2015 Program Evaluation Report

Road Improvement Program

June 2015

Tarek Sayed, Ph.D., P. Eng.

Emanuele Sacchi, Ph.D.

Prepared for the Insurance Corporation of British Columbia

TABLE of CONTENTS

List of Tables

List of Figures

Executive Summary

ES-1: Evaluation Objectives

The objective of this study was to conduct a time-series (before to after) evaluation of the safety performance of a sample of locations that have been improved under the ICBC's Road Improvement Program. The overall effectiveness of the Road Improvement Program can be determined by:

1) Determining whether the frequency and/or severity of collisions at the improvement sites has been reduced after the implementation of the improvement; and,
2) Quantifying the program costs versus the economic safety benefits to determine the return on ICBC's road safety investment.

Based on the results from this evaluation study, it is possible to determine whether the goals and objectives of ICBC's Road Improvement Program have been achieved.

ES-2: Evaluation Methodology

It is imperative that the evaluation methodology is rigorous, such that the results are robust and can withstand technical scrutiny. To ensure that this objective is achieved, the evaluation has incorporated the latest techniques in road safety evaluation.

There are three main factors that affect the validity of time-series road safety evaluations. These three factors, which are often referred to as confounding factors, include history, maturation and regression to the mean or sometimes referred to as regression artifacts. The methodology that has been used in this evaluation study addresses these three factors by making use of comparison groups.

The methodology used for this evaluation study is the full Bayes (FB) method. The FB approach was shown to have several advantages, including the ability to account for greater uncertainty in the data; to provide more detailed inference; to allow inference at more than one level for hierarchical models; and to efficiently integrate the estimation of the safety model and treatment effects in a single step. To support the reliable methodology, it was also necessary to obtain reliable data for the evaluation.

ES-3: Evaluation Data

To ensure accurate and reliable evaluation results, a significant effort was required to obtain the data that is necessary for a successful evaluation. Collision and traffic volume data was required for each site within two distinct groups of sites:

1) Treatment Group Sites:

- These are the sites to be evaluated, where treatments (road improvements) were completed in 2008, 2009, or 2010, as part of the Road Improvement Program.
- A total of 111 treatment sites were selected for the evaluation.
- Criteria were established to select projects that would be suitable for the evaluation and to respond to the resources available to complete the evaluation.
- A total of 72 treatment sites were urban intersections, with an ICBC contribution of $3,699,500 and 39 treatment sites were rural highway segments, with a total ICBC contribution of $1,903,100.
- The treatment sites that were selected characterize some of the typical projects that are completed as part of the Road Improvement Program.

2) Comparison Group Sites:
- These are sites that have NOT been improved, but are subjected to similar traffic and environmental conditions as the treatment group sites. More information associated with the comparison group sites is provided in Chapter 4 of the report
- A total of 203 comparison sites were selected and were used to generate 67 different comparison groups, which were used in the evaluation process to correct for the confounding factors of history and maturation.

It is also noted that claim-based collision data was used for the evaluation of urban sites and police-reported collision data was used for the rural sites. The rationale for the use of these two collision data sets is provided in Chapter 4 of the report.

ES-4: Evaluation Results

Overall, the ICBC's Road Improvement Program showed a considerable reduction in collision frequency from the before to the after period. Considering all 111 treatment sites, there was found to be a 24.0% reduction in severe collisions (fatal + injury collisions combined) and a 15.4% reduction in PDO (property damage only) collisions. The improvement projects were separated by the location type, including urban intersections and rural highway segments. Overall, the total reduction of severe and PDO collision frequency for urban intersections was found equal to -19.6% and -7.6%, respectively. For rural highway segments, severe collisions were reduced of -28.2% and PDO collisions of -22.5%. These results are summarized in Table ES-1.

Table ES-1: Overall Collision Reductions

Location Type	Collision Change	
Urban Intersections	Severe	-19.6%
	PDO	-7.6%
Rural Highways	Severe	-28.2%
	PDO	-22.5%
ALL Locations (Urban and Rural)	Severe	-24.0%
	PDO	-15.4%

Within these two groups, the improvement projects were further grouped into four specific treatment types as listed below. Details of the specific improvements projects can be found in Chapter 4 of this report. The results for the four groups of treatment types, by collision severity level are shown in the table below.

1) New pedestrian signal installations (for urban intersections);
2) Geometric design improvements (for urban intersections);
3) Traffic signal upgrades (for urban intersections); and,
4) Segment treatments (for highway segments).

Table ES-2: Collision Reductions for Different Type of Treatments

Location Type	Treatment Type	Collision Change	
Urban Intersections	Pedestrian Signal Installation (13 sites)	Severe	-24.5%
		PDO	-6.3%*
	Geometric Design Improvements (30 sites)	Severe	-23.0%
		PDO	-10.8%
	Traffic Signal Upgrades (29 sites)	Severe	-13.8%
		PDO	-5.0%*
Rural Highways	Segment Improvements (39 sites)	Severe	-28.2%
		PDO	-22.5%
		PDO	-15.4%

*Not significant at the 95% C.L.

The results for the change in PDO and severe collisions at each improvement site grouped according to the treatment type, are shown in figures ES-1 to ES-4:

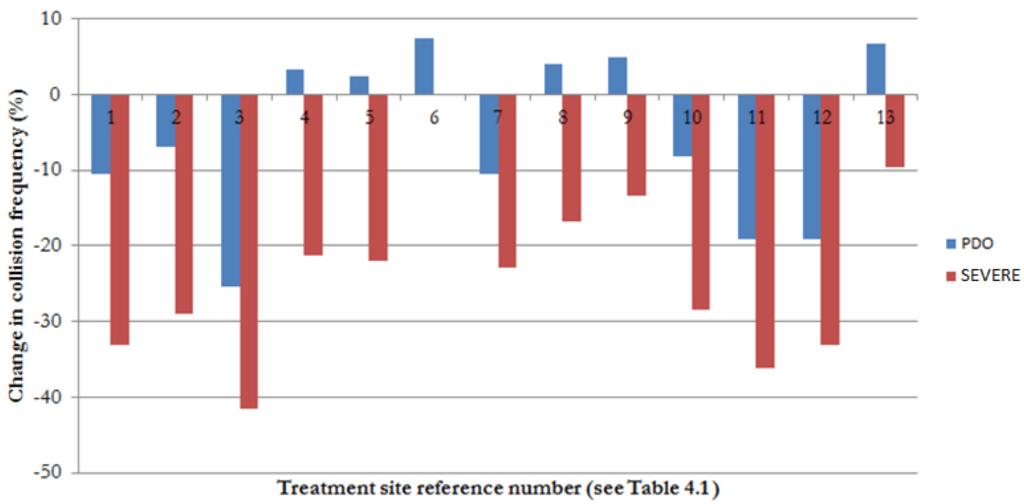

Figure ES.1: Change in Collisions for New Pedestrian Signal Installations (At Urban Intersections)

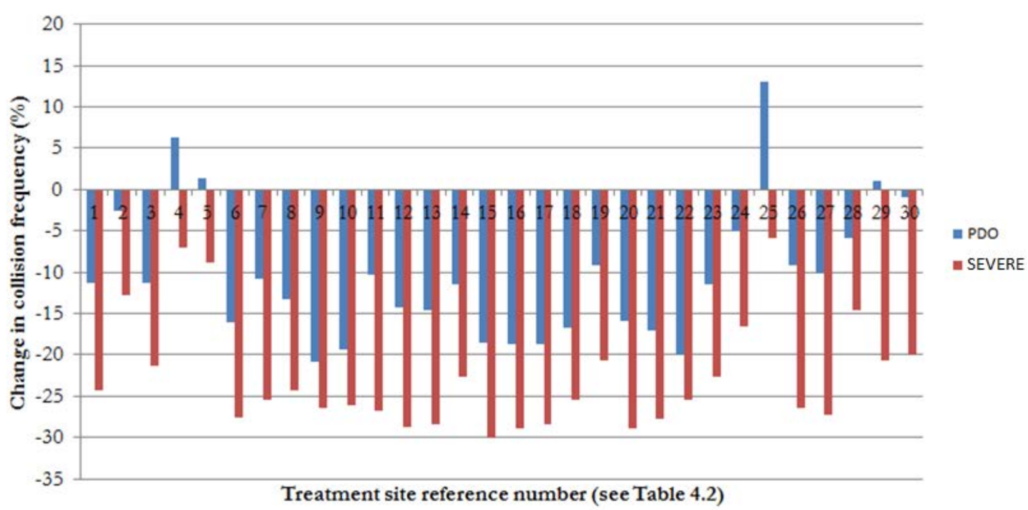

Figure ES.2: Change in Collisions for Geometric Design Improvements (At Urban Intersections)

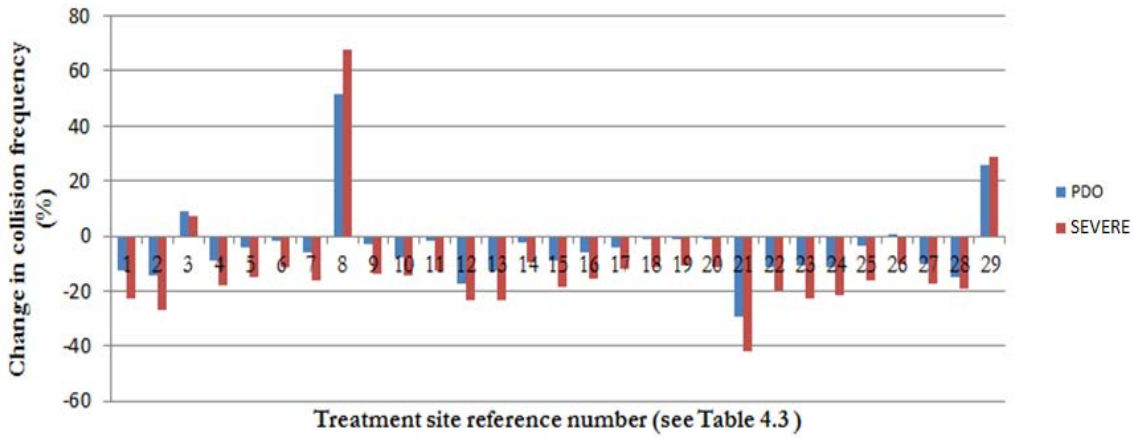

Figure ES.3: Change in Collisions for Urban Traffic Signal Upgrades (At Urban Intersections)

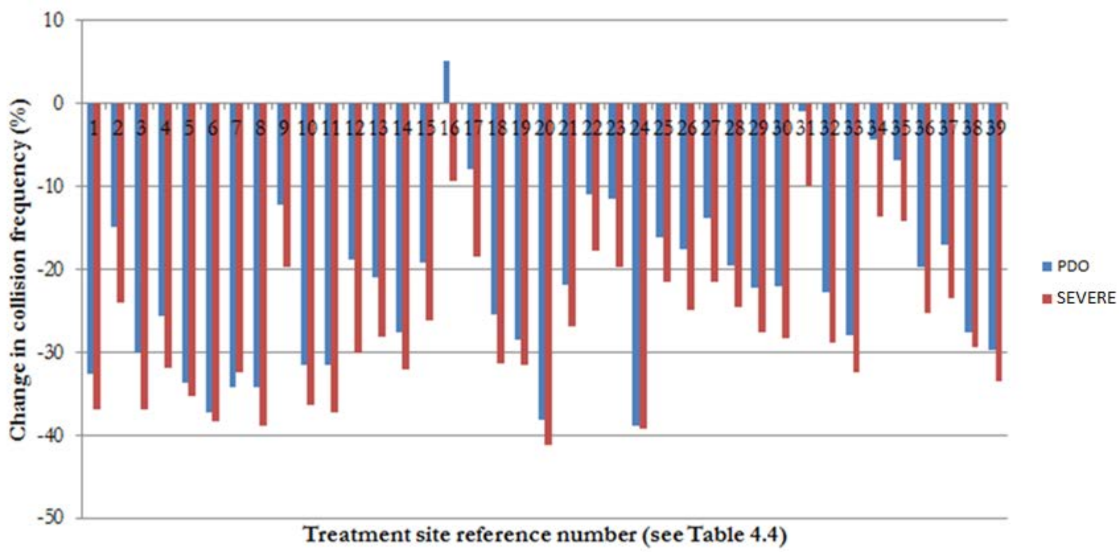

Figure ES.4: Change in Collisions for Segment Improvements (Rural Highway Segments)

As shown in the results presented from Figure ES.1 to ES.3, the change in collisions at the 72 treated urban intersections includes:

- 59 of the urban intersections out of 72 had a reduction in PDO incidents; and,

- 69 of the urban intersections out of 72 had a reduction in severe incidents.

The results presented in Figure ES.4 indicate that the change in collisions at the 39 treated rural highway segments includes:

- A total of 38 sites out of 39 experienced a reduction in PDO incidents; and,

- All 39 sites experienced a reduction in severe incidents.

ES-5: Economic Evaluation

In addition to the change in collision frequency, it is also important to determine if ICBC's contribution to the road improvement projects achieves the desired return on investment. To determine this, two economic indicators are used, including the net present value (NPV) and the benefit cost ratio (B/C). The net present value is a measure to describe the equivalent present worth of a series of future economic safety benefits, which are discounted to a current value. The benefit cost ratio is a measure to express the economic benefits versus the costs for a project, and thus, when the B/C ratio is greater than 1.0, it means that the benefits are greater than the costs.

In determining the cost and benefits associated with the results, it is necessary to assign an average collision cost value. The average collision costs for this study are shown in Table ES-3. In previous RIP evaluations, the average collision cost for rural sites was increased by a multiplier to reflect the difference between claims based collision data and police reported collision data (i.e., for any given location, there is likely to be more collisions recorded by auto insurance claims than by reports filed by the police). However, it was not possible to obtain information to quantify the difference between claims based collision data and the police reported collision data. As a result, the same average collision cost values were used for both the urban intersection sites and the rural highway sites, which should result in a conservative estimate for the economic benefits for the rural sites.

Table ES-3: Average Collision Cost Values

Collision Data Source	Property Damage Only Incidents	Severe (Fatal + Injury) Incidents
Urban Sites (Claim-based data)	$3,029	$33,307
Rural Sites (Police reported data)	$3,029*	$33,307*

* Assumed the same of claim-based data

The NPV, expressed in millions of dollars, and the B/C for the treatment sites are based on a 5-year service life and a discount rate of 3% and are reported in Table ES-4 below. The table shows that for every dollar invested in a road improvement project, there were 4.7 dollars returned to ICBC (on average) over a five-year service life as a result of a reduction in collisions costs.

Table ES-4: Economic Evaluation for Treatment Sites (5-Year Service Life)

Collision Data Source	Net Present Value (NVP)	Benefit Cost Ratio (B/C)
Urban Sites (72 sites)	$12.2M	4.3
Rural Sites (39 sites)	$7.9M	5.2
All Sites (111 sites)	$20.1M	4.7

It is noted that many of the road improvement projects are likely to have safety benefits extending well beyond the 5-year service life, which is the basis for the return on investment results presented above. Therefore, the actual economic effectiveness of the Road Improvement Program may be higher than the results in Table ES-4, which represent the outcome of a conservative assumption with regard to the service life of many treatments.

1 Introduction

1.1 Background

The Insurance Corporation of British Columbia (ICBC) started a program known as the Road Improvement Program in 1989. Staff from ICBC recognized that tangible benefits, measured by a reduction in claim costs, could be achieved by providing funding for road safety improvements. At the outset of the program, there was limited funding available for road improvements and the program only targeted a very few locations; only those locations that offered the greatest potential to reduce collisions and the associated reduction in ICBC claim costs. Due to the success in reducing collisions and claim costs, the program has grown considerably since its inception in 1989, with a current annual budget of approximately $8 million.

