SITE SELECTION PROCESS AND METHODOLOGY FOR THE DEPLOYMENT OF INTERSECTION SAFETY CAMERAS IN BRITISH COLUMBIA

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ABSTRACT

The Intersection Safety Camera Program (ISCP) in British Columbia (BC), Canada has been proven to be effective in reducing the frequency of collisions at locations where the intersection safety cameras (also known as 'red light cameras') have been deployed. Post-implementation evaluations of the ISCP conducted by the Insurance Corporation of British Columbia indicated that there was a 14% reduction in injury collisions 18 months after the program was implemented. Latter, a follow-up study examined the safety performance 36 months after ISCP implementation, which indicated that the injury collisions were reduced by 6.4%. Given the on-going and long-term success of the ISCP at reducing collisions, it was decided that the program should be expanded.

To support ISCP expansion, it was necessary to examine how the program had been implemented and to learn from the results of the previous program evaluations. A critical element of the ISCP is the selection of sites to be targeted for intersection safety camera deployment. The selected sites should have a demonstrated safety problem, such that the site will offer significant potential for improvement after an intersection safety camera has been implemented. In addition, sites should be selected such that the life-cycle cost of the intersection safety camera deployment will be less than the safety benefits that will be accrued in terms of reduced collisions and the associated collision costs.

This paper presents the process and methodology that was used to select candidate sites for the deployment of an expanded ISCP in British Columbia.

1. INTRODUCTION

The Intersection Safety Camera Program (ISCP) in British Columbia (BC), Canada is a program that installs, operates and maintains intersection safety cameras (ISC), which are often referred to as 'red-light cameras'.

The goal of the ISCP is to target motorists who choose to run red lights, thereby creating an unsafe condition and the potential for intersection collisions. The ISCP makes use of advanced technologies to assist in the enforcement of red-light running violations, which has been shown to improve driver behaviour and the overall safety performance (i.e., a reduction in the frequency and severity of collisions) at targeted intersections.

The ISC photo enforcement program in BC began approximately ten years ago and included a total of 120 intersections. Not all 120 locations were equipped with a permanent camera, but rather a smaller number of cameras rotated between the 120 intersections that were configured for camera operation. This is a common practice with some ISC Programs, as it is believed that the effect of the ISC infrastructure will have a positive effect on driver behaviour whether a camera is installed or not (i.e., motorists do not know whether a camera is operation, so they adjust their behaviour accordingly).

In the province of BC, the ISCP has been proven to be effective in reducing the frequency of collisions at locations where the intersection safety cameras have been deployed. Post-implementation evaluations of the ISCP (*1, 2*) have indicated that overall, there was a 14% reduction in bodily injury collisions 18 months after the program was implemented. A follow-up study that examined the safety performance 36 months after the ISC Program was implemented indicated that the bodily injury collisions continued to be reduced by 6.4 %. Given the on-going and long-term success of the ISCP, it was decided that the program should be expanded.

To support the expansion of the ISCP, it was necessary to examine how the program had been implemented and to learn from the results of the various program evaluations. A critical element of the ISCP is the selection of candidate sites to be targeted for ISC deployment. The selected sites should have a demonstrated safety problem, such that the site will offer significant potential for improvement after an ISC has been implemented. In addition, sites should be selected such that the life-cycle cost of the ISC deployment will be less than the safety benefits that will be accrued in terms of reduced collisions and the associated collision costs.

The objective of this paper is to review the effectiveness of Intersection Safety Cameras as an enforcement tool and for collision reduction. In addition, this paper will present the process and methodology that was used to select candidate sites for the deployment of an expanded ISCP in BC.

2. LITERATURE REVIEW

The literature concerning intersection safety / red-light camera programs focus primarily on the enforcement and safety effects that are realized after the implementation of the photo enforcement initiative. The following is a brief summary of the literature concerning the effectiveness of intersection safety camera programs.

Literature related to the enforcement effects of ISC is quite clear, indicating that these systems are a very effective enforcement tool. Most studies show that the violation frequency is significantly reduced after the implementation of an intersection safety camera program.

The reduction in violation frequency occurs at locations where ISC are deployed, but violation reductions can also occur locations without an ISC, a phenomenon referred to as the 'halo' effect. A summary of the literature concerning ISC effectiveness as an enforcement tool is provided in Table 1.

