step is to estimate the mean annual expected number of collisions using SPFs developed for the "Before Period". The estimate of the mean annual expected number of collisions would not incorporate some other determinants of the safety such as traffic, weather, and vehicle mix, which generally change from year to year. The effect of such changes must be controlled using the EB approach suggested by Hauer (1). The mean annual expected numbers of collisions obtained directly from SPFs for all years are used to calculate multipliers for every single year (the "Before and After Periods") to account for temporal variations in these factors using the following equation:

$$C_{i,y} = E_{i,y} / E_{i,1}$$
 (B-1)

Where  $C_{i,y}$  = annual multiplier for location *i* for year *y*,

 $E_{i,y}$  = mean annual expected number of collisions for location *i* for year *y*, and

 $E_{i,1}$  = mean annual expected number of collisions for location *i* for year 1.

The above multipliers were then used to compute the expected number of collisions and variances for each of the treated sites and for each of the years in the "After Period" using the EB method. This was achieved by using the following equations. In these equations, the assumption is that the "Before Period" consists of y = 1, ..., Y and the "After Period" includes y = Y + 1, Y + 2, ..., Z.

$$m_{i,1} = (k+x) / \left[ \frac{k}{E_{i,1}} + \sum_{y=1}^{Y-1} C_{i,y} \right]$$
(B-2)

$$Var(m_{i,1}) = m_{i,1} / \left[ \frac{k}{E_{i,1}} + \sum_{y=1}^{Y-1} C_{i,y} \right]$$
(B-3)

$$m_{i,y} = C_{i,y}(m_{i,1})$$
 (B-4)

$$Var(m_{i,y}) = (C_{i,y})^2 Var(m_{i,1})$$
 (B-5)

Where,  $m_{i,1}$  = Expected number of collisions at treated location (SOG-activated intersection) *i* in year 1,

 $m_{i,y}$  = Expected number of collisions at treated location (SOG-activated intersection) *i* in year *y*,

 $Var(m_{i,1})$  = Variance of expected number of collisions at treated location (SOG-activated intersection) *i* in year 1,

 $Var(m_{i,y})$  = Variance of expected number of collisions at treated location (SOG-activated intersection) *i* in year *y*,

k = Over dispersion parameter, and

x = Sum of observed number of collisions at location *i* during the "Before Period".

The aggregate of the expected number of collisions that would have occurred in the "After Period" without the treatment ( $\pi$ ) is then obtained by summing over all SOG-activated intersections and comparing with observed collisions for the same intersections in the "After Period" ( $\lambda$ ). The variance of  $\pi$  was also computed by summing over



variances of all intersections in the treatment group. The index of effectiveness ( $\theta$ ) is then determined using the following equations (1).

$$\pi = \sum_{y=1}^{y} m_{i,y} \tag{B-6}$$

$$\theta = \frac{\frac{\lambda}{\pi}}{\left[1 + \frac{Var(\pi)}{\pi^2}\right]} \tag{B-7}$$

$$Var(\theta) = \theta^2 \frac{\frac{Var(\lambda)}{\lambda^2} + \frac{Var(\pi)}{\pi^2}}{\left[1 + \frac{Var(\pi)}{\pi^2}\right]^2}$$
(B-8)

To determine, whether  $\theta$  is significant or not, the lower and upper bounds of the 95% confidence interval for  $\theta$  is calculated as follows if the number of SOG-activated locations are larger than 30 based on the central limit theorem:

$$\theta \pm 1.96\sqrt{(var(\theta))} \tag{B-9}$$

A value of  $\theta$  smaller than 1 shows that the activation of the SOG function has resulted in a reduction in collision frequency; conversely, a value of  $\theta$  greater than 1 indicates that it has contributed to an increase in collision frequencies.  $\theta$  is the expected value of the effectiveness and should be checked to identify whether it is statistically significant or not. The lower and upper bounds of  $\theta$  at a 95% confidence interval are calculated in Equation (*B*-9). If both the lower and upper bounds for a  $\theta$  value are greater than 1 or smaller than 1, it shows that the value of  $\theta$  is statistically significant at a 95% confidence interval. However, if the lower bound is smaller than 1 and the upper bound is greater than 1, it shows that the confidence interval contains 1.0 and the value of  $\theta$  is not statistically significant at a 95% confidence interval.