The approach used for ICBC's Road Improvement Program (RIP) is to establish effective partnerships with local road authorities in British Columbia and to work cooperatively to make sound investments in road safety improvements. ICBC's road authority partners are varied and have included local municipalities, the Ministry of Transportation, First Nations, BC Ferries, BC Parks, Public Works Canada, among others. The common goal for ICBC and the partnering road authority is to reduce the frequency and severity of collisions, thereby reducing deaths, injuries and insurance claim costs. The road safety improvement partnership includes contributions from the both the road authority and from ICBC, which typically involves the following tasks:

- Identify locations that may be suitable candidates for improvement;
- Investigate the causal factors of the safety problem(s) at the site;
- Develop the road improvement strategies/improvements; and
- Calculate the level of ICBC investment for the project.

Over the years, ICBC's Road Improvement Program has had considerable success in partnering with road authorities in BC on many types of road safety projects. The types of improvement projects are highly varied, ranging from short-term, low cost safety improvements such as enhanced signing and delineation, to long-term, high-cost improvements such as roadway re-alignments and road widening, geometric improvements at intersections, traffic signal installation and roundabouts.

1.2 Road Improvement Program Projects

Some examples of typical projects where ICBC's Road Improvement Program have been involved are presented in the following section.

A typical example of a short-term, low-cost safety improvement could be additional or enhanced traffic signal visibility. Improving signal visibility includes using such as upgrading signal lens size, installing new backplates, adding reflective tapes to existing backplates, and installing additional signal heads. The safety impact of this treatment is typically the greatest within the first two years. Moreover, in a recent study, El-Basyouny and Sayed (2013) found that reductions for this kind of treatment are more significant for night-time severe collisions and day-time non-severe collisions.

Another good example of a low-cost, but highly effective safety treatment is the use of shoulder rumble strips (SRS), installed on the shoulder area of a roadway or centreline rumble strips (CRS), installed on the centreline between opposing traffic. ICBC's Road Improvement Program has provided funding for many rumble strip projects over the years.

With the topography in many regions in BC, there is a need to address roadside safety. Roadside barrier and retaining walls can be very effective safety features of roadways to prevent errant vehicles from entering a hazardous roadside area, or to prevent a hazardous roadside from becoming a roadway hazard. The safety benefit associated with the roadside barrier clearly illustrates the high potential for a severe incident without a roadside barrier.

Another important consideration of the Road Improvement Program involves the safe accommodation of vulnerable road users such as pedestrians and cyclists. Collisions between motor vehicles and vulnerable road users can be very severe, often resulting in life-altering injuries. Over the years, the Road Improvement Program has invested funds for projects that provide safer facilities for vulnerable road users, including crosswalks, walkways, lighting and mid-block pedestrian crossing facilities.

An example of a long-term, high-cost safety improvement is the widening of a road or highway. Engineering literature indicates that safety will be improved with additional highway lanes as a result of better traffic flow and safer passing opportunities. ICBC has partnered with various road authorities in BC to share in the costs of roadway widening. Each candidate site is reviewed for its potential to reduce collisions and ICBC's contribution is based on this safety benefit potential. Another example of a high-cost, long-term road safety improvement is the re-alignment of an existing road or the construction of a new road. For instance, when an existing road has a sharp horizontal curve and difficult/skewed connections from the adjacent minor roadways, a new roadway can be designed to flatten the sharp curve and re-align the connections at a safer, 90-degree intersection angle.

1.3 ICBC's Investment in Road Improvements

The criteria for ICBC's level of investment for road improvement projects have changed over the years. Below is a summary of the evolution of the investment criteria for ICBC's Road Improvement Program.

Initially, ICBC's contribution for road improvement projects was calculated based on a target return on investment of 2:1 over two years. In other words, for every dollar that ICBC invested into a road improvement project, ICBC would expect to save at least two dollars in claims costs within two years. This initial investment criterion was selected to be aggressive such that ICBC could be assured that the funding dedicated to road safety improvements would realize benefits in terms of reduced claim costs at the locations that were improved. The 2:1 return over a 2-year time period investment criteria remained in place until the year 2002.

After an evaluation of the Road Improvement Program in 2001, which showed a 4.7:1 return on investment over a two year period, the funding criteria was changed to 3:1 in two years to better reflect the actual rate of return that ICBC was achieving. However, it was later determined that the 3:1 criteria, which was discussed in 2002 and implemented in 2003, was too aggressive, causing a significant reduction in the level of ICBC contribution, which in turn, marginalized ICBC's involvement in some projects. In other words, the levels of ICBC contribution become too low for some projects to attract road authority participation.

To address this issue, the funding criterion was changed again in 2007, such that ICBC would expect to achieve a 50% internal rate of return. This funding criterion would allow a more meaningful ICBC contribution for road improvement projects. In addition, the 50% internal rate of return criterion could also allow a project's service life to extend up to 5 years, to better reflect some projects that have benefits accruing beyond 2 years.

In 2009, another option for the allowable service life for projects was implemented. For projects that are expected to realize safety benefits well into the future, a service life of 10 years could be used to calculate ICBC contribution. It is widely accepted that many road safety improvements (e.g., traffic signals, roundabouts, geometric improvements) offer safety benefits for at least 10 years, and most likely longer.

1.4 Program Evaluation Objectives

The objective of this specific study was to conduct a time-series (before to after) evaluation of the safety performance of a sample of locations that have been improved under the ICBC Road Improvement Program. The study evaluated the effectiveness of the program by quantifying the cost and benefits of each improvement project. The evaluation methodology used the latest knowledge and experience in the field of road safety evaluation, and included the following:

- Use of collision data (ICBC claim data and police reported collision data);
- The development and application of advanced collision prediction models (non-linear intervention models); and,
- Accounting for the change in traffic volume at improvement sites.

Several evaluations have been completed over the years to determine whether the goals and objectives of ICBC's Road Improvement Program have been satisfied and to provide justification for ICBC's expenditure on road improvements. The first program evaluation was conducted in 1996 to ensure the cost-effectiveness of road safety investments in the various road improvement projects. There have been five subsequent program evaluations, conducted in 1997, 1998, 2001, 2006, and 2009 with the evaluation methodology improving over time. This report is the latest program evaluation, which focuses on the effectiveness of road improvement projects that were completed between 2008 and 2010. The evaluation methodology deploys state of the art techniques to ensure reliable and robust evaluation results, as will be described in Chapter 3 of this report.

1.5 Evolution of the Program Evaluation Methodology

To measure the success of the Road Improvement Program and to ensure the proper allocation of available funding, a study was initiated in 1993 to establish a framework for evaluating the economic feasibility of road safety improvement projects. The study described simple methods that could be used to quantify the costs and benefits of road improvements. Realizing the limitations of the 1993 study and the need to conduct a more accurate and robust economic evaluation of the road improvement program, another study was completed in 1996. The 1996 study demonstrated the need to consider the random nature of collision occurrence when conducting a formal program evaluation. The methodology reported in the 1996 study was useful for conducting reliable economic evaluations of safety improvement projects.

Since the preparation of the 1996 Program Evaluation study, there have been several advances in road safety research. The use of collision prediction models has become standard safety practice and is commonly used for time series safety evaluations. Methods for assessing the reliability of evaluation results are also more frequently used, and overall, a better understanding of evaluation techniques has been achieved. As a result, the methodology that was used in the 2001, 2006 and 2009 Road Improvement Program Evaluation studies deployed evaluation techniques that ensured reliable results. A more advanced technique, known as full Bayes method with non-linear intervention models, was used for this 2015 Program Evaluation. The added advantages of this innovative technique are described in section 2.5.

1.6 Program Evaluation Components

An effective and robust program evaluation requires considerable effort. Sections of this report provide the details of the various components of the Road Improvement Program evaluation process. The main components of the evaluation are listed below, together with a short description.

- Selection of sites to evaluate: it is important to select road improvement projects that will be representative of the types of projects that are typically completed by the Program.

- Compilation of the evaluation data: it is also important to obtain and compile reliable data to accurately evaluate the effectiveness of road improvement projects, including the necessary collision data, project data and traffic volume data.

- Formulating the evaluation methodology: the evaluation methodology used should withstand technical scrutiny and incorporate the latest advances in road safety research such that reliable results can be obtained.

- Development of advanced collision prediction models (i.e., non-linear intervention models): the development and application of advanced collision prediction models (CPMs) is necessary to improve the accuracy of road safety performance for the time-series evaluation.

- The computation of results: Collision reduction and economic indicators: The success of the Program is determined by computing the reduction in collisions, as well as two economic indicators, including the benefit-cost ratio (B/C) and the net present value (NPV).

1.7 Report Structure

Chapter 1 of this report has provided a short introduction, listing the objectives and providing some general background information. Chapter 2 describes the importance and necessity of effective evaluation of road safety programs; the obstacles to performing a program evaluation; and the techniques to ensure effective evaluations are completed. Chapter 3 provides the details of the program evaluation methodology. Chapter 4 provides a discussion of the data elements used in road safety evaluations, including the data used for this evaluation. Chapter 5 details the results of the program evaluation, listing the reduction in collisions and the economic indicators of the results. Finally, Chapter 6 concludes the report. A comprehensive list of references and Appendices are provided at the end of this report.

2 Evaluation of Road Safety Initiatives

This chapter of the report is intended to provide background information related to the completion of accurate and reliable road safety evaluations. It is included in the interest of completeness so that the reader can understand the complexity of the latest road safety evaluation techniques.

2.1 Why Evaluate Road Safety

There are several reasons to conduct a thorough and robust evaluation of road safety initiatives. These main reasons are summarized as follows:

- In the majority of cases, the success of a road safety initiative is not self-evident, even to road safety professionals that have considerable practical experience and knowledge.
- Road safety research has definitively indicated that the relationship between the various causal factors and the occurrence of collisions is not a clear and definitive relationship.
- There is rarely a simple cause and effect relationship associated with road safety initiatives. Usually, several factors that influence safety in different ways operate simultaneously within a transportation system, including such things as changes in traffic volume level, the driver population, operating speeds, and weather conditions (among others).

2.2 What to Evaluate

Evaluating a road safety initiative is usually undertaken by comparing the level of safety before the initiative was implemented, to the level of safety after the initiative was implemented. The level of safety can be defined in several ways, but most often the collision frequency is used, which will form the basis for this evaluation study.

Therefore, given that the requisite data is both available and reliable, the evaluation of the ICBC Road Improvement Program will be undertaken by comparing the number of collisions that occurred after the implementation of the various improvement projects that were funded by the Road Improvement Program, to what would have been the number of collisions at the locations if the road safety improvements not been implemented. The main assumption is that if nothing else happens, then a change in the number of collisions must be attributed to the safety initiative.

2.3 Safety Evaluation Methods

Time-series and cross-sectional studies are two techniques that are frequently used to estimate the effect of specific road safety interventions. The most common method to estimate the effectiveness of safety initiatives is a time-series analysis, which is often referred to as before-after (BA) analysis as mentioned earlier. This approach attempts to measure the change in safety over time due to the implementation of a safety initiative. A cross-sectional study compares the expected collision frequencies of a group of locations having a specific component of interest (treatment) to the expected collision frequency of a group of similar locations that lack the presence of this specific component. Any differences in collision frequency between the two groups are attributed to the change in conditions, representing the safety effect of the treatment. Cross-sectional studies are generally considered inferior to time-series analysis (before-after studies) since no actual change has taken place. BA studies are known as observational when countermeasures have been implemented in an effort to improve the road network and treatment sites are selected where concerns about collision frequency were raised. Observational studies are much more common in road safety literature than experimental studies, i.e., studies where treatments have been implemented randomly in some locations to specifically estimate their effectiveness. Indeed, random selection in assigning treatments is an impractical and uneconomical solution for traffic agencies to undertake (Highway Safety Manual, 2010). An observational before-and-after study is generally perceived to be an effective way to estimate the safety effect of changes in traffic and roadway characteristics.

An observational BA study, where the treatment effect is naively evaluated as the change in observed collision frequency between the before and the after period, is known as a simple BA evaluation. The simple BA evaluation has many shortcomings; the collision frequency observed at a road location during a certain period of time is a biased measure that does not correctly reflect the location level of safety during that time period. The reason is that traffic collisions are events that have a random component. Collision frequency is, in fact, a stochastic variable and the single number of collision observed represents only one realization of its true (expected) value. Therefore, determining treatment effect should deal with the difference between the true safety levels, estimated with the use of statistical techniques, rather than the observed safety levels available in collision records.

For these reasons, other study types are preferred over a simple BA evaluation. For BA analysis, Bayesian methods are commonly used within an odds-ratio (OR) analysis for their ability to treat unknown parameters such as predicted collision frequency as random variables having their own probability distributions. Examples of Bayesian evaluation techniques include the Empirical Bayes (EB) (Hauer, 1997; Sayed et al., 2004) and fully Bayes (FB) (El-Basyouny & Sayed, 2010). A typical EB before-after study requires the collection of data for three distinct sets of data: i) treatment sites, ii) comparison sites, and iii) reference sites. The comparison group is used to correct time-trend effects and other unrelated effects and includes sites that have not been treated but experience similar traffic and environmental conditions. The reference group is used to correct the regression-to-the-mean artifact. Usually, the reference group includes a larger number of sites that are similar to the treatment sites and is used to develop a Collision Prediction Model (CPM). The EB approach is used to refine the estimate of the expected number of collisions at a location by combining the observed number of collisions (at the location) with the predicted number of collisions from the CPM.

Alternatively, the FB approach has been proposed in road safety literature to conduct before-after studies. The FB approach is appealing for several reasons, which can be categorized into methodological and data advantages. In terms of methodological advantages, the FB approach has the ability to account for all uncertainty in the data, to provide more detailed inference, and to allow inference at more than one level for hierarchical models, among others (El-Basyouny & Sayed, 2010). In terms of data requirements, the FB approach efficiently integrates the estimation of the CPM and treatment effects in a single step, whereas these are separate tasks in the EB method thereby negating the need for a reference group and reducing the data requirement.

To benefit from the additional advantages of the FB approach, several researchers have proposed the use of intervention models in the context of a before-after safety evaluation. Collision prediction models have been proposed to conduct collision intervention analysis by relating the collision occurrence on various road facilities as a function of time, treatment, and interaction effects. These intervention models acknowledge that safety treatment (intervention) effects do not occur instantaneously but are spread over future time periods and are used to capture the effectiveness of safety interventions.

2.4 Confounding Factors

As mentioned earlier, the evaluation process should ensure that a noted change in the safety performance is caused by the safety initiative and not by other "confounding" factors or causes. If other factors are allowed to contribute to the noted change, then sound conclusions about the effect of the countermeasure cannot be made. This report will focus on the main factors that are most relevant to road safety evaluations.

The RTM phenomena introduced before is considered the most important among them since a countermeasure is not assigned randomly to sites but to locations with high-collision frequency. This high-collision frequency may regress toward the mean value in the post-treatment period regardless of the effect of the treatment. This condition will lead to an overestimation of the treatment effect in terms of the collision reduction. Usually, a group of reference sites are used to correct the RTM phenomenon by developing CPMs, i.e., a calibrated relationship between collision frequency and annual average daily traffic (AADT) volumes. The reference group includes a larger number of sites that are similar to the treatment sites but have not undergone any improvements from the before to the after periods. Full Bayes techniques have been shown to account for the regression to the mean using comparison groups (El-Basyouny & Sayed, 2012).

Other confounding factors, theorized to have an effect on the frequency of collisions attributed to a road safety measure, are: the exposure effect, unrelated effect, and trend effects (maturation).

- Exposure effect: the most common measure of exposure is traffic volume, which can be represented in a number of ways (such as the total volume entering the location in a set period, or be separated into major or minor entering traffic volumes, or even be separated down to the particular movement). Traffic volume can vary over time because of various reasons such as increased demand of travel, population growth, or a change in the capacity of the intersection. It is important that the methodology used accounts for exposure.

- Unrelated effect: refers to the possibility that factors other than the treatment being investigated caused all or part of the observed change in collisions. For example, traffic and driver composition, enforcement level, weather conditions, etc. can be changed from the before period to the after period.

- Maturation: refers to changes in long-term collision trends. Comparing collisions before and after implementing a specific countermeasure may indicate a reduction attributed to the countermeasure. However, it is possible that the collision reduction could be attributed to a continuing decreasing trend (e.g., caused by improvements to vehicle performance / vehicle crashworthiness).