TABLE 1 - Effectiveness of Red-Light Cameras as Enforcement Tools

Author	Year	Country	Effectiveness Measure & Estimates
Oei et al. (*3*)	1997	Netherlands	56% reduction in violations
Arup (*4*)	1992	Australia	78% reduction in violations at camera sites 67% reduced violations at non-camera sites
Chin (*5*)	1989	Singapore	42% reduction in violations at camera sites 27% reduced violations at non-camera sites
Retting et al. (*6*)	1999a	USA	44% reduction in violations at camera sites 34% reduced violations at non-camera sites
Retting et al. (*7*)	1999b	USA	40% reduction in violations at camera sites 50% reduced violations at non-camera sites
Chen et al. (*8*)	2001	Canada	69% reduction in violations after 1 month 38% reduction in violations after 38 months Both reductions were at non-camera sites

The findings of studies that investigated the safety effects resulting from intersection safety camera programs are somewhat varied but in general, these photo enforcement systems can produce a moderate reduction in total collisions and a significant reduction in high severity collisions. The results of these studies generally suggest that the more severe angle-type collisions (aka "t-bone" collisions) are significantly reduced however, a slight increase in the less severe, rear-end type collisions can often occur. The literature also discusses the potential for a 'halo' effect (aka a 'spillover' effect), where the effect of an intersection safety camera location may extend to nearby, untreated intersection. The details of the literature review of the safety impacts in terms of collision reduction credited to intersection safety camera programs are summarized in Table 2.

There are a few studies that provide evidence contrary to the view that intersection safety cameras will reduce collisions and in fact, some studies suggest that intersection safety cameras will actually cause and increase collision frequency after the camera has been implemented. Several studies tried to explore the economic consequence of installing intersection safety cameras but the analysis is based on several assumptions and how the authors perceive the cost per collision estimates.

Unfortunately, the literature specifically related to the process and methodology for ISC site selection is very limited. In many cases, it would appear that the site selection methodology is based entirely on collision frequency, such that intersections with the highest number of total collisions would be the most suitable candidates for ISC deployment. In other cases, site selection appeared to be based largely on anecdotal information provided by various stakeholders. Neither of these approaches to site selection is not the best criterion for ISC site selection This paper will focus entirely on the process and methodology that was developed in BC, which can be used to select the most promising locations for the deployment of ISCs to maximize overall benefits.

TABLE 2 - Effectiveness of Red-Light Cameras For Collision Reduction

<table>
<tr><th>Author</th><th>Year</th><th>Country</th><th colspan="3">Effectiveness Measure & Estimates</th></tr>
<tr><td rowspan="3">Persaud et al. (9)</td><td rowspan="3">2005</td><td rowspan="3">USA</td><td></td><td>Total Crashes</td><td>Injuries</td></tr>
<tr><td>Right angle</td><td>-25%</td><td>-16%</td></tr>
<tr><td>Rear end</td><td>15%</td><td>24%</td></tr>
<tr><td>Council et al. (10)</td><td>2005</td><td>USA</td><td colspan="3">Using aggregated safety costs, a $28,000 to $50,000 economic benefit per site per year.</td></tr>
<tr><td>Burkey & Obeng (11)</td><td>2004</td><td>USA</td><td colspan="3">40% increase in total crashes
40 to 50% increase in PDO and injury crashes</td></tr>
<tr><td>Hillier et al. (12)</td><td>1993</td><td>Australia</td><td colspan="3">8% reduction in total crashes
26% reduction in injury crashes
29% increase in total right angle crashes
108% increase in total rear end crashes</td></tr>
<tr><td>Andreassen (13)</td><td>1995</td><td>Australia</td><td colspan="3">7% increase in total crashes
13% reduction in total right angle crashes
20% increase in total rear end crashes</td></tr>
<tr><td>Mann et al. (14)</td><td>1994</td><td>South Australia</td><td colspan="3">6% increase in total crashes
8% increase in total right angle crashes
12% increase in total rear end crashes
20% reduction in injury crashes
26% reduction in injury right angle crashes
1% reduction in injury rear end crashes</td></tr>
<tr><td>Ng et al. (15)</td><td>1997</td><td>Singapore</td><td colspan="3">9% reduction in injury crashes
10% reduction in injury right angle crashes
6% increase in injury rear end crashes</td></tr>
<tr><td>Retting & Kyrychenko (16)</td><td>2002</td><td>USA</td><td colspan="3">7% reduction in total crashes
32% reduction in total right angle crashes
3% increase in total rear end crashes
29% reduction in injury crashes
68% reduction in injury right angle crashes</td></tr>
<tr><td>Sayed and deLeur (17)</td><td>2007</td><td>Canada</td><td colspan="3">11% reduction in total crashes
17% reduction in right-angle collision
12% reduction in rear-end crashes
6% reduction in injury collisions
14% reduction in PDO collisions</td></tr>
</table>

3. PROCESS FOR INTERSECTION SAFETY CAMERA SITE SELCETION

Although the post-implementation evaluations of BC's initial ISCP proved that the program was very successful in reducing collisions, it was felt that even greater results might have been realized if the process and methodology dedicated to the selection of ISC sites process could be improved. For the initial rollout of the ISCP, the site selection was typical of most intersection safety camera programs, where the site selection process was based primarily on high collision frequency at candidate intersections in combination with input from the various stakeholders, particularly the police agencies.
Program decision makers, who had considerable experience gained from the initial rollout of the ISCP, realized it was necessary to bring together important stakeholders and participants for the site selection component of the program. To this end, an ISC Site Selection Committee was formed, which included key representatives several agencies, including the British Columbia Ministry of Solicitor General, the Royal Canadian Mounted Police (RCMP), the Insurance Corporation of British Columbia (ICBC) and the British Columbia Ministry of Transportation and Infrastructure (BCMOT).

The Site Selection Committee, who would report to the Project's overall Steering Committee, had several skill sets including local knowledge of enforcement concerns, technical knowledge of camera deployment requirements, collision data analysis and processing skills, an understanding of violation data requirements and ISC deployment cost implications.

The overall goal of the Site Selection Committee was to provide a list of recommended sites that could be used for ISC deployment. The sites on the list should offer significant potential for success, which would be measured by a reduction in the frequency and severity of collisions. To achieve this goal, a series of specific objectives for the Site Selection Committee were developed as follows:

Objective 1: Develop an Analysis-Based Methodology for ISC Site Section
There are several factors that contribute to the potential success of an ISC at a proposed location. These factors would be identified based on the previous ISC Program evaluations and from other information sources that detail the effectiveness of ISC Programs. Once these factors are identified, an analysis-based procedure, based on the important factors would be developed to determine the appropriateness of each site for inclusion in the expanded ISCP in BC.

Objective 2: Identify Existing ISC Sites to Remain in the ISC Program
The analysis-based procedure that would be developed for ISC site selection will be applied to the existing 120 ISC sites to determine the sites that should remain in the expanded ISCP.

Objective 3: Determine New Sites to be added into the ISC Program
Using the analysis-based process developed for ISC site selection, attempt to examine as many signalized intersections as possible in the province to identify locations that offer the greatest potential for collision reduction and which should be added to an expanded ISCP.

Objective 4: Address Issues / Concerns from the Project Steering Committee

The Site Selection Committee would have to address concerns and issues from the Project's overall Steering Committee, including any specific issues concerning the allocation of ISCs sites throughout the province.

After the Site Selection Committee was formed and the objectives of the committee were established, the next step was to explore the information and data sources that would be available to support the development of the methodology for ISC site selection. This included data sources related to collision type and characteristic data, traffic volume or traffic exposure data, site characteristics data and any tools that could be used to assess safety performance. Considerable effort was dedicated to the collection and processing of collision data, which was available from ICBC, police agencies and the road authorities. In addition, some important safety performance analysis tools including collision prediction models, which had been developed by ICBC and the BCMOT, were considered to be potentially useful in the site selection process.

The Site Selection Committee would then meet regularly over the course of approximately 18 months, meeting at least once per month and in advance of the rollout of the expanded ISCP. During this time frame, the methodology was being continually modified and refined, based on the data and information that became available during the time available for site selection and based in input from the project steering committee.

4. METHODOLOGY FOR INTERSECTION SAFETY CAMERA SITE SELECTION

A total of twelve factors were identified and that would be considered in the development of an analysis-based method for ISC site selection. Each of these factors will be presented below. Not all 12 factors were ultimately included in the development of the ISC Site Selection Model (SSM), but each factor is presented in the interest of completeness.