2.5 Full Bayes Approach

Researchers have recently introduced the use of the full Bayesian (FB) approach to evaluate the effect of road safety countermeasures (Li et al., 2008; El-Basyouny & Sayed, 2010, 2012). As discussed earlier, the FB method has several advantages over the commonly used EB technique including the ability to:

- Conduct multivariate analysis. Collisions of different severity and types can be strongly correlated, thus, multivariate modeling can lead to more accurate and precise estimations.
- Allow inference at more than one level for hierarchical (multi-level) models. It has been proposed that aside from being correlated across different severities and types, collision data exhibit a multi-level structure. For instance, the EB method is incapable of accounting for the spatio-temporal level.
- Treat each time period as an individual data point; that is, if the time period selected for the analysis is by month, then each month of the year represents a separate data point in the FB analysis, while the EB method typically deals with the entire study period as a single data point (either total or calculated as per year). This has two advantages: the ability to account for seasonal changes throughout the year and to look for changes in treatment effects with respect to time.
- Integrate the estimation of the CPM and treatment effects in a single step. The FB method differs in that the model parameters have prior distributions and, therefore, the posterior distribution integrates and includes both prior information and all available data. Then, the expected collision frequency is a distribution of likely values rather than be a point estimate.

3 Program Evaluation Methodology

3.1 Methodology to Evaluate the RIP Program

The methodology that is used to evaluate ICBC's Road Improvement Program employs a full-Bayes BA study with advanced CPMs (i.e., non-linear intervention models).

Consider an observational BA study where collision data are available for a reasonable period of time before and after the intervention (treatment). In addition, a set of collision data for the same period of time is available for a comparison group similar to the treatment sites (time-series cross sectional modeling). Let Y_{it} denote the collision count recorded at site i ($i = 1, 2, \ldots, n$) during year t ($t = 1,2, \ldots, m$). Using a hierarchical model, such as Poisson-Lognormal, with site-level random effects ε_i and assuming that the Y_{it} are independently distributed, it is possible to define the non-linear intervention model. To introduce this model, the following notation is used: T_i is a treatment indicator (equals 1 for treated sites, zero for comparison sites), t_{0i} is the intervention year for the i^{th} treated site and its matching comparison group, I_{it} is a time indicator (equals 1 in the after period, 0 in the before period), V_{1it} and V_{2it} denote the annual average daily traffic (AADT) at the major and minor approaches respectively (for intersections). For highway segment, V_{1it} and V_{2it} are replaced with $V_{TOT,\,it}$ and L_i, which denote the total circulating AADT and the length of the stretch of highway analyzed, respectively.

3.2 The Poisson-Lognormal Non-Linear Intervention (Koyck) Model

A non-linear intervention model (dynamic regression) is employed to identify the lagged effects of the treatment in order to measure its effectiveness. The consequences of the intervention can be modeled using distributed lags along with a first-order autoregressive (AR1) model as a proxy for the time effects (Judge et al., 1988) (Pankratz, 1991).

As already said, it is assumed that the Y_{it} are independently distributed as

$$Y_{it} | \theta_{it} \sim \text{Poisson}(\theta_{it}) \quad (3.1)$$

$$\ln(\theta_{it}) = \ln(\mu_{it}) + \varepsilon_i \quad (3.2)$$

$$\varepsilon_i \sim \text{Normal}(0, \sigma^2_{\varepsilon}) \quad (3.3)$$

Equations 1, 2, and 3 represent the hierarchical structure of the Poisson-Lognormal model. The regression equation for the rational distributed lag model is given by:

$$\ln(\mu_{it}) = \alpha_0 + \alpha_1 T_i + [\omega/(1-\delta B)] I_{it} + [\omega^*/(1-\delta B)] T_i I_{it} + \beta_1 \ln(V_{1,it}) + \beta_2 \ln(V_{2,it}) + \nu_t, \qquad (3.4)$$

where B denotes the backshift operator $(BZ_t = Z_{t-1})$, $|\delta| < 1$ and ν_t satisfies the following stationary AR1 equation

$$\nu_t = \phi \nu_{t-1} + e_t, \qquad |\phi| < 1, \qquad e_t \sim N(0, \sigma_\nu^2), \qquad t = 2, 3, \ldots, m. \qquad (3.5)$$

Consider the expansion $(1-\delta B)^{-1} I_{it} = I_{it} + \delta I_{i,t-1} + \delta^2 I_{i,t-2} + \ldots$, and note that the rational distributed lag model depicts an everlasting treatment effect as $\ln(\mu_{it})$ is tacitly assumed to be a function of the infinite distributed lags $(I_{it}, I_{i,t-1}, I_{i,t-2}, \ldots)$. The parsimonious model (3.4) is known as the Koyck model (Koyck, 1954) in which the lag weights $\omega\delta^k$ and $\omega^*\delta^k$ decline geometrically for $k = 0, 1, 2, \ldots$. Consequently, the earlier years following the intervention are more heavily weighted than distant years. It should also be noted that although the weights never reach zero, they will eventually become negligible. The two parameters ω (the intervention effect) and ω^* (intervention effects across treated and comparison sites) are impact multipliers, whereas δ is a decay parameter controlling the rate at which the weights decline.

3.3 Index of Treatment Effectiveness

To estimate the index of effectiveness of the countermeasure, let μ_{TBi} and μ_{TAi} denote the predicted collision counts for the ith treated site averaged over appropriate years during the before and after periods, respectively, and let μ_{CBi} and μ_{CAi} denote the corresponding quantities for the matching comparison group where the predicted collision counts are averaged over appropriate sites (all sites in the matching comparison group) and years. The ratio μ_{CAi}/μ_{CBi} can be used to adjust the prediction for general trends between the before and after periods at the ith treated site. Thus, the predicted crashes in the after period for the ith treated site had the countermeasures not been applied is given by $\pi_{TAi} = \mu_{TBi}(\mu_{CAi}/\mu_{CBi})$. The index of effectiveness of the countermeasures at the ith treated site is given by the ratio μ_{TAi}/π_{TAi}, which reduces to

$$\theta_i = \mu_{TAi}\, \mu_{CB} / \mu_{TBi}\, \mu_{CA} \tag{3.6}$$

or

$$\ln(\theta_i) = \ln(\mu_{TAi}) + \ln(\mu_{CB}) - \ln(\mu_{TBi}) - \ln(\mu_{CA}) \tag{3.7}$$

The overall index can be computed from

$$\ln(\theta) = \frac{1}{NT} \sum_{i=1}^{NT} \ln(\theta_i). \tag{3.8}$$

where NT is the total number of treatment sites. The overall treatment effect is calculated from $(\theta - 1)$, while the overall percentage of reduction in predicted collision counts is given by $(1 - \theta) \times 100$. Actually, the index in Equation 3.6 may also be estimated without the term μ_{CB}/μ_{CA} as recent research has shown that the resulting outcome would provide very similar results to Equation 3.6. This is because the set of comparison sites within the full Bayes approach is already included and accounted for in the estimation of the non-linear intervention model.

In this study, the statistical software WinBUGS (Spiegelhalter et al., 2005) was selected as the modeling platform to obtain full Bayes estimates of the unknown parameters (e.g., α_j and β_j). First, it is required to specify prior distributions for the parameters. To do so, prior distributions for all parameters are assumed and then the posterior distributions are sampled using Markov Chain Monte Carlo (MCMC) techniques available in WinBUGS. The most commonly used priors are diffused normal distributions (with zero mean and large variance) for the regression parameters and Gamma(ε, ε) or Gamma(1, ε) for the precision (inverse variance) parameters, where ε is a small number (e.g., 0.01 or 0.001).

Second, the whole set of parameters were assumed as non-informative with normal distribution with zero mean and large variance, i.e., normal (0, 10^3), to reflect the lack of precise knowledge of their value (prior distribution). Instead, the variance, σ_ε^2, of random effects was assumed Inverse-Gamma (0.001, 0.001). The posterior distributions needed in the full Bayes approach were sampled using the Markov Chain Monte Carlo (MCMC) techniques. The BGR statistics (Brooks and Gelman, 1998), ratios of the Monte Carlo errors relative to the standard deviations of the estimates and trace plots for all model parameters were monitored for convergence.

Finally, to implement the Koyck model in WinBUGS, Equation 3.4 was rewritten and decomposed in three different equations (for t=1, t=2, and t≥3). The regression models obtained are showed in APPENDIX A.1.

The BUGS code produced draws from the posterior distribution of the parameters and, given those draws, MCMC techniques was used to approximate the posterior mean and standard deviation of the parameters. Hence, the posterior summaries in this study were computed by running two independent Markov chains for each of the parameters in the models for 60,000 iterations. Chains were thinned using a factor of 100 and the first 10,000 iterations in each chain were discarded as burn-in runs. The convergence was monitored by reaching ratios of the Monte Carlo errors relative to the standard deviations for each parameter less than 5% using the BGR statistics of WinBUGS and also using visual approaches such as observing trace plots.

3.4 Calculating the Economic Effectiveness of the Program

Two indicators are used to measure the effectiveness of a road safety improvement project: the net present value (NPV) and the benefit-cost ratio (B/C). The first step in calculating these indicators is to convert the Odds Ratios for PDO and severe collisions into an annualized reduction (or increase) in collision frequency. These reductions (or increases) are then converted to annual benefits (or dis-benefits) using average collision costs. The expected B/C can be calculated by using equation (3.9) as follows:

$$E\,(B/C) = k_1 \times E(\textit{pdo claims}) + k_2 \times E(\textit{injury claims}) \qquad (3.9)$$

$k_1 = (\text{pdo.Cost}) \times (P/A,i,t)\ /\text{Cost}_{\text{implementation}}$; $k_2 = (\text{inj.Cost}) \times (P/A,i,t)\ /\text{Cost}_{\text{implementation}}$;

where: E (B/C) = Expected value of B/C ratio;

pdo.Cost = Average PDO collision cost;

inj.Cost = Average injury collision cost;

t/i = Payback period (years) / discount rate (%); and,

(P/A,i,t) = Present worth factor, given payback period, discount rate.

The expected net present value (NPV) is calculated using equation (3.10) as follows:

$$E(NPV) = [k_1 \times E(\textit{pdo claims}) + k_2\, E(\textit{injury claims})] - Cost_{implementation} \quad (3.10)$$

where: E (NPV) = Expected value of NPV;

k_1 =(pdo.Cost) × (P/A,i,t); and,

k_2= (inj.Cost) × (P/A,i,t).

4 Program Evaluation Data

This chapter of the report provides information related to the data used for the evaluation of ICBC's Road Improvement Program. The data for the evaluation can be separated into two distinct groups of sites. The two groups are listed below with a brief description. The details for each group and the corresponding data for each group are provided in subsequent sections of this chapter.

- Treatment Group Sites: this is the group of sites (projects) selected for the evaluation that have been improved with assistance from ICBC's Road Improvement Program.
- Comparison Group Sites: this is a group of sites that have not been improved, but are subjected to similar traffic and environmental conditions as the treatment group sites.

4.1 Treatment Group Sites

Treatment group sites for this evaluation report were selected from projects that were completed in 2008, 2009 and 2010. Criteria were established to select projects that would be suitable for the evaluation and in consideration of the resources that were available to complete the evaluation The project selection criteria and the rationale are described below, for both the urban and rural sites and further details can be found in Appendix A.3.

Urban Sites:

- Studies, safety reviews and research projects were not included since they are not an implementation project (i.e., where an actual road improvement was made).
- Projects with a defined contribution were not included. These are projects where the ICBC contribution was pre-defined based on proven countermeasure effectiveness and/or a policy decision (e.g., funding for uninterrupted power supplies (UPS) at signalized intersections).
- Projects where the ICBC contribution for the improvement project was under $10,000 were not included. This would focus the evaluation on the more significant road improvement projects.
- Only intersection sites were selected for the evaluation (i.e., no mid-block locations or corridors) because intersections represent the largest proportion of improvement

projects completed in an urban environment. In addition, there are limitations with the claims-based collision data for mid-block / corridor locations.

- Within the group of intersection sites, only signalized intersections were selected for the evaluation (non-signalized intersections were not included) because of the lack of traffic volume data at non-signalized locations.
- Projects from small communities were eliminated due to difficulty in obtaining the data necessary for the evaluation, including an adequate group of comparison sites.
- The supporting data, including the traffic volume, must be available for each treatment site both before and after the road improvements were implemented.

Rural Sites:

- Studies, safety reviews and research projects were not included since they are not an implementation project (i.e., where an actual road improvement was made).
- Projects with a defined contribution were not included. These are projects where the ICBC contribution was pre-defined based on proven countermeasure effectiveness and/or a policy decision (e.g., funding for UPS at signalized intersections).
- Projects where the ICBC contribution for the improvement project was under $10,000 were not included. This would focus the evaluation on the more significant road improvement projects.
- Projects with a total capital cost more than $10M were not included because it would be difficult to isolate the effects of the safety treatment relative to the larger project.
- Only projects with corridor improvements were included. Project at intersections were not included in the evaluation of rural sites since intersections were being evaluated in the urban environment and since corridor improvements represent the largest proportion of improvement projects completed in a rural environment.
- Rumble strip projects were not included in the evaluation since a separate evaluation has already been completed on rumble strip projects and thus, there was no desire to evaluate more rumble strip sites.
- The supporting data, including the traffic volume, must be available for each treatment site both before and after the road improvements were implemented.

A total of 890 road improvement projects were completed in 2008, 2009 and 2010 and were candidates for inclusion in the evaluation. However, using the criteria described previously, a total of 111 sites were selected to serve as the treatment group of sites for the evaluation. This sample of projects would allow for the evaluation of the ICBC's Road Improvement Program and would generally reflect some of the typical activities program, which includes improvements to both intersections and roadway segments, and undertaken in both urban and rural environments. As such, the treatment group of sites was divided into two distinct groups:

- Treatment Group 1: Urban intersections; and,
- Treatment Group 2: Rural highway segments.

The urban intersection treatment sites included a total of 72 intersections that were divided into three different groups: intersection with new pedestrian signal installations (13 sites), intersections with geometric design improvements (e.g., left-turn lanes) (30 sites), and intersections with traffic signal upgrades (e.g., new traffic signals) (29 sites). The details for the 72 intersections for Treatment Group 1 are shown in Table 4.1, Table 4.2 and Table 4.3, for the three groups listed above. The tables also provide a reference identification number, the year of implementation for the project, the location, and a brief project description.

The second treatment group (Treatment Group 2) included a total of 39 sites where road improvements were implemented on rural highway segments. All of these locations were implemented on the provincial highway network (i.e., sites are located within the jurisdiction of the BC MOT and on primary, numbered highways). A summary of the locations for Treatment Group 2 is provided in Table 4.4, which includes a reference identification number, the year of implementation, a general description of the location, and some details of the improvements that were implemented.

Accurate traffic volume and collision data was required for each site within the two treatment groups for a period of time before and after the implementation of the road improvement. The before data included 3 complete calendar years before the year in which the improvements were implements. The after data also included 3 complete calendar years of data after the year in which the improvements were implements (i.e., the year in which the improvement project was implemented was excluded from the before and after time periods). Considerable effort was undertaken to collect reliable traffic volume data for both the before and after time periods.

Collision and the traffic volume data for all treatment sites are included in Appendix A.4. It is noted that claim-based collision data is used to evaluate the urban sites and police reported collision data is used to evaluate rural sites. Self-reported claims based collision data cannot accurately locate incidents on a rural highway and thus the police reported collision data is used since the data is coded at 100m intervals along a rural corridor / highway.