4.1 Factor 1: Potential for Improvement (Difference)

The first factor to be considered in the site selection methodology is a factor called Potential for Improvement (PFI) (Difference). This factor is determined by subtracting the expected normal safety performance at an intersection from the observed safety performance. In other words, this factor is the difference between the total observed / historical collisions at a site and what is considered to be the 'normal' or 'average' collision frequency at the site.

Using the traffic volumes for the major and minor roads at an intersection, the expected normal collision frequency at each candidate ISC location is calculated using a collision prediction model (CPM). A CPM is a mathematical model developed using historical collision counts and traffic volumes from a reference population of sites that are similar in character. CPMs are becoming the standard method in the measurement of road safety performance.

Previous evaluations of the ISCP (*2*) included the development of CPMs that could be used for the site selection methodology as shown in equation 1. The CPM predicts the total collisions per 3 years (Coll/3 yrs) based on the average annual daily traffic (AADT) volume on the major and minor roads of the candidate intersection.

$$Exp_{(Coll)} = 0.000524 \times V_1^{0.5390} \times V_2^{0.7191} \qquad \text{EQ (1)}$$

Where: $Exp_{(Coll)}$ = Expected normal collision frequency (Coll/3 yrs)
V_1 = Major road traffic volume (AADT (vehicles / day))
V_2 = Minor road traffic volume (AADT (vehicles / day))

The collision prediction modeling exercise produces a dispersion parameter (K) that is used in a statistical process known as empirical Bayes (EB) to account for normal variability that is inherent in collision data (i.e., the rare and random nature of collisions). The observed collision frequency at each candidate location is refined using the EB procedure by combining the expected normal collision frequency with the observed collision frequency using the dispersion parameter (K), as shown in equation 2.

$$EB_{(Coll)} = \left(\frac{Exp_{(Coll)}}{K + Exp_{(Coll)}} \right) \times \left(K + Observed \right) \qquad \text{EQ (2)}$$

Where: $EB_{(Coll)}$ = EB estimate for observed collision frequency (Coll/3 yrs)
$Exp_{(Coll)}$ = Expected normal collision frequency (Coll/3 yrs)
K = Dispersion parameter
Observed = Observed collision frequency (Coll/3 yrs)

With the expected normal collision frequency and the EB estimate for the observed collision frequency calculated for each site, the PFI (Difference) can be calculated as shown in equation 3. This factor will help to identify candidate sites with a large number of collisions, which is typical of the many ISC site selection programs. However, what is different from the typical process is that the candidate site is not selected only due to a high number of collisions but rather, is selected due to a large difference between a high number of collisions and a collision frequency that is considered normal, thereby identifying the potential for improvement.

$$PFI_{Difference} = EB_{(Coll)} - Exp_{(Coll)} \qquad \text{EQ (3)}$$

4.2 Factor 2: Potential for Improvement (Ratio)

The second factor to be considered in the ISC site selection methodology is very similar to the PFI (Difference) as described previously, except that the ratio between the EB safety estimate and the expected normal safety estimate is used rather than the difference between these two measures. The equation for the PFI (Ratio) is shown is equation 4.

$$PFI_{Ratio} = EB_{(Coll)} / Exp_{(Coll)} \qquad \text{EQ (4)}$$

Unlike the PFI (Difference), this factor will not favor sites will high collision frequencies but will help to identify sites that are significantly worse than a normal level of safety performance but may only have a relatively small number of collisions.

4.3 Factor 3: Collision Severity

The third factor that was to be considered for the ISC site selection methodology would be based on the collision severity levels at candidate sites. The overall goal of the ISCP was to address injury-producing collisions and as such, it was important to explicitly examine the collision severity characteristics at each candidate site and identify sites with the most severe collisions.

Two collision severity measures were considered, including a collisions severity index (CSI) and an equivalent property damage only (EPDO) measure. The CSI, which is shown in equation 5, simply applies weightings to the collision frequency associated with the three collision severity categories, namely, 1) fatal, 2) injury and 3) property damage only (PDO), and then normalizes the result by using the total number of collisions. There are many weighting schemes but in the province of BC, the collision weightings are 100 for fatal collisions, 10 for injury collisions and 1 for PDO collisions.

The EPDO measure is very similar to the CSI measure except that the results from the weighting of the collision severity categories are not normalized by the total number of collisions. This was developed because the CSI could identify sites with very high CSI scores, but had very few collisions.

$$\mathrm{CSI} = \frac{(100 \times \mathrm{Fatal}) + (10 \times \mathrm{Injury}) + (1 \times \mathrm{PDO})}{(\mathrm{Fatal} + \mathrm{Injury} + \mathrm{PDO})} \qquad \text{EQ (5)}$$

$$\mathrm{EPDO} = (100 \times \mathrm{Fatal}) + (10 \times \mathrm{Injury}) + (1 \times \mathrm{PDO}) \qquad \text{EQ (6)}$$

4.4 Factor 4: High Proportion of Target Collisions

The fourth factor to be considered for the ISC site selection methodology was to identify candidate sites that exhibited a high proportion of collision types that would be effectively addressed by an ISC. The target collision types included a 90-degree, side-impact collision (commonly referred to as a “t-bone” collision) and head-on collisions, which are caused as a result of an impending side-impact avoidance maneuver. Collision type information was available to support this type of analysis.

A statistical test called the chi-square test can be used to examine collision records and search for deviant patterns in the data. In order to identify deviant collision patterns with an acceptable level of confidence, the frequency of collisions must be sufficiently high, thereby providing an indication that the specific collision pattern is noteworthy and ‘over-represented’ in the data.

The chi-square statistic is calculated by comparing the observed collision frequency of a given collision type (in this case side impact and head-on) with the expected collision frequency, assuming that the collision types occur at the site in the same proportion as that of a reference population. A chi-square (χ^2) value is calculated and compared to a theoretical χ^2 value, based on a selected level of confidence (a 95% confidence level for the theoretical χ^2

value (χ^2 =3.84) was used for the site selection methodology). When the calculated χ^2 value is greater than the theoretical χ^2 value, the occurrence of the collision pattern is considered deviant or abnormally high. The chi-square test was calculated using equation 7.

$$\chi^2 = \sum \frac{\left(|f_i - f_{ei}| - \frac{1}{2} \right)^2}{f_{ei}} \qquad \text{EQ (7)}$$

Where: χ^2 = Calculated chi-square test value
f_i = Frequency of a type i collision at a site
f_{ei} = Frequency of a type i collision at a site, $f_{ei} = f \times p_i$
p_i = Proportion of a collision type in a reference population, and
f = Total collision frequency at the site

4.5 Factor 5: Low Proportion of Non-Target Collisions

The fifth factor to be considered for the ISC site selection methodology was to identify candidate sites that exhibited a low proportion of collision types that would be negatively impacted due to the deployment of an ISC. As mentioned earlier, the literature suggests that an ISC can cause an increase in rear-end type collisions and as such, it would be important to identify sites that exhibit a low proportion of rear-end collisions.

The site selection methodology used the same chi-square test as described above and shown in equation 7 to determine if a location had a significantly low proportion of rear-end collisions.

It should be noted that ISC site selection factors 4 and 5 concerning the collision types were inversely correlated, since the different collision types come from the same population. In other words, it was common to find locations that had both a high proportion if side-impact collisions and a low proportion of rear-end collisions.

4.6 Factor 6: Results from Previous ISC Evaluations

The sixth factor that was considered by the ISC Site Selection Committee was the results that were generated from the previous evaluations from the ISCP (*1, 2*). These studies provided the post-implementation effectiveness results for 70 of the initial 120 sites, quantifying the success of these 70 sites at reducing collisions. Existing ISC sites that showed a higher level of success in reducing collisions would be favored over the sites that were less effective in reducing collisions.

The site selection criteria based on the effectiveness of existing ISC sites was considered to be of limited value because it could only differentiate between 70 existing sites and all other sites (existing or new), would have to be evaluated using a constant and assumed value for the ISC effectiveness, thereby not allowing for the distinction between candidate sites.

4.7 Factor 7: Direction of Travel

The seventh factor that was considered by the site selection committee in the developing the analysis-based site selection methodology was the direction of travel for the at-fault motorist involved in the collision. This is important because the ISC deployment would be applied only in one direction at an intersection, and as such, it was important to try to isolate which intersection approach direction was the most problematic.