Table 4.1 New Pedestrian Signal Installation (Treatment Group 1)

ID	Complete	City	Major Road	Minor Road	Project Description
1	2008	Vancouver	West 12th Avenue	Trafalgar Street	New Pedestrian Signal Installation
2	2008	Vancouver	West 12th Avenue	Vine Street	New Pedestrian Signal Installation
3	2008	Vancouver	Fir Street	West 14th Avenue	New Pedestrian Signal Installation
4	2008	Vancouver	Cambie Street	West 14th Avenue	New Pedestrian Signal Installation
5	2008	Vancouver	Cambie Street	West 17th Avenue	New Pedestrian Signal Installation
6	2009	Vancouver	Denman Street	Alberni Street	New Pedestrian Signal Installation
7	2010	Vancouver	Cordova Street	Princess Avenue	New Pedestrian Signal Installation
8	2010	Vancouver	Granville Street	West 15th Avenue	New Pedestrian Signal Installation
9	2010	Vancouver	West 41st Avenue	Yew Street	New Pedestrian Signal Installation
10	2008	Vancouver	West 70th Avenue	Heather Street	New Pedestrian Signal Installation
11	2009	Port Coquitlam	Prairie Avenue	Wellington Street	New Pedestrian Signal Installation
12	2010	Port Coquitlam	Pitt River Road	Pooley Avenue	New Pedestrian Signal Installation
13	2010	New West Minister	Royal Avenue	7th Street	New Pedestrian Signal Installation

Table 4.2 Geometric Design Improvements (Treatment Group 1)

ID	Complete	City	Major Road	Minor Road	Project Description
1	2008	Vancouver	West 12th Avenue	Heather Street	Left Turn Lane Installation
2	2009	Coquitlam	Como Lake Avenue	Gatensbury Road	Left Turn Lane Installation
3	2010	Maple Ridge	Lougheed Hwy	224th Street	Left Turn Lane Installation
4	2009	Port Coquitlam	Coast Meridian Rd.	Riverwood Gate	Left Turn Lane Installation
5	2009	Port Coquitlam	Kingsway Avenue	Broadway Street	Left Turn Lane Installation
6	2009	Coquitlam	Como Lake Avenue	Poirier Street	Left Turn Lane Installation

7	2009	Burnaby	Canada Way	Gilmore Avenue	Left Turn Lane Installation
8	2008	Mission	Cedar St	7th Ave	Left Turn Lanes on all approaches & Signal Head Upgrades
9	2008	Abbotsford	Old Clayburn Rd	McKee Drive	New Traffic Signal & Left Turn Lane installations
10	2009	Abbotsford	Gladwin Rd	Harris Rd	New Traffic Signal & right turn lane on the NB Gladwin Rd approach
11	2009	City of Langley	Fraser Hwy	203rd St	Installation of a left turn lane & EBLT Signal Phasing on the EB Fraser Hwy approach
12	2010	Township of Langley	64th Ave	197th St	Installation of Left turn lanes on the 64th Ave EB & WB approaches
13	2010	Township of Langley	208th St	80th Ave	Installation of Left turn lanes on the 208th St approaches
14	2008	Surrey	Fraser Hwy	148th St	Left Turn Lanes on the 148th St approaches & Signal Head Upgrades
15	2008	Surrey	72nd Ave	140th St	Left Turn Lanes on the 140th St approaches & extension of the existing EB left turn lane
16	2008	Surrey	72nd Ave	130th St	New Traffic Signal & Left Turn Lane installations on the NB & SB approaches
17	2009	Surrey	32nd Ave	168th St	Installation of Left turn lanes on the EB, WB, & SB approaches & a right turn lane on the NB approach
18	2009	Surrey	168th St	84th Ave	New Traffic Signal & Left Turn Lane installations on the 168th St NB & SB approaches
19	2010	Surrey	144th St	60th Ave	New Traffic Signal & Left Turn Lane installations
20	2010	Delta	Nordel Way	Brooke Rd	Installation of Left turn lanes on the Nordel Way EB & WB approaches
21	2010	Delta	Nordel Way	Shepherd Way	Installation of Left turn lanes on the Nordel Way EB & WB approaches

22	2010	Delta	Derwent Way	Chester Rd	New Traffic Signal & Left Turn Lane installations
23	2008	Kelowna	Springfield Rd	Graham Ave	Centre Median Installation
24	2008	Vernon	43rd Avenue	20th Street	Curb Extension Installations
25	2008	Kelowna	Springfield Rd	Leckie Rd	Signal phase and median improvements
26	2008	Kelowna	Springfield Rd	Benvoulin Rd	New NB right turn lane
27	2009	Kelowna	Benvoulin Rd	KLO Rd	Extension of SB left turn lane
28	2009	Kelowna	Lakeshore Rd	Lequime Rd	Lakeshore and Lequime Left Turn Bay
29	2010	Penticton	Channel Parkway	Green/Warren/Dunca n	Channel Parkway Modified RT Lanes
30	2009	Prince George	Hwy 16	Domano Blvd	Geometric and phasing improvements

Table 4.3 Traffic Signal Upgrades (Treatment Group 1)

ID	Complete	City	Major Road	Minor Road	Project Description
1	2008	Vancouver	Marine Drive	Yukon Street	New Traffic Signal Installation
2	2009	Vancouver	Homer Street	Helmcken Street	New Traffic Signal Installation
3	2009	Vancouver	West 2nd Avenue	Yukon Street/Wylie	New Traffic Signal Installation
4	2009	West Vancouver	Marine Drive	24th Street	New Traffic Signal Installation
5	2009	North Vancouver City	Chesterfield Avenue	15th Street	New Traffic Signal Installation
6	2008	Maple Ridge	232nd Street	128th Avenue	New Traffic Signal Installation
7	2009	Maple Ridge	Dewdney Trunk Road	Cottonwood	New Traffic Signal Installation
8	2010	Maple Ridge	Abernethy Way	224th Street	New Traffic Signal Installation
9	2010	Coquitlam	North Road	Delestre Road	New Traffic Signal Installation
10	2008	Burnaby	Cariboo Road	10th Avenue	New Traffic Signal Installation
11	2010	Burnaby	Central Blvd.	Bonsar Avenue	New Traffic Signal Installation
12	2008	Abbotsford	Marshall Rd	Abbotsford Way	New Traffic Signal
13	2008	City of Langley	56th Ave	198th St	New Traffic Signal
14	2009	Township of Langley	16th Ave	216th St	New Traffic Signal

15	2009	Township of Langley	Fraser Hwy	240th St	Installation of Left Turn Signal Phasing on the EB & WB Fraser Hwy approaches
16	2008	Richmond	Granville Ave	Buswell St	New Traffic Signal
17	2009	Richmond	No 2 Rd	Francis Rd	Installation of Left Turn Signal Phasing on the EB & WB Francis Rd approaches
18	2010	Richmond	No 1 Rd	Blundell Rd	Installation of Left Turn Signal Phasing on the SB & WB approaches
19	2010	Richmond	Granville Ave	St Albans Rd	Installation of Left Turn Signal Phasing on the EB & WB approaches
20	2010	Richmond	Blundell Rd	St Albans Rd	Installation of Left Turn Signal Phasing on the EB approach
21	2009	Chilliwack	Yale Rd	Hodgins Ave	Installation of Left Turn Signal Phasing on the SB Yale Rd approach
22	2008	Surrey	King George Hwy	68th Ave	Installation of Left Turn Signal Phasing on the KGH approaches
23	2009	Surrey	192nd St	24th Ave	New Traffic Signal
24	2009	Delta	Scott Rd	Sunwood Dr	New Traffic Signal
25	2010	Kelowna	Lakeshore Rd	Barrera Rd	New traffic signal
26	2010	West Kelowna	Old Okanagan Hwy	Butt Rd	New traffic signal
27	2008	Prince George	Ospika Blvd	15th Ave	Signal phasing improvement
28	2008	Kamloops	Various	Various	Kamloops Signal Head Upgrade 2008
29	2009	Kamloops	Pacific Way	Hugh Allan Dr	NB and EB left turn protected phase

Table 4.4 Segment Improvements (Treatment Group 2)

ID	Complete	Nearest City	Highway	Project Description
1	2008	Nanaimo	1	Access control to restrict movements from the side roads onto Highway 1
2	2008	Princeton	3	Improvements to the signing, delineation, and the pedestrian / cyclist facilities
3	2008	Surrey	10	Four-laning of Highway 10 with access consolidation, signing, paving, delineation, median
4	2008	Squamish	99	Improved signing, pavement marking, and deployment of rumble strips
5	2008	Port Alberni	4	Cross-sectional improvements including shoulder widening and pavement treatments
6	2008	Williams Lake	20	Improvements to the level of delineation provided on the corridor
7	2008	Port Alice	30	Improved vertical alignment, super-elevation, delineation, pavement marking and drainage

8	2008	Grand Forks	3	Improved cross-section with channelization, delineation, pavement marking, pedestrian facility
9	2008	Merritt	5A	Improved signing including enhanced curve delineation with W54 signs
10	2008	Vernon	6	Installation of concrete barrier and inlaid thermal pavement markings
11	2008	Smithers	16	Improve signing, delineation, channelization, access control, widening, and super-elevation
12	2008	Prince George	97	Pavement treatments, install median barrier, improved delineation and rut removal
13	2009	Abbotsford	1	New WB climbing lane to reduce friction, congestion and weaving at Mt. Lehman I/C
14	2009	Victoria	17	Installation of a real-time congestion warning system responding to peaking ferry traffic
15	2009	West Kelowna	97	Installation of median barrier to prevent cross-over incidents
16	2009	Prince George	97	Widening of Hwy 97 and improve intersection operations at Railway, Terminal and Pacific
17	2009	Langford	1	Signing, delineation, drainage, access management; install deceleration lanes, widen shoulders and CRB
18	2009	Nanaimo	1	Improve road signing, install lighting, and introduction of speed control measures
19	2009	Elko	3	Shoulder widening, rumble strips, improve signing, pavement marking, speed control measures
20	2009	Dease Lake	37	Improved level of delineation, pavement marking, and pavement treatments
21	2009	Ucluelet	4	Improve the roadside hazards, including barrier installation and pavement treatments
22	2009	Kelowna	97C	Improve positive guidance with the in-laid thermo plastic pavement marking
23	2009	West Kelowna	97	Improve signing, delineation, pavement marking, sight distance, signal and channelization
24	2010	Hope	3	Improve signing and delineation, speed reader board, LED chevrons, CRS/SRS, thermo
25	2010	Chilliwack	1	Improve signing, pavement marking, extend barrier, install wider rumble strips
26	2010	Nanoose	19	Installation of glare screen and improvements to the signing and delineation
27	2010	Malahat	1	Address roadside hazards by installing barrier and impact attenuators
28	2010	Kamloops	5A	Improve signing, delineation, pavement marking, speed control measures, pavement treatments
29	2010	Sparwood	3	Construct passing lanes, widen, improve signs, marking, delineation, drainage, access, lighting
30	2010	Yahk	3	Improve surface, O/S and highly reflective of signs, improve delineation and guidance
31	2010	Keremeos	3A	Improve surface, install reflectors on all existing CRB and upgrade of W-54 signs
32	2010	Cranbrook	93	Resurface, improve shoulders, delineators, turning/ slip by lanes, drainage / runoff control
33	2010	Coquihalla	5	Surface improvements, replace concrete panels with asphalt pavement, replace drainage system

34	2010	Langford	14	Repaving, improve shoulder, installation of bus pull-outs at key bus stops along the corridor
35	2010	Surrey	99	Installation of Cable Barrier in median to prevent cross-over incidents
36	2010	Chilliwack	1	Installation of Cable Barrier in median to prevent cross-over incidents
37	2010	Nanaimo	1	Improve cross-section, CRB/CMB, access management delineation, signs, illumination, sight distance
38	2010	Port Alberni	4	Improve signing, speed control measures, install RWIS with variable message boards
39	2010	Langley	10	Improve median treatment, access control, railway crossing, extend CMB, install crash attenuator

4.2 Comparison Group Sites

The comparison group of sites is used to correct for time trend effects, including the confounding factors of history and maturation. The comparison group sites were selected to ensure that they had similar traffic and environmental conditions as the treated sites. To ensure that there was a similarity in the traffic conditions between treatment and comparison sites in an urban setting, the comparison site had to be a signalized intersection. In the rural setting, the comparison site had to have the same highway classification as the treatment site. The MOTI use a classification system that will classify a highway based on:

1) Urban (U) or Rural (R)
2) Arterial (A), Expressway (E) or Freeway (F)
3) Undivided (U) or Divided (D)
4) 2 Lanes (2) or More than 4 Lanes (4)

Thus, a typical 2-lane rural highway would be categorized as a RAU2, whereas a freeway through Vancouver would be categorized as a UFD4.

To ensure similar environmental conditions (e.g., weather) the proximity to the treatment site was the main criterion used for the selection of comparison group sites. Care was exercised in selecting comparison group sites to ensure the time periods for the treatment and comparison sites are similar and that the factors influencing safety are similar between the two groups of sites. A summary of the control group data is provided in Appendix A5.

A total of 203 comparison sites were selected and used to generate 67 different comparison groups for the 111 treatment sites. Similarly to the treatment sites, the requisite before and after traffic volume and collision data was required for each comparison group site. The before traffic volume and collision data included a minimum of 3 year time period and the after traffic volume and collision data ranged from 4 to 5 years to match the treatment sites.

5 Program Evaluation Results

This section of the evaluation report presents the results that show the effectiveness of ICBC's Road Improvement Program in achieving its objectives, namely, a reduction in the frequency and/or severity of collisions, as well as obtaining a desired return on road improvement investments.

5.1 Overall Change in Collision Frequency

The main outcome from the models is θ, described in Equation 3.8, which represents an average treatment effectiveness across the treated locations. The full set of estimated model parameters is reported in appendix A.2. The estimated effectiveness of the treatment in reducing collisions "C.R." can easily be estimated from the following equation:

$$C.R. = 100 \times (1 - \theta) \quad (5.1)$$

Overall, the ICBC's Road Improvement Program showed a considerable reduction in collision frequency from the before to the after period. Considering all 111 treatment sites, there was found to be a 24.0% reduction in severe collisions (fatal + injury collisions combined) and a 15.4% reduction in PDO (property damage only) collisions. The total reduction of severe and PDO collision frequency for urban intersections was found equal to -19.6% and -7.6%, respectively. For rural highway segments, severe collisions were reduced of -28.2% and PDO collisions of -22.5%. The results of the overall collision reduction are provided in Table 5.1.

Table 5.1: Overall Collision Reductions

Location Type	Collision Change	
Urban Intersections	Severe	-19.6%
	PDO	-7.6%
Rural Highways	Severe	-28.2%
	PDO	-22.5%
ALL Locations (Urban and Rural)	Severe	-24.0%
	PDO	-15.4%

The results for the change in PDO and severe collisions by the 4 specific treatment types are summarized in four tables, presented as follows:

Table 5.2: Treatment Effectiveness for New Pedestrian Signal Installations (Urban Intersections)

	θ ± st. deviation	**5% Confidence Level**	**95% Confidence Level**	**Estimated Collision Reduction (C.R.)**
PDO	0.937± 0.079	0.814	1.073	-6.3%*
Severe	0.755± 0.081	0.629	0.894	-24.5%

* Not significant at the 95% confidence level.

Table 5.3: Treatment Effectiveness Geometric Design Improvements (Urban Intersections)

	θ ± st. deviation	**5% Confidence Level**	**95% Confidence Level**	**Estimated Collision Reduction (C.R.)**
PDO	0.892± 0.042	0.824	0.963	-10.8%
Severe	0.770± 0.035	0.714	0.830	-23.0%

Table 5.4: Treatment Effectiveness for Traffic Signal Upgrades (Urban Intersections)

	θ ± st. deviation	**5% Confidence Level**	**95% Confidence Level**	**Estimated Collision Reduction (C.R.)**
PDO	0.950 ± 0.037	0.889	1.012	-5.0%**
Severe	0.862 ± 0.048	0.787	0.944	-13.8%

* *Not significant at the 95% confidence level but significant at the 90% confidence level.