The collision data for the site selection methodology came from the ICBC, which is a public auto insurance company for the province. As such, it was possible to obtain the direction of travel for the vehicles involved in a collision and the assignment of fault by vehicle for all collisions, as this information is obtained during the normal process to settle auto insurance claims after a collision has occurred. In fact, this collision data from ICBC is very valuable data because of the post-collision examination of the events that led to the collision and the allocation of fault.

Candidate sites with a very distinct or well-defined intersection approach that was problematic could be given preference in the site selection methodology over other intersections where the safety problem was approximately equal on all four approaches to the intersection.

4.8 Factor 8: Commercial Vehicle Involvement

The eighth factor considered for ISC site selection methodology involved an examination of locations with a high occurrence of collisions involving large, multi-unit commercial vehicles. ISC deployments that target large, multi-unit commercial vehicles required that the front license plate be photographed instead of the rear license plate, which is contrary to other vehicle types. This is because the license plate on the tractor unit may be different that on the trailer unit and thus, the violation must be linked to the tractor.

The collision data allowed for the examination of vehicle types, such that locations with a high proportion of commercial vehicle collisions could be identified in the site selection process. The chi-square statistic, as described earlier and shown in equation 7 was used to determine if a location had an abnormally high proportion of commercial vehicles collisions. The data also supported the direction of travel for the commercial vehicles collisions, which was also used to identify the intersection approach where the ISC should be focused for large, multi-unit commercial vehicles.

4.9 Factor 9: Collision Data Stability

Another important consideration in the ISC site selection methodology was the examination collision data stability, since many site selection factors were based on collision data. The fluctuation of annual collision frequency has some normal variability, however, excessive variability can cast uncertainty about the true safety performance of a location. Tests to ensure data stability may help to eliminate candidate ISC sites from further consideration due to collision data problems or uncertainty.

Using some traditional statistical measures of sample mean, standard deviation and coefficient of variation, a threshold could be established to identify locations that have an unusually high level of variation in the annual collision frequencies. This would prompt the

Site Selection Committee to examine the data and the specific location to determine if something may have contributed to the variability in annual collisions at the intersection.

The statistical measures that were calculated to investigate collision data stability included the sample mean ($\bar{x}$) of the annual collision frequency (equation 8), the standard deviation (s) for the annual collision frequency (equation 9) and the coefficient of variation (V) (equation 10).

$$\bar{x} = \frac{\sum x}{n} \qquad \text{EQ (8)}$$

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}} \qquad \text{EQ (9)}$$

$$V = \frac{s}{\bar{x}} \bullet 100 \qquad \text{EQ (10)}$$

Where: *x* = Sample data (annual collision frequencies)
n = Sample size (number of years of data)

4.10 Factor 10: Economic Assessment

The tenth factor that was identified as an important consideration by the Site Selection Committee for the inclusion in the ISC site selection methodology was the economic assessment of each candidate location. The future safety benefits at each candidate site were estimated by assuming a reduction in collision after the implementation of an ISC. The estimate of future safety benefit at each site was dependant upon whether the site was an existing ISC site or whether the site would be a new site (i.e., a new deployment site). For the existing sites, the expected collision reduction was estimated to be 6% per year and for a total of 5 years, which was conservatively assumed to be the effective timeframe for safety benefit accrual. For new ISC sites, the safety benefit was estimated to be 14% in year 1, 11% in year 2, and 6% per year in years 3 to 5. These estimated collision reduction percentages were based on the results for the previous ISCP evaluations (*1, 2*).

Knowing the expected collision reduction potential for all candidate sites, it was then necessary to convert the collision reduction into an economic savings or benefit. To do this, the average cost of collisions was required. Unlike many jurisdictions that use a societal or willingness to pay cost of collisions, the ISCP in BC uses direct collision cost values based on information available at ICBC. As such, the actual average direct cost of an injury producing collision was approximately $30,000 per incident and the average cost of a property damage only incident was approximately $2,000 per incident.

Using the estimate for the expected collision reduction at each candidate site and the average cost of collisions, the economic safety benefits were calculated at each candidate site over the 5-year benefit accrual timeframe and converted into a net present value (NPV). A discount rate of 6% was used in the calculation of the NPV.