Table 5.5: Treatment Effectiveness for Segment Improvements (Rural Highway Segments)

	θ ± st. deviation	5% Confidence Level	95% Confidence Level	Estimated Collision Reduction (C.R.)
PDO	0.775 ±0.040	0.710	0.842	-22.5%
Severe	0.718 ±0.040	0.655	0.787	-28.2%

It is important to note that these outcomes were provided along with standard deviations, which show how much variation exists from the mean and certain percentile values that reflect better the distribution of the result. The confidence level for this study was set at 95%. The specification of a level of confidence reflects the fact that statistical inferences are estimates and that the outputs are irrelevant if the required level of confidence needed to accept or reject the results is not given. For instance, the reduction of PDO collisions for new pedestrian signal installations is not significant at the 95% confidence level, since the upper confidence level include values equal or higher than 1.

5.2 Change in Collision Frequency by Site

The results for the change in PDO and severe collisions at each improvement site and grouped according to the treatment type, are shown in several figures, presented as follows:

Figure 5.1: Change in Collisions for New Pedestrian Signal Installations (Urban Intersection)

Figure 5.2: Change in Collisions for Geometric Design Improvements (Urban Intersection)

Figure 5.3: Change in Collisions for Traffic Signal Upgrades (Urban Intersection)

Figure 5.4: Change in Collisions for Segment Improvements (Rural Highway Segments)

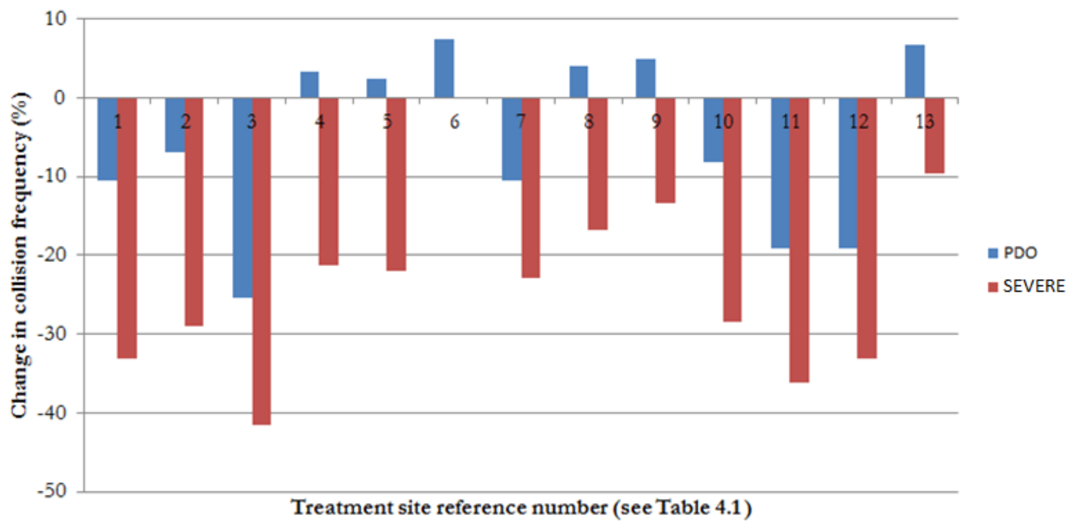

Figure 5.1: Change in Collisions for New Pedestrian Signal Installations. (at Urban Intersections)

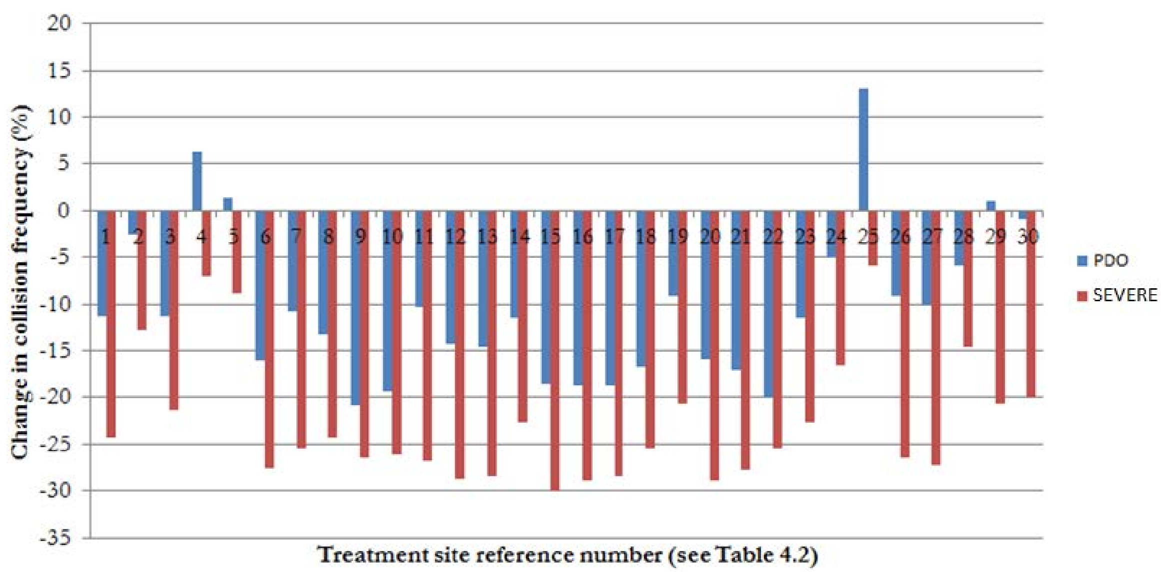

Figure 5.2: Change in Collisions for Geometric Design Improvements). (at Urban Intersections)

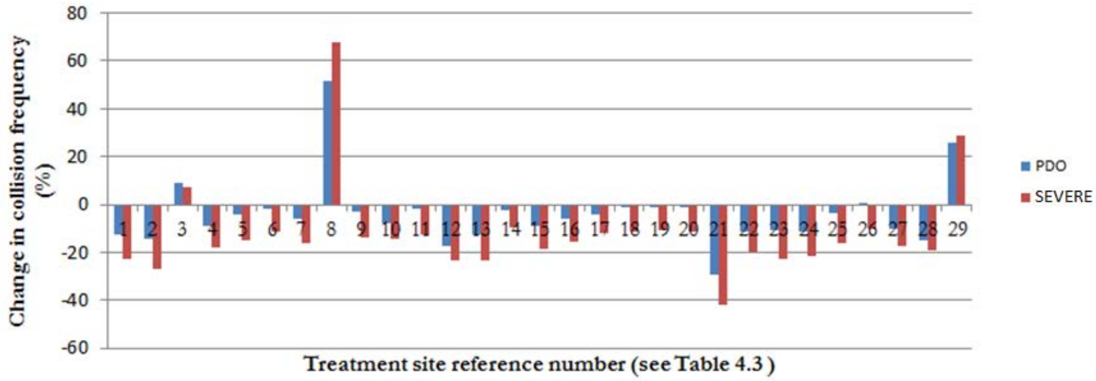

Figure 5.3: Change in Collisions for Urban Traffic Signal Upgrades (at Urban Intersections)

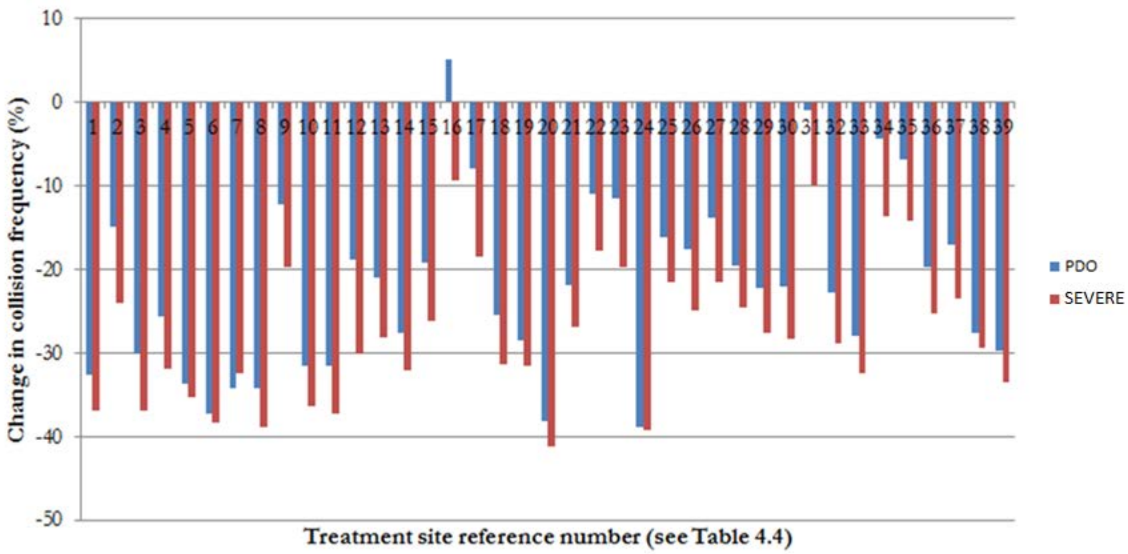

Figure 5.4: Change in Collisions for Segment Improvements (Rural Highway Segments)

As can be seen from the results presented from Figure 5.1 to 5.4, the change in collisions at the 72 treated urban intersections includes:

- Change in PDO incidents range from a reduction of 29.2% to an increase of 51.6%;
- Change in severe incidents range from a reduction of 41.7% to an increase of 67.9%;
- 59 of the urban intersections out of 72 had a reduction in PDO incidents; and,
- 69 of the urban intersections out of 72 had a reduction in severe incidents.

The results presented in Figure 5.4 indicate that the change in collisions at the 39 treated rural highway segments includes:

- Change in PDO incidents range from a reduction of 58.3% to an increase of 5.2%;
- Change in severe incidents range from a reduction of 50.6% to 9.3%;
- A total of 38 sites out of 39 experienced a reduction in PDO incidents; and,
- All 39 sites experienced a reduction in severe incidents.

5.3 The Net Present Value (NPV) and the Benefit Cost Ratio (B/C)

The last objective used to gauge the success of the Road Improvement Program is whether ICBC's contribution to projects achieves the desired return on investment. To determine this, the net present value (NPV) and benefit – cost ratio (B/C) are calculated according to Equation 3.9 and 3.10.

The first step in calculating the NPV and the B/C is to convert the treatment effect into an annualized reduction (or increase) in collisions. The reductions (or increases) are then converted into annual benefits (or dis-benefits) using average collision cost values as shown in Table 5.6. It is duly noted that a discount rate of 3% was used in the calculation of the NPV and the B/C, based on information provided by ICBC.

Table 5.6: Average Collision Cost Values

Collision Data Source	Property Damage Only Incidents	Severe (Fatal + Injury) Incidents
Urban Sites (Claim-based data)	$3,029	$33,307
Rural Sites (Police reported data)	$3,029*	$33,307*

* Assumed the same of claim-based data

It is noted that in previous RIP Evaluation Studies, the average collision cost for rural sites was increased by a multiplier to reflect the difference between claims based collision data and police reported collision data (i.e., for any given location, there is likely to be more collisions recorded by auto insurance claims than by the collision reports filed by the police). However, it was not possible to obtain information to quantify the difference between claims based collision data and the police reported collision data. As a result, the same average collision cost values were used for both the urban intersection sites and the rural highway sites as reported in Table 5.7. This assumption should result in a conservative estimate for the economic benefits for the rural sites.

The NPV, expressed in millions of dollars, and the B/C for the treatment sites are based on a 5-year service life and a discount rate of 3% and are reported in Table 5.6 below. The costs used in the calculation of the B/C and the NPV are based on ICBC contributions to the road improvement projects. The table shows that for every dollar invested in a road improvement project, there were 4.7 dollars returned to ICBC (on average) over a five-year service life as a result of a reduction in collisions costs.

Table 5.7: Economic Evaluation for Treatment Sites (5-Year Service Life)

Collision Data Source	Net Present Value (NVP)	Benefit Cost Ratio (B/C)
Urban Sites (72 sites)	$12.2M	4.3
Rural Sites (39 sites)	$7.9M	5.2
All Sites (111 sites)	$20.1M	4.7

It is noted that many of the road improvement projects are likely to have safety benefits extending well beyond the 5-year service life, which is the basis for the return on investment results presented above. Therefore, the actual economic effectiveness of the Road Improvement Program may be higher than the results reported in Table 5.6, which represent the outcome of a conservative assumption with regard to the service life of many treatments.

The detailed results for the NPV and the B/C for each treatment site were provided in Table 5.8 for each urban intersection and in Table 5.9 for the rural highway segments.

Table 5.8: Summary of Evaluation Results for Treatment Group 1: Urban Intersections

	ID	CITY	MAJOR Road Name	MINOR Road Name	Cost (ICBC contribution)	5 years	
						B/C	NPV
Pedestrian Signal Improvement	1	Vancouver	West 12th Avenue	Trafalgar Street	$32,000	5.19	$134,116
	2	Vancouver	West 12th Avenue	Vine Street	$24,500	6.64	$138,083
	3	Vancouver	Fir Street	West 14th Avenue	$95,000	1.88	$83,191
	4	Vancouver	Cambie Street	West 14th Avenue	$95,000	1.66	$62,394
	5	Vancouver	Cambie Street	West 17th Avenue	$95,000	1.62	$59,259
	6	Vancouver	Denman Street	Alberni Street	$70,000	-0.05	-$73,557
	7	Vancouver	Cordova Street	Princess Avenue	$75,000	1.24	$18,048
	8	Vancouver	Granville Street	West 15th Avenue	$35,000	2.90	$66,525
	9	Vancouver	West 41st Avenue	Yew Street	$20,000	3.98	$59,621
	10	Vancouver	West 70th Avenue	Heather Street	$30,000	4.09	$92,657
	11	Port Coquitlam	Prairie Avenue	Wellington Street	$30,000	3.67	$80,104
	12	Port Coquitlam	Pitt River Road	Pooley Avenue	$20,000	6.20	$104,051
	13	New Westminister	Royal Avenue	7th Street	$20,000	2.14	$22,842
Geometric Design Improvement	1	Vancouver	West 12th Avenue	Heather Street	$45,000	8.92	$356,315
	2	Coquitlam	Como Lake Avenue	Gatensbury Road	$75,000	2.29	$96,789
	3	Maple Ridge	Lougheed Hwy	224th Street	$25,000	11.30	$257,517
	4	Port Coquitlam	Coast Meridian Road	Riverwood Gate	$45,000	1.93	$41,796
	5	Port Coquitlam	Kingsway Avenue	Broadway Street	$35,000	2.70	$59,455
	6	Coquitlam	Como Lake Avenue	Poirier Street	$65,000	6.39	$350,290
	7	Burnaby	Canada Way	Gilmore Avenue	$33,000	18.00	$561,006
	8	Mission	Cedar St	7th Ave	$86,000	3.19	$188,184
	9	Abbotsford	Old Clayburn Rd	McKee Dr	$24,000	5.69	$112,671
	10	Abbotsford	Gladwin Rd	Harris Rd	$88,000	0.63	-$32,389
	11	City of Langley	Fraser Hwy	203rd St	$25,000	13.03	$300,828
	12	Township of Langley	64th Ave	197th St	$116,000	4.61	$419,276
	13	Township of Langley	208th St	80th Ave	$34,000	13.34	$419,636
	14	Surrey	Fraser Hwy	148th St	$89,000	4.60	$320,472
	15	Surrey	72nd Ave	140th St	$75,000	7.63	$496,910
	16	Surrey	72nd Ave	130th St	$75,000	5.40	$329,670
	17	Surrey	32nd Ave	168th St	$80,000	4.00	$240,065
	18	Surrey	168th St	84th Ave	$56,000	3.17	$121,783
	19	Surrey	144th St	60th Ave	$120,000	1.48	$57,498
	20	Delta	Nordel Way	Brooke Rd	$164,000	3.36	$386,902
	21	Delta	Nordel Way	Shepherd Way	$64,000	4.67	$235,175