With an understanding of the safety benefits of ISC deployment at each candidate site, it was then necessary to estimate the costs of ISC deployment at each ISC site. The costs of ISC deployment would be dependant upon whether the site was an existing site or a new ISC site, with existing ISC sites costing less due to the opportunity to re-use some of the existing infrastructure. The estimated deployment costs per ISC site ranged from approximately $180,000 to $240,000, which included the capital costs as well as the ongoing maintenance and operation costs. Similar to the benefits, the costs were converted to a NPV using a discount rate of 6%.

The safety benefits of the ISC deployment could be compared to the costs to produce a ‘pass’ or ‘fail’ test for each site. A ‘pass’ indicator was assigned to a site when the estimated safety benefits of the ISC exceeded the estimated costs for ISC deployment. Conversely, a ‘fail’ indicator was assigned to a site when the estimated safety benefits of the ISC were less than the estimated costs for ISC deployment.

4.11 Factor 11: Analysis of Site Characteristics / Suitability

Another important consideration in the ISC site selection methodology is the technical feasibility and suitability of each site to accommodate an ISC. There are several considerations and checks that which were examined or tested at each candidate site to ensure that the ISC deployment would perform as expected. Local knowledge of Site Selection Committee members was invaluable is assessing the suitability of sites. The local knowledge was often supplemented with site visits and/or a review of locations using Google maps and images. Some examples of the analysis of site characteristics included the following:

- Ensure that the traffic signal and traffic signal controller was appropriate to accommodate the ISC requirements;
- Ensure that all pavement markings are provided at the intersection such that the ISC images can be effectively enforced;
- Ensure that the location was not newly re-designed and improved to address some of the safety concerns that may have existed before the improvements (i.e., the safety problems may have already been improved);
- Ensure that the configuration of the intersection, including horizontal and vertical alignments is suitable to accommodate the ISC requirements;
- Ensure that the location of the intersection is in an area that will not be targeted by excessive vandalism.

4.12 Factor 12: Spatial Distribution and Regional Equity Considerations

One final consideration that was deemed to be very important in the ISC site selection methodology was the spatial relationships between candidate locations and the need to address some regional equity considerations.

The ISC Site Selection Committee understood that to realize the greatest overall benefit of the ISCP that some consideration had to be given to the spatial distribution of ISC sites. Deploying an excessive number of ISC at intersection along one corridor or in close proximity to one another may limit the ‘halo’ effect that is sometimes identified with the deployment of intersection safety cameras. The ‘halo’ effect of ISC deployment refers to the ability of an ISC to have a positive effect at nearby, un-treated intersections, created by having a longer-term influence on driver behavior (i.e., drivers will not run red lights are intersections in close proximity to intersections equipped with an ISC). The true effectiveness of the halo effect is a subject of debate among those who study ISC effectiveness, however, spatial allocation of candidate sites was considered important to the Site Selection Committee.

Some general rules or guidelines were developed that would help members of the Site Selection Committee determine whether ISCs were too close together or that there were too many ISC locations on a particular corridor. As a general rule, it was proposed that ISC locations should be at least 8 city blocks apart, particularly if the cameras were to be targeting traffic on the same corridor and in the same direction. ISC locations could be closer than the 8-city block limit if the cameras were to be focused in alternate directions. For example, cameras could be close than 8-city blocks if one camera targeting southbound traffic and the other camera targeting northbound traffic.

The Project Steering Committee for the expanded ISCP provided some rules for the Site Selection Committee concerning the need for regional equity and the transition from the initial rollout of the program to the expanded program. Various different scenarios were examined in an attempt to maintain the ISCP presence in as many communities as possible, while selecting the best possible sites to ensure that significant safety benefits could be achieved.

5. APPLICATION OF THE SITE SELECTION METHODOLOGY

A total of 12 factors were identified and developed by the Site Selection Committee that would be considered in the development of the analysis-based method to identify candidate ISC sites. The next step was to conduct a final review all the factors and determine which factors should be included into a final ISC Site Selection Model (SSM) to be used to screen all potential ISC locations.

A critical part of this exercise was to review the various factors and assign importance weightings to the different factors, as it was believed that some site selection factors would be more important than others. Furthermore, some of the site selection factors were felt to be either marginally important or the intent of the factor duplicated another factor, and as such, should not be included into the final SSM.