	22	Delta	Derwent Way	Chester Rd	$38,000	2.22	$46,197
	23	Kelowna	Springfield Rd	Graham Ave	$28,500	7.91	$196,998
	24	Vernon	43rd Avenue	20th Street	$21,700	8.82	$169,665
	25	Kelowna	Springfield Rd	Leckie Rd	$101,400	0.93	-$6,859
	26	Kelowna	Springfield Rd	Benvoulin Rd	$24,200	35.84	$843,047
	27	Kelowna	Benvoulin Rd	KLO Rd	$20,100	38.99	$763,534
	28	Kelowna	Lakeshore Rd	Lequime Rd	$18,400	4.37	$62,051
	29	Penticton	Channel Parkway	Green/Warren/Duncan	$222,800	2.93	$429,728
	30	Prince George	Hwy 16	Domano Blvd	$128,600	3.38	$306,606
Traffic Signal Upgrades	1	Vancouver	Marine Drive	Yukon Street	$35,000	5.54	$158,747
	2	Vancouver	Homer Street	Helmcken Street	$60,000	2.17	$70,490
	3	Vancouver	West 2nd Avenue	Yukon Street/Wylie	$40,000	-2.38	-$135,224
	4	West Vancouver	Marine Drive	24th Street	$25,000	8.68	$192,031
	5	North Vancouver City	Chesterfield Avenue	15th Street	$28,000	1.98	$27,529
	6	Maple Ridge	232nd Street	128th Avenue	$25,000	1.53	$13,268
	7	Maple Ridge	Dewdney Trunk Road	Cottonwood	$20,000	6.29	$105,748
	8	Maple Ridge	Abernethy Way	224th Street	$30,000	-7.69	-$260,726
	9	Coquitlam	North Road	Delestre Road	$100,000	1.12	$12,284
	10	Burnaby	Cariboo Road	10th Avenue	$45,000	4.69	$166,071
	11	Burnaby	Central Blvd.	Bonsar Avenue	$30,000	1.80	$23,981
	12	Abbotsford	Marshall Rd	Abbotsford Way	$74,000	2.03	$75,920
	13	City of Langley	56th Ave	198th St	$32,000	3.95	$94,340
	14	Township of Langley	16th Ave	216th St	$61,000	0.60	-$24,125
	15	Township of Langley	Fraser Hwy	240th St	$18,000	9.08	$145,489
	16	Richmond	Granville Ave	Buswell St	$29,000	3.17	$63,008
	17	Richmond	No 2 Rd	Francis Rd	$18,000	8.85	$141,371
	18	Richmond	No 1 Rd	Blundell Rd	$45,000	2.42	$63,926
	19	Richmond	Granville Ave	St Albans Rd	$27,000	5.18	$112,748
	20	Richmond	Blundell Rd	St Albans Rd	$13,000	7.15	$79,997
	21	Chilliwack	Yale Rd	Hodgins Ave	$35,000	15.86	$519,925
	22	Surrey	King George Hwy	68th Ave	$34,000	8.50	$254,938
	23	Surrey	192nd St	24th Ave	$40,000	1.97	$38,704
	24	Delta	Scott Rd	Sunwood Dr	$28,000	8.72	$216,151
	25	Kelowna	Lakeshore Rd	Barrera Rd	$24,100	2.99	$47,874
	26	West Kelowna	Old Okanagan Hwy	Butt Rd	$31,300	1.21	$6,489
	27	Prince George	Ospika Blvd	15th Ave	$17,600	10.54	$167,922
	28	Kamloops	Various	Various	$40,700	30.13	$1,185,565
	29	Kamloops	Pacific Way	Hugh Allan Dr	$29,600	-7.69	-$257,188

Table 5.9: Summary of Evaluation Results Treatment Group 2: Rural Hwy Segments

ID	Nearest CITY	Cost (ICBC contribution)	5 years	
			B/C	NPV
1	Nanaimo	$35,400	9.38	$296,565
2	Princeton	$42,500	9.35	$354,778
3	Surrey	$86,100	4.35	$288,701
4	Squamish	$94,200	2.21	$114,107
5	Port Alberni	$41,500	6.99	$248,564
6	Williams Lake	$26,100	18.34	$452,584
7	Port Alice	$46,300	9.42	$389,797
8	Grand Forks	$59,100	3.04	$120,637
9	Merritt	$31,400	13.93	$405,852
10	Vernon	$63,000	4.26	$205,432
11	Smithers	$56,300	5.31	$242,516
12	Prince George	$46,400	4.87	$179,755
13	Abbotsford	$40,400	4.95	$159,571
14	Victoria	$73,000	1.32	$23,006
15	West Kelowna	$78,900	2.94	$153,331
16	Prince George	$46,300	3.03	$94,166
17	Langford	$63,300	3.30	$145,794
18	Nanaimo	$45,100	4.03	$136,801
19	Elko	$13,100	29.16	$368,934
20	Dease Lake	$10,100	11.42	$105,199
21	Ucluelet	$51,600	6.57	$287,531
22	Kelowna	$48,100	3.21	$106,377
23	West Kelowna	$45,700	5.12	$188,367
24	Hope	$86,600	3.12	$183,509
25	Chilliwack	$42,100	7.51	$274,182
26	Nanoose	$41,500	2.08	$44,822
27	Malahat	$17,800	11.06	$179,084
28	Kamloops	$78,300	3.98	$233,654
29	Sparwood	$48,700	6.62	$273,484
30	Yahk	$20,900	9.53	$178,214
31	Keremeos	$39,300	4.45	$135,650
32	Cranbrook	$35,700	11.30	$367,533
33	Coquihalla	$10,100	21.13	$203,301
34	Langford	$61,800	5.63	$286,428
35	Surrey	$68,600	2.00	$68,533
36	Chilliwack	$32,100	5.25	$136,577
37	Nanaimo	$71,300	3.37	$168,633
38	Port Alberni	$63,500	2.71	$108,444
39	Langley	$40,900	2.37	$56,115

6 Summary and Conclusions

The objective of this evaluation study was to conduct a time-series (before to after) evaluation of the safety performance of a sample of locations that have been improved under the ICBC's Road Improvement Program (i.e., urban sites and highway segments). The overall effectiveness of the Road Improvement Program can be determined by:

1) Determining if the frequency and/or severity of collisions at the improvement sites has reduced after the implementation of the improvement; and by,

2) Quantifying the program costs versus the economic safety benefits to determine the return on road safety investment.

The evaluation has incorporated the latest techniques in road safety analysis in a way to provide a high level of confidence in the results that were produced. The methodology used for this evaluation study is the full Bayes (FB) method The FB approach was shown to have several advantages, including the ability to account for greater uncertainty in the data; to provide more detailed inference; to allow inference at more than one level for hierarchical models; and to efficiently integrate the estimation of the safety model and treatment effects in a single step. To support the reliable methodology, it was also necessary to obtain reliable data for the evaluation.

To support the reliable methodology, it was also necessary to obtain reliable data for the evaluation. Collision and traffic volume data was required for each site within two distinct groups of sites, which included 111 treatment sites (i.e., road improvement projects that were completed in 2008, 2009, or 2010, as part of the Road Improvement Program) and 203 comparison sites (i.e., sites that have not been improved, but are subjected to similar traffic and environmental conditions as the treatment group sites). It is also noted claim-based collision data was used for the evaluation of urban sites and police-reported collision data was used for the rural sites.

Overall, the ICBC's Road Improvement Program showed a considerable reduction in collision frequency from the before to the after period. Considering all 111 treatment sites, there was found to be a 24.0% reduction in severe collisions (fatal + injury collisions combined) and a 15.4% reduction in PDO (property damage only) collisions. The total reduction of severe and PDO collision frequency for urban intersections was found equal to -19.6% and -7.6%, respectively. For rural highway segments, severe collisions were reduced of -28.2% and PDO collisions of -22.5%. The results of the overall collision reduction are provided in Table 6.1.

Table 6.1: Overall Collision Reductions

Location Type	Collision Change	
Urban Intersections	Severe	-19.6%
	PDO	-7.6%
Rural Highways	Severe	-28.2%
	PDO	-22.5%
ALL Locations (Urban and Rural)	Severe	-24.0%
	PDO	-15.4%

For each site in the two Treatment Groups, the change in the collision frequency for both PDO collisions and severe collisions were calculated. With regards to 72 treated urban intersections, the results showed that:

- 59 of the urban intersections out of 72 had a reduction in PDO incidents; and,

- 69 of the urban intersections out of 72 had a reduction in severe incidents.

For rural highway segments, the results indicated that:

- A total of 38 sites out of 39 experienced a reduction in PDO incidents; and,

- All 39 sites experienced a reduction in severe incidents.

Finally, in addition to the change in collision frequency, it was also important to determine if ICBC's contribution to the road improvement projects achieved the desired return on investment. To do that, two economic indicators were used, including the net present value (NPV) and the benefit cost ratio (B/C). The NPV, expressed in millions of dollars, and the B/C for the treatment sites were based on a 5-year service life and a discount rate of 3%. The summary of the resulting values is reported in Table 6.2. The table shows that for every dollar invested in a road improvement project, there were 4.7 dollars returned to ICBC (on average) over a five-year service life as a result of a reduction in collisions costs.

Table 6.2: Economic Evaluation for Treatment Sites (5-Year Service Life)

Collision Data Source	Net Present Value (NVP)	Benefit Cost Ratio (B/C)
Urban Sites (72 sites)	$12.2M	4.3
Rural Sites (39 sites)	$7.9M	5.2
All Sites (111 sites)	$20.1M	4.7

7 References

American Association of State Transportation Officials, (2010). Highway Safety Manual. AASHTO, Washington, D.C., USA.

Brooks, S.P. and Gelman, A. (1998). General Methods for Monitoring Convergence of Iterative Simulations. Journal of Computational and Graphical Statistics, 7, p. 434–455.

El-Basyouny, K., Sayed, T., (2010). A Full Bayes Approach to before–after safety evaluation with matched comparisons: a case study of stop-sign in-fill program. Transportation Research Record 2148, Pages 1–8.

El-Basyouny, K., Sayed, T., (2012). Measuring safety treatment effects using full Bayes non-linear safety performance intervention functions. Accident Analysis and Prevention, Volume 45, Pages 152–163.

El-Basyouny, K., & Sayed, T. (2013). Evaluating the signal head upgrade program in the city of Surrey. Accident Analysis & Prevention, 50, 1236-1243.

Hauer, E., (1997). Observational Before-After Studies in Road Safety. Pergamon Press, Elsevier Science Ltd., Oxford, United Kingdom.

Judge, G.G., Hill, R.C., Griffiths, W.E. Lutkepohl, H. and Lee, T.C., 1988. Introduction to the Theory and Practice of Econometrics, 2nd edition. Wiley: New York.

Koyck, L.M., 1954. Distributed Lags and Investment Analysis. North-Holland: Amsterdam.

Li, W., Carriquiry, A.L., Pawlovich, M., Welch, T., (2008). The choice of statistical models in road safety countermeasure effectiveness studies in Iowa. Accident Analyses and Prevention Vol. 40, Pages 1531-1542.

Pankratz, A., 1991. Forecasting with Dynamic Regression Models. Wiley: New York

Sayed, T., de Leur, P., Sawalha, Z., (2004). Evaluating the Insurance Corporation of British Columbia Road Safety Improvement Program. Transportation Research Record 1865, Pages 57–63.

Spiegelhalter, D., Thomas, A., Best, N., Lunn, D., (2005). WinBUGS User Manual. MRC Biostatistics Unit, Cambridge. <http://www.mrc-cam.ac.uk/bugs>.

Appendices

A.1 Derivations of the Koyck model for WinBUGS

Rewriting Equation (3.4) as $\ln(\mu_{it}) = C_{it} + \nu_t$, the AR1 Equation (3.5) implies that $\nu_t = \phi[\ln(\mu_{i,t-1}) - C_{i,t-1}] + e_t$. Substituting this last expression in (3.4) leads to

$$\ln(\mu_{it}) = (1-\phi)\alpha_0 + (1-\phi)\alpha_1 T_i + [\omega/(1-\delta B)] I_{it}^* + [\omega^*/(1-\delta B)] T_i I_{it}^*$$
$$+ \beta_1 X_{1it} + \beta_2 X_{2it} + \phi \ln(\mu_{i,t-1}) + e_t , \qquad \text{(A.1)}$$

where $I_{it}^* = I_{it} - \phi I_{i,t-1}$, $X_{1it} = \ln(V_{1it}) - \phi \ln(V_{1i,t-1})$, and $X_{2it} = \ln(V_{2it}) - \phi \ln(V_{2i,t-1})$.

Applying the operator $(1-\delta B)$ to both sides of (A.1) yields

$$\ln(\mu_{it}) = (1-\phi)(1-\delta)\alpha_0 + (1-\phi)(1-\delta)\alpha_1 T_i + \omega I_{it}^* + \omega^* T_i I_{it}^*$$
$$+ \beta_1 X_{1it}^* + \beta_2 X_{2it}^* + (\phi+\delta)\ln(\mu_{i,t-1}) - \phi\delta \ln(\mu_{i,t-2}) + e_t , \qquad \text{(A.2)}$$

where $X_{1it}^* = X_{1it} - \delta X_{1i,t-1}$ and $X_{2it}^* = X_{2it} - \delta X_{2i,t-1}$.

Equation (A.2) holds for $t = 3, 4, \ldots, m$. The regression model for t=1 (with no lags) is obtained from Equation (A.1) as follows

$$\ln(\mu_{i1}) = \alpha_0 + \alpha_1 T_i + \beta_1 \ln(V_{1,i1}) + \beta_2 \ln(V_{2,i1}) + \nu_1 ,\ \nu_1 \sim N(0, \sigma_\nu^2/(1-\phi^2)) ,$$

whereas the regression model for t=2(with one lag) is obtained from Equation (A.1) as follows

$$ln(\mu_{i2}) = (1-\phi)\alpha_0 + (1-\phi)\alpha_1 T_i + \beta_1 [ln(V_{i2}) - \phi ln(V_{i1})] + \beta_2 [\ln(V_{2,i2}) - \phi \ln(V_{2,i1})]$$
$$+ \phi \ln(\mu_{i1}) + e_2 .$$

To derive the variance of ν_1, the AR1 Equation (3.5) implies that $\text{var}(\nu_t) = \phi^2 \text{var}(\nu_{t-1}) + \sigma_\nu^2$. For $|\phi| < 1$ (stationary AR1), $\text{var}(\nu_t) = \sigma_\nu^2/(1-\phi^2)$, for all *t*.

It is important to check the appropriateness of such models for a given dataset by monitoring in WinBUGS the posterior probabilities of the stationary conditions $(|\hat{\delta}| \le 1)$ and $(|\hat{\phi}| \le 1)$. For posterior probability of non-stationarity $(|\phi| \ge 1)$, a $N(0, \tau)$ prior can be used (stationarity is not imposed) where τ is small, e.g., 1 or 0.5 (Congdon, 2006).

A.2 Model Coefficient Estimates

In this section, the whole set of coefficient estimates, sourced from WinBUGS output, were listed and sorted in different tables, one for each model considered.