Some site selection factors may not require an importance weighting but rather would be used as a screening tool to either include or reject candidate sites. Each factor needed to be examined in relation to one another to select the most suitable factors for the final SSM. The factors to be included and the importance weighting of the including factors to be used in the SSM was formed based on group discussions and debate.

The final ISC SSM included 9 of the 12 factors, as listed below with the importance weighting for each factor shown (if applicable) or how the factor would be used in the ISC SSM.

1) Potential for Improvement (PFI) (Difference):
    - Importance Weighting = 0.35

2) Collision Severity: Equivalent Property Damage Only (EPDO) Measure:
   - Importance Weighting = 0.30
3) Target Collision Type: Side-Impact and Head-On Collision Types:
   - Importance Weighting = 0.35
4) Direction of Travel for At-Fault Motorist:
   - Used to select the intersection approach for ISC deployment
5) Commercial Vehicle Involvement:
   - Used to identify locations for front plate ISC deployment
6) Collision Data Stability:
   - Used to flag locations with data problems / unreliable data
7) Economic Assessment
   - Used as a 'Pass' or 'Fail' criteria for each candidate site
8) Site Suitability / Technical Feasibility
   - Used as a 'Pass' or 'Fail' criteria for each candidate site
9) Spatial Distribution and Regional Equity
   - Guidelines developed to avoid over-saturation of ISC sites
   - Rules developed to address regional equity requirements

To apply the ISC SSM, collision data and traffic volume data was obtained for approximately 1450 intersections within the province. Some preliminary screening of the sites reduced the number of candidate sites to 779. The preliminary screening was based on minimum collision frequency levels and the need to pass the economic assessment test (Factor 7 above) and the test for suitability / technical feasibility of the intersection for ISC deployment (Factor 8 above). The 779 candidate sites was an acceptable number of sites, recognizing that the expanded ISC program would likely have less than a total of 200 ISC sites.
The values for Factors 1, 2 and 3 from the list above were calculated for all candidate ISC sites. All candidate sites were then ranked based on the objective of the factor. For example, the PFI (Difference) was calculated for each candidate site and then all sites were sorted with the highest value for PFI (Difference) receiving a rank of "1" and the lowest PFI (Difference) value receiving a rank of "779".

The next step was to combine Factors 1, 2 and 3 by applying the importance weighting that were established by the Site Selection Committee. A 'Priority Score' was established by multiplying the individual rankings for each factor by the corresponding importance weighting and then sorting all sites from 'best' (ranked "1") to 'worst' (ranked "779").

From this priority listing, the candidate sites were again screened based on the economic assessment test (Factor 7 above) and the test for suitability / technical feasibility of the intersection for ISC deployment (Factor 8 above). Also, any sites that had problematic data were removed from consideration (Factor 6 above). This produced a list of approximately 300 candidate sites, listed in terms of in priority.

The next step in the ISC SSM was to work through the list in descending order of priority and consider factor 9, the spatial distribution and regional equity factor. The regional allocation of ISC sites was assigned as required by the project Steering Committee and spatial distribution of the proposed ISC sites were checked using the guidelines developed.

The final step in the application of the ISC SSM was to select the direction of travel of greatest interest (Factor 4), such that the ISC could be focused on the most problematic approach to the intersection. There were some requirements for the number of ISC sites that would capture commercial vehicle violators, and thus Factor 5 was used to identify sites from the priority listing, where commercial vehicle collisions were determined to be problematic.

6. SUMMARY

This paper has presented a process and methodology that can be used to identify and select successful sites for an intersection safety camera program (ISCP), which is also known as a red-light camera program.

The ISC site selection methodology makes use of a total of 9 different factors to ensure that candidate ISC sites will be effectively targeted if an ISC is deployed. Some of the factors produce a calculated value that allow for the ranking of candidate sites, while other factors provide a screening tool to accept or reject candidate sites. It must be emphasized that the final site selection model that was developed for the expanded ISCP in BC is highly dependant upon data inputs.

The site selection process and methodology has been effectively used in British Columbia Canada in support of the expansion of the existing ISCP. With the significant effort dedicated to the site selection process, it is felt that future post-implementation evaluations of the expanded ISCP should produce very favorable results.

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