Table A.2.1 Parameter Mean Values and Standard Errors for Urban Intersections (new pedestrian signal installations)

Parameter	PDO	Severe
α_0	0.345 ± 0.931	-2.642 ± 1.182
α_1	-1.522 ± 0.266	-0.907 ± 0.249
β_1	0.229 ± 0.074	0.361 ± 0.093
β_2	0.059 ± 0.042	0.165 ± 0.065
δ	0.703 ± 0.319	0.622 ± 0.271
ϕ	0.548 ± 0.144	0.322 ± 0.126
ω	0.002 ± 0.055	-0.018 ± 0.043
ω^*	0.031 ± 0.060	-0.090 ± 0.076
σ_v	0.072 ± 0.028	0.074 ± 0.030
σ_ε	0.711 ± 0.085	0.549 ± 0.068

Table A.2.2 Parameter Mean Values and Standard Errors for Urban Intersections (geometric design improvements)

Parameter	PDO	Severe
α_0	-7.240 ± 1.001	-9.134 ± 1.025
α_1	-0.174 ± 0.135	0.120 ± 0.126
β_1	0.766 ± 0.099	0.818 ± 0.098
β_2	0.253 ± 0.064	0.354 ± 0.064
δ	0.446 ± 0.321	0.022 ± 0.175
ϕ	0.050 ± 0.079	-0.075 ± 0.050

ω	-0.036 ± 0.038	0.054 ± 0.033
ω^*	-0.093 ± 0.057	-0.297 ± 0.058
σ_v	0.091 ± 0.040	0.047 ± 0.018
σ_ε	0.574 ± 0.047	0.532 ± 0.043

Table A.2.3 Parameter Mean Values and Standard Errors for Urban Intersections (traffic signal upgrades)

Parameter	PDO	Severe
α_0	-7.750 ± 0.930	-7.758 ± 0.828
α_1	-0.243 ± 0.117	-0.220 ± 0.114
β_1	0.657 ± 0.079	0.658 ± 0.075
β_2	0.424 ± 0.057	0.374 ± 0.050
δ	0.975 ± 0.087	-0.121 ± 0.406
ϕ	-0.495 ± 0.184	0.039 ± 0.054
ω	-0.043 ± 0.019	0.025 ± 0.029
ω^*	-0.039 ± 0.018	-0.216 ± 0.093
σ_v	0.062 ± 0.021	0.048 ± 0.018
σ_ε	0.528 ± 0.037	0.495 ± 0.034

Table A.2.4 Parameter Mean Values and Standard Errors for Rural Highway Segments

Parameter	PDO	Severe
α_0	-2.034 ± 0.837	-2.928 ± 0.859
α_1	-0.095 ± 0.150	0.120 ± 0.142
β_1	0.376 ± 0.070	0.421 ± 0.072
β_2	0.323 ± 0.083	0.455 ± 0.081

δ	-0.021	$\pm$ 0.243	0.488	$\pm$ 0.253
ϕ	0.280	$\pm$ 0.076	0.172	$\pm$ 0.098
ω	0.040	$\pm$ 0.064	-0.014	$\pm$ 0.054
ω^*	-0.196	$\pm$ 0.060	-0.197	$\pm$ 0.057
σ_v	0.200	$\pm$ 0.063	0.111	$\pm$ 0.039
σ_ε	0.527	$\pm$ 0.049	0.514	$\pm$ 0.045

A.3 Summary of Treatment Site Selection

Urban Sites:

2008 Municipal Partnership Contracts	**Projects**	**2009 Municipal Partnership Contracts**	**Projects**	**2010 Municipal Partnership Contracts**	**Projects**
Studies, Reviews and Research Projects	13	Studies, Reviews and Research Projects	8	Studies, Reviews and Research Projects	6
Projects with Defined Contributions	21	Projects with Defined Contributions	18	Projects with Defined Contributions	25
Projects with ICBC Funding <$10K	26	Projects with ICBC Funding <$10K	41	Projects with ICBC Funding <$10K	33
No Signal Intersection/Corridor Projects	60	No Signal Intersection/Corridor Projects	58	No Signal Intersection/Corridor Projects	56
Projects with Data Issues / Limitations	17	Projects with Data Issues / Limitations	10	Projects with Data Issues / Limitations	11
Projects in Small Communities	12	Projects in Small Communities	5	Projects in Small Communities	6
Projects Selected for RIP Evaluation	**25**	**Projects Selected for RIP Evaluation**	**25**	**Projects Selected for RIP Evaluation**	**22**

Rural Sites:

2008 MOTI Partnership Contracts	**Projects**	**2009 MOTI Partnership Contracts**	**Projects**	**2010 MOTI Partnership Contracts**	**Projects**
Studies, Reviews and Research Projects	0	Studies, Reviews and Research Projects	0	Studies, Reviews and Research Projects	0
Projects with Defined Contributions	4	Projects with Defined Contributions	4	Projects with Defined Contributions	5
ICBC Funding <$10K or >$10M	19	ICBC Funding <$10K or >$10M	33	ICBC Funding <$10K or >$10M	36
Intersection/Intersection Related Projects	25	Intersection/Intersection Related Projects	19	Intersection/Intersection Related Projects	21
Projects with Data Issues / Limitations	11	Projects with Data Issues / Limitations	5	Projects with Data Issues / Limitations	9
Rumble Strip Projects	12	Rumble Strip Projects	11	Rumble Strip Projects	21
Projects Selected for RIP Evaluation	**12**	**Projects Selected for RIP Evaluation**	**11**	**Projects Selected for RIP Evaluation**	**16**

A.4 Summary of Treatment Sites

Urban Sites: New Pedestrian Signal Installation (Treatment Group 1)

TREATMENT Group Information				CG	LOCATION Description			TRAFFIC DATA (AADT)																		COLLISION DATA								
Site No.	ICBC Contribution ($)	PROJECT Year	ICBC Region		CITY	MAJOR Road Name	MINOR Road Name	2005		2006		2007		2008		2009		2010		2011		2012		2013		2005	2006	2007	2008	2009	2010	2011	2012	2013
								MAJOR	MINOR	MAJOR	MINOR	MAJOR	MINOR	MAJOR	MINOR	MAJOR	MINOR	MAJOR	MINOR	MAJOR	MINOR	MAJOR	MINOR	MAJOR	MINOR									
1	$ 32,000	2008	GV	A	Vancouver	West 12th Avenue	Trafalgar Street	16000	1500	16200	1600	16500	1500	16800	1400	16500	1500	16300	1400	16000	1300	16000	1350	15800	1350	5	3	3	5	6	3	1	4	3
2	$ 24,500	2008	GV	A	Vancouver	West 12th Avenue	Vine Street	16000	3000	16200	3100	16500	3150	17000	3100	17200	3000	17000	3000	16800	2800	16500	2700	16000	2700	2	11	8	9	7	2	3	6	4
3	$ 95,000	2008	GV	A	Vancouver	Fir Street	West 14th Avenue	14500	600	14500	610	14500	610	1400	620	14000	630	13500	630	13500	650	13000	650	12500	700	7	6	6	3	7	3	3	2	1
4	$ 95,000	2008	GV	A	Vancouver	Cambie Street	West 14th Avenue	44000	2000	45000	2200	45500	2100	45800	2200	44000	2000	44500	2200	44800	2300	44900	2400	45000	2500	20	14	1	7	11	6	10	12	11
5	$ 95,000	2008	GV	A	Vancouver	Cambie Street	West 17th Avenue	44000	1500	45000	1500	44300	1500	44000	1500	44500	1600	44800	1650	44800	1650	44900	1650	45000	1650	20	10	4	3	10	9	10	11	3
6	$ 70,000	2009	GV	A	Vancouver	Denman Street	Alberni Street	21670	3000	21500	3000	21000	3100	21000	3200	21500	3100	21800	10000	21500	9500	21000	9300	21050	9300	27	22	17	20	18	23	23	25	25
7	$ 75,000	2010	GV	A	Vancouver	Cordova Street	Princess Avenue	15864	550	15500	650	15300	750	15030	800	14000	900	13200	1000	12580	1180	12361	1200	13195	1330	9	3	8	2	5	3	4	0	4
8	$ 35,000	2010	GV	A	Vancouver	Granville Street	West 15th Avenue	48000	800	48000	800	47800	800	47500	800	47800	800	47600	800	47500	800	47300	800	47000	800	14	28	25	20	22	17	23	19	17
9	$ 20,000	2010	GV	A	Vancouver	West 41st Avenue	Yew Street	34000	1500	34500	1500	34800	1500	35200	1600	35300	1600	35400	1600	35500	1700	35700	1700	36000	1700	13	16	26	15	15	24	15	13	10
10	$ 30,000	2008	GV	C	Vancouver	West 70th Avenue	Heather Street	15500	800	16000	800	16200	800	16500	800	16300	800	16600	850	17000	850	17500	850	17200	800	4	10	5	4	2	0	2	4	3
11	$ 30,000	2009	GV	F	Port Coquitlam	Prairie Avenue	Wellington Street	4925	975	5030	990	5125	995	5150	990	5200	1000	5250	1000	5120	990	5025	980	5100	1000	8	5	9	6	8	5	3	9	4
12	$ 20,000	2010	GV	F	Port Coquitlam	Pitt River Road	Pooley Avenue	6400	1730	6470	1740	6500	1750	6450	1780	6400	1872	6450	1850	6400	1820	6430	1830	6450	1850	1	1	0	1	3	1	1	1	2
13	$ 20,000	2010	GV	G	New Westminister	Royal Avenue	7th Street	17000	1720	17266	1750	18500	1780	19200	1800	20000	1938	20000	1980	21000	1990	22500	1980	23000	1970	8	8	8	5	6	3	12	7	11

Urban Sites: Geometric Design Improvements (Treatment Group 1)

TREATMENT Group Information				CG	LOCATION Description			TRAFFIC DATA (AADT)																		COLLISION DATA								
Site No.	ICBC Contribution ($)	PROJECT Year	ICBC Region		CITY	MAJOR Road Name	MINOR Road Name	2005		2006		2007		2008		2009		2010		2011		2012		2013		2005	2006	2007	2008	2009	2010	2011	2012	2013
								MAJOR	MINOR	MAJOR	MINOR	MAJOR	MINOR	MAJOR	MINOR	MAJOR	MINOR	MAJOR	MINOR	MAJOR	MINOR	MAJOR	MINOR	MAJOR	MINOR									
1	$ 45,000	2008	GV	B	Vancouver	West 12th Avenue	Heather Street	29000	3600	29500	3600	29800	3550	29700	3400	29500	3450	29200	3500	29000	3550	29200	3600	29000	3600	14	28	20	28	9	6	20	19	10
2	$ 75,000	2009	GV	B	Coquitlam	Como Lake Avenue	Gatensbury Road	18300	4900	19200	5600	20000	6195	20100	6200	20300	6300	20500	6400	20700	6500	20900	6600	21100	6700	15	19	12	33	25	10	5	7	7
3	$ 25,000	2010	GV	B	Maple Ridge	Lougheed Hwy	224th Street	20300	4000	20800	4000	21000	4400	20300	4600	20150	4500	20000	4100	19800	4500	20160	4300	20200	5100	21	27	29	15	20	20	4	10	14
4	$ 45,000	2009	GV	F	Port Coquitlam	Coast Meridian Road	Riverwood Gate	13000	8900	14000	9000	15000	9200	16000	9500	17000	9800	17988	10500	18200	10600	19000	10750	20000	10985	8	15	15	21	14	11	14	16	19
5	$ 35,000	2009	GV	F	Port Coquitlam	Kingsway Avenue	Broadway Street	13800	5100	13287	5300	14345	5500	14467	5800	15010	6500	15630	7500	15910	7800	16150	7900	16400	8100	4	10	9	14	4	16	16	16	17
6	$ 65,000	2009	GV	F	Coquitlam	Como Lake Avenue	Poirier Street	24300	3600	24000	3500	23578	3400	23600	3400	23800	3400	24000	3400	24200	3400	24400	3400	24600	3400	11	20	20	19	22	16	6	7	2
7	$ 33,000	2009	GV	G	Burnaby	Canada Way	Gilmore Avenue	23500	16000	23800	16300	24000	16600	24051	16654	24096	16684	23945	16580	23838	16506	22929	15877	22800	15500	43	39	51	47	44	33	37	31	43
8	$ 86,000	2008	FV	A	Mission	Cedar St	7th Ave	12457	6413	12583	6478	12710	6543	12838	6609	12968	6676	13099	6744	13231	6812	13365	6881	13500	6950	10	21	31	28	22	21	15	25	26
9	$ 24,000	2008	FV	A	Abbotsford	Old Clayburn Rd	McKee Dr	8514	1474	8600	1489	8603	1504	8690	1519	7970	1535	8050	1550	8405	1565	8490	1580	8575	1595	2	5	3	1	6	4	3	4	4
10	$ 88,000	2009	FV	A	Abbotsford	Gladwin Rd	Harris Rd	3140	980	3170	990	3200	1000	2970	1010	3000	1020	3030	1030	3060	1040	3090	1050	3120	1060	19	25	30	20	16	14	10	8	8
11	$ 25,000	2009	FV	B	City of Langley	Fraser Hwy	203rd St	10473	11119	10579	11231	10686	11345	10794	11459	10903	11575	11013	11692	11124	11810	11237	11930	11350	12050	22	15	25	21	18	18	20	17	25
12	$ 116,000	2010	FV	B	Township of Langley	64th Ave	197th St	21289	6856	21504	6925	21721	6995	21940	7066	22162	7137	22386	7209	22612	7282	22840	7356	23071	7430	24	29	33	24	23	6	9	16	8
13	$ 34,000	2010	FV	B	Township of Langley	208th St	80th Ave	16471	7834	16637	7913	16805	7993	16975	8074	17147	8155	17320	8238	17495	8321	17672	8405	17850	8490	14	11	18	23	18	14	14	24	32
14	$ 89,000	2008	FV	E	Surrey	Fraser Hwy	148th St	19880	9090	19800	9100	19600	9130	19400	9180	19210	9170	21480	11710	21265	11593	20640	11120	20640	11231	48	55	60	53	42	42	48	53	41
15	$ 75,000	2008	FV	E	Surrey	72nd Ave	140th St	24000	6300	24420	6770	25000	6000	25720	5650	25000	5700	24950	6150	24000	6300	23900	6480	22450	8640	38	51	47	45	33	34	41	36	39
16	$ 75,000	2008	FV	E	Surrey	72nd Ave	130th St	24000	2500	24420	2525	25000	2550	25720	2576	25000	2602	24950	2628	24000	2654	23900	2680	22450	2707	21	25	24	30	17	20	20	25	22
17	$ 80,000	2009	FV	E	Surrey	32nd Ave	168th St	13759	4201	13898	4244	14038	4287	14180	4330	14000	4400	13770	4550	14000	4600	14200	4700	14400	4800	8	15	24	12	13	10	13	6	11
18	$ 56,000	2009	FV	E	Surrey	168th St	84th Ave	9700	2100	9890	2190	11070	1980	11000	1975	11110	1970	11221	1990	11333	2010	11447	2030	11561	2050	9	9	13	4	4	2	2	3	3
19	$ 120,000	2010	FV	E	Surrey	144th St	60th Ave	10056	5155	10157	5207	10260	5260	10363	5313	10466	5366	10571	5419	10677	5474	10783	5528	10891	5584	8	10	16	11	18	21	4	11	7
20	$ 164,000	2010	FV	F	Delta	Nordel Way	Brooke Rd	30167	3124	30472	3156	30777	3188	31084	3219	31395	3252	31709	3284	32026	3317	32347	3350	32670	3384	19	30	24	20	22	21	24	17	20
21	$ 64,000	2010	FV	F	Delta	Nordel Way	Shepherd Way	29700	565	30000	571	30300	577	30603	582	30909	588	31218	594	31530	600	31846	606	32164	612	12	12	10	9	9	21	6	6	13
22	$ 38,000	2010	FV	F	Delta	Derwent Way	Chester Rd	2812	3888	2840	3927	2869	3966	2898	4007	2927	4047	2956	4087	2986	4128	3016	4170	3046	4211	8	7	7	4	8	3	3	2	6
23	$ 28,500	2008	SI / NC	A	Kelowna	Springfield Rd	Graham Ave	25,858	1,252	25,967	1,227	26,076	1,202	26,185	1,177	26,294	1,152	26,402	1,129	25,869	1,068	25,336	1,007	24,803	947	2	3	1	4	0	0	0	1	0
24	$ 21,700	2008	SI / NC	A	Vernon	43rd Avenue	20th Street	11,862	11,430	12,200	11,750	12,528	12,072	12,500	12,000	12,500	12,000	12,500	12,000	12,500	12,000	12,500	12,000	12,520	12,064	3	6	7	8	1	1	5	4	5
25	$ 101,400	2008	SI / NC	A	Kelowna	Springfield Rd	Leckie Rd	30,000	6,400	30,255	6,433	35,340	6,641	40,425	6,849	38,715	6,559	40,060	6,787	39,485	6,689	39,311	6,660	39,465	6,686	17	20	17	15	23	16	13	14	12
26	$ 24,200	2008	SI / NC	A	Kelowna	Springfield Rd	Benvoulin Rd	33,809	24,008	33,001	24,118	32,193	24,220	31,385	24,322	31,236	24,206	31,087	24,090	30,938	23,974	30,789	23,858	30,639	23,743	110	67	76	79	69	59	81	60	67
27	$ 20,100	2009	SI / NC	A	Kelowna	Benvoulin Rd	KLO Rd	29,438	19,652	29,365	19,200	29,292	18,748	29,220	18,296	27,984	17,522	28,956	18,130	28,540	17,870	28,415	17,791	28,526	17,861	33	46	43	29	50	49	23	45	43
28	$ 18,400	2009	SI / NC	A	Kelowna	Lakeshore Rd	Lequime Rd	14,158	710	14,324	725	14,490	740	14,656	755	14,822	770	14,988	785	14,154	800	15,324	816	15,490	831	2	1	1	4	3	1	0	0	1
29	$ 222,800	2010	SI / NC	A	Penticton	Channel Parkway	Green/Warren/Duncan	36,230	15,467	36,596	15,623	36,965	15,781	37,339	15,940	37,716	16,101	38,093	16,262	38,474	16,425	38,859	16,589	39,247	16,755	53	48	58	47	41	29	17	15	14
30	$ 128,600	2009	SI / NC	B	Prince George	Hwy 16	Domano Blvd	23,947	13,457	25,526	14,344	25,535	14,349	25,544	14,354	25,553	14,359	25,562	14,364	25,571	14,369	25,580	14,374	25,589	14,379	43	63	61	70	54	38	44	43	41

Urban Sites: Traffic Signal Upgrades (Treatment Group 1)

TREATMENT Group Information				CG	LOCATION Description			TRAFFIC DATA (AADT)																		COLLISION DATA								
Site No.	ICBC Contribution ($)	PROJECT Year	ICBC Region		CITY	MAJOR Road Name	MINOR Road Name	2005		2006		2007		2008		2009		2010		2011		2012		2013		2005	2006	2007	2008	2009	2010	2011	2012	2013
								MAJOR	MINOR	MAJOR	MINOR	MAJOR	MINOR	MAJOR	MINOR	MAJOR	MINOR	MAJOR	MINOR	MAJOR	MINOR	MAJOR	MINOR	MAJOR	MINOR									
1	$ 35,000	2008	GV	C	Vancouver	Marine Drive	Yukon Street	51000	700	52000	700	52500	700	52500	700	51000	500	51000	650	52000	700	53000	750	53000	750	6	8	25	16	9	13	9	16	15
2	$ 60,000	2009	GV	C	Vancouver	Homer Street	Helmcken Steet	8000	3750	8200	4900	8400	4500	8600	4500	8200	4000	8000	3800	7800	3500	7800	3400	8000	3500	2	18	15	7	10	6	5	3	4
3	$ 40,000	2009	GV	C	Vancouver	West 2nd Avenue	Yukon Street/Wylie	29130	4000	39334	4200	38700	4000	39200	4300	39800	4800	40900	5200	42100	5600	43763	7200	44500	5500	4	13	23	15	8	3	6	6	8
4	$ 25,000	2009	GV	D	West Vancouver	Marine Drive	24th Street	26300	5900	26350	5900	26400	6000	26500	6000	26600	6100	26400	6200	26350	6100	25800	6000	25700	6000	8	7	11	9	6	4	7	5	6
5	$ 28,000	2009	GV	D	North Vancouver City	Chesterfield Avenue	15th Street	11700	1000	12737	1000	12900	1100	13014	1050	13100	1000	13200	1100	13300	1000	13400	1100	13500	1200	4	11	5	6	4	2	6	3	3
6	$ 25,000	2008	GV	E	Maple Ridge	232nd Street	128th Avenue	6701	2471	6129	2579	6953	2534	6952	2888	6832	2975	6900	2960	7135	3090	6463	3109	6641	5371	7	5	12	8	5	5	4	5	6
7	$ 20,000	2009	GV	E	Maple Ridge	Dewdney Trunk Road	Cottonwood	17000	4000	17300	4200	17500	4230	18468	4500	17392	4750	16800	4980	16200	5100	15239	5300	18120	5500	0	2	2	1	1	2	4	0	4
8	$ 30,000	2010	GV	E	Maple Ridge	Abernethy Way	224th Street	4106	3918	4463	4022	4500	4421	4605	4672	5117	4520	9370	4092	13095	4455	13300	4326	13732	5162	4	2	8	7	18	9	3	5	4
9	$ 100,000	2010	GV	F	Coquitlam	North Road	Delestre Road	25500	2000	26000	2020	26360	2090	27800	2190	28300	2210	28750	2280	29240	2350	29960	2380	29500	2400	6	8	7	10	8	7	8	6	13
10	$ 45,000	2008	GV	G	Burnaby	Cariboo Road	10th Avenue	27400	8900	27800	9300	28110	9700	28250	10042	28500	10110	28750	10038	29000	9966	29250	9610	29500	9700	8	11	12	8	9	11	13	5	5
11	$ 30,000	2010	GV	G	Burnaby	Central Blvd.	Bonsar Avenue	11780	2080	11980	2100	12150	2120	12242	2090	12507	2080	12417	2100	12328	2200	11886	2250	11700	2100	12	10	9	9	13	9	8	6	11
12	$ 74,000	2008	FV	A	Abbotsford	Marshall Rd	Abbotsford Way	13880	2435	14020	2460	15672	3772	15830	3810	13553	3168	13690	3200	15513	2356	15670	2380	15827	2404	8	9	13	5	9	11	9	10	7
13	$ 32,000	2008	FV	B	City of Langley	56th Ave	198th St	15000	1500	15150	1515	15302	1530	15455	1545	15609	1561	15765	1577	15923	1592	16082	1608	16243	1624	6	6	9	6	3	8	8	2	5
14	$ 61,000	2009	FV	B	Township of Langley	16th Ave	216th St	8888	1670	8940	1680	10000	1700	12000	1750	12120	1768	12241	1785	12364	1803	12487	1821	12612	1839	11	3	13	7	11	8	9	11	6
15	$ 18,000	2009	FV	B	Township of Langley	Fraser Hwy	240th St	18877	4077	19067	4118	19260	4160	19453	4202	19647	4244	19844	4286	20042	4329	20242	4372	20645	4416	23	23	26	23	15	24	18	20	18
16	$ 29,000	2008	FV	C	Richmond	Granville Ave	Buswell St	21602	1302	21821	1315	22041	1328	22264	1342	22489	1355	22716	1369	22945	1383	23177	1397	23411	1411	21	12	14	15	9	11	10	10	18
17	$ 18,000	2009	FV	C	Richmond	No 2 Rd	Francis Rd	22206	11186	22428	11298	22652	11411	22879	11525	23108	11640	23339	11757	23572	11874	23808	11993	24046	12113	20	23	24	20	18	17	14	18	24
18	$ 45,000	2010	FV	C	Richmond	No 1 Rd	Blundell Rd	19433	6765	19627	6833	19824	6901	20022	6970	20222	7040	20424	7110	20629	7181	20835	7253	21043	7326	18	23	23	38	19	25	18	19	15
19	$ 27,000	2010	FV	C	Richmond	Granville Ave	St Albans Rd	20761	13092	20971	13224	21182	13358	21396	13493	21612	13629	21831	13767	22051	13906	22274	14046	22499	14188	30	25	21	23	33	26	19	16	13
20	$ 13,000	2010	FV	C	Richmond	Blundell Rd	St Albans Rd	13756	7745	13895	7823	14036	7902	14177	7982	14321	8062	14465	8144	14611	8226	14759	8309	14908	8393	17	15	32	20	21	21	15	22	18
21	$ 35,000	2009	FV	D	Chilliwack	Yale Rd	Hodgins Ave	18030	10450	18050	10600	18100	10770	18180	11250	16770	10540	14170	9270	13610	9510	13700	9800	13960	10110	23	27	41	26	20	24	26	18	27
22	$ 34,000	2008	FV	E	Surrey	King George Hwy	68th Ave	25839	9625	26100	9723	26364	9821	26630	9920	26640	9940	26610	9500	26400	9450	26300	9400	26210	9370	52	54	43	48	48	52	44	27	46
23	$ 40,000	2009	FV	E	Surrey	192nd St	24th Ave	5300	2780	5470	2870	5600	2810	5740	2800	5900	2700	6110	2620	6171	2710	6233	2800	6295	2900	13	14	9	11	10	5	4	5	1
24	$ 28,000	2009	FV	F	Delta	Scott Rd	Sunwood Dr	30000	3000	30300	3030	30603	3060	30909	3091	31218	3122	31530	3153	31846	3185	32164	3216	32486	3249	1	5	1	3	2	3	4	1	2
25	$ 24,100	2010	SI / NC	A	Kelowna	Lakeshore Rd	Barrera Rd	19,665	994	20,524	920	21,383	845	20,592	838	19,800	831	19,358	892	18,916	953	18,474	1,015	18,032	1,076	3	3	4	5	3	3	2	3	2
26	$ 31,300	2010	SI / NC	A	West Kelowna	Old Okanagan Hwy	Butt Rd	6,828	3,599	6,897	3,635	6,967	3,672	7,037	3,709	7,108	3,746	7,180	3,784	7,253	3,822	7,326	3,861	7,400	3,900	3	8	6	5	5	5	3	6	8
27	$ 17,600	2008	SI / NC	B	Prince George	Ospika Blvd	15th Ave	15,817	13,929	15,634	13,787	15,451	13,645	15,268	13,503	14,817	13,104	14,570	12,885	14,606	12,917	14,234	12,739	14,352	12,793	18	45	30	37	24	21	17	10	14
28	$ 40,700	2008	SI / NC	C	Kamloops	Various	Various	91,941	44,129	94,882	45,541	96,229	46,188	95,655	45,912	88,162	42,316	93,194	44,731	90,744	43,555	91,198	43,773	91,654	43,992	64	67	72	82	50	50	66	62	64
29	$ 29,600	2009	SI / NC	C	Kamloops	Pacific Way	Hugh Allan Dr	13,200	6,900	12,900	6,750	13,050	6,850	13,207	6,950	14,958	7,771	16,709	8,592	18,461	9,414	20,691	10,551	22,920	11,688	8	19	26	21	19	22	21	12	15

Rural Sites: Segment Improvements (Treatment Group 2)(PART 1)

TREATMENT Group Information				COMPARE Group	LOCATION Description			TRAFFIC DATA (AADT)									COLLISION DATA								
Site No.	ICBC Contribution ($)	PROJECT Year	ICBC Region		CITY	Hwy No.	Segment No.	2005	2006	2007	2008	2009	2010	2011	2012	2013	2005	2006	2007	2008	2009	2010	2011	2012	2013
1	$35,400	2008	MOTI	E	Nanaimo	1	0452	12101	12222	12546	12158	12380	12706	12524	12413	12657	21	16	16	23	11	8	13	10	8
2	$42,500	2008	MOTI	C	Princeton	3	2210	2832	2832	3239	3236	3239	3239	3239	3236	2737	49	60	56	50	38	27	34	42	33
3	$86,100	2008	MOTI	B	Surrey	10	3110	16067	16157	15932	15930	15932	15932	15932	15930	15932	7	1	9	1	4	7	8	12	8
4	$94,200	2008	MOTI	A	Squamish	99	2928	7750	7578	7525	7516	7517	7517	7517	7516	7517	18	18	17	11	15	12	9	17	8
5	$41,500	2008	MOTI	E	Port Alberni	4	2350	1865	1906	1916	1937	1953	1969	1987	2003	2024	15	25	13	15	13	14	11	2	6
6	$26,100	2008	MOTI	D	Williams Lake	20	3320	225	266	266	266	266	266	181	195	194	8	11	6	4	2	0	1	0	0
7	$46,300	2008	MOTI	E	Port Alice	30	2397	471	490	496	544	570	630	632	629	674	8	7	5	10	0	1	3	5	3
8	$59,100	2008	MOTI	C	Grand Forks	3	2226	4166	4232	4232	4230	3744	3906	3876	3929	3931	10	21	31	12	7	8	6	2	4
9	$31,400	2008	MOTI	C	Merritt	5A	1720	1720	1724	1715	1909	1996	2125	2166	2250	2337	36	26	18	12	11	18	6	17	10
10	$63,000	2008	MOTI	C	Vernon	6	1971	4744	4965	5256	5255	5256	5256	5256	4956	4813	24	21	19	23	12	17	12	18	10
11	$56,300	2008	MOTI	D	Smithers	16	1524	2864	2959	3092	3090	3092	3092	2590	1900	2072	18	13	20	4	8	16	8	20	16
12	$46,400	2008	MOTI	D	Prince George	97	1155	19801	20678	20627	20318	19700	19052	19657	19860	19925	32	29	21	13	13	19	19	28	25
13	$40,400	2009	MOTI	B	Abbotsford	1	533	33289	33577	34049	33642	34200	34963	34895	34783	35770	35	31	31	23	30	23	24	25	18
14	$73,000	2009	MOTI	E	Victoria	17	0307	7159	7221	7687	7686	6824	7648	7755	8168	8169	19	22	23	24	15	20	22	14	13
15	$78,900	2009	MOTI	C	West Kelowna	97	1216 1217	9383	9578	9891	9532	9917	10401	10327	10306	10535	11	5	4	3	3	6	4	7	1
16	$46,300	2009	MOTI	D	Prince George	97	1151	18283	18286	20115	21941	23772	25601	27429	29255	31086	5	14	8	2	3	6	5	7	5
17	$63,300	2009	MOTI	E	Langford	1	420	16103	17953	17986	18928	18928	18928	18928	18934	18965	59	50	35	58	45	43	44	36	34
18	$45,100	2009	MOTI	E	Nanaimo	1	452 453	12101	12222	12546	12158	12380	12706	12524	12413	12657	7	5	9	9	3	0	0	5	1
19	$13,100	2009	MOTI	C	Elko	3	1470	4553	4832	4775	5071	5250	5424	5599	5789	5948	6	3	4	3	0	0	2	0	1
20	$10,100	2009	MOTI	D	Dease Lake	37	3765	413	413	413	413	413	342	290	291	290	1	1	1	3	1	1	2	0	0

Rural Sites: Segment Improvements (Treatment Group 2)(PART 2)

TREATMENT Group Information				COMPARE Group	LOCATION Description			TRAFFIC DATA (AADT)									COLLISION DATA								
Site No.	ICBC Contribution ($)	PROJECT Year	ICBC Region		CITY	Hwy No.	Segment No.	2005	2006	2007	2008	2009	2010	2011	2012	2013	2005	2006	2007	2008	2009	2010	2011	2012	2013
21	$51,600	2009	MOTI	E	Ucluelet	4	2350	1985	1963	2006	1953	1998	2038	1958	1869	1893	44	58	34	35	21	31	18	15	12
22	$48,100	2009	MOTI	C	Kelowna	97C	2035 2030	2223	2287	2401	2403	2538	2737	2705	2676	2733	26	28	14	9	3	8	5	3	7
23	$45,700	2009	MOTI	C	West Kelowna	97	1216 1217	15106	16682	17424	18417	19409	20401	21393	22390	23377	31	29	17	9	14	20	16	21	20
24	$86,600	2010	MOTI	B	Hope	3	2205	3092	3027	3141	2536	2495	2528	2401	2365	2438	7	6	4	5	5	6	6	5	2
25	$42,100	2010	MOTI	B	Chilliwack	1	534 535	20656	23405	23405	23434	22485	24201	24928	25636	26352	13	20	17	9	15	11	13	9	10
26	$41,500	2010	MOTI	E	Nanoose	19	2315	27686	29087	29418	31624	31692	31718	31745	30364	31505	5	4	3	4	4	5	0	2	1
27	$17,800	2010	MOTI	E	Malahat	1	420	16103	17953	17986	18928	18928	18928	18928	18934	18965	5	7	2	3	3	3	1	5	4
28	$78,300	2010	MOTI	C	Kamloops	5A	1720	1720	1724	1715	1909	1996	2125	2166	2250	2337	16	5	7	4	2	10	1	3	2
29	$48,700	2010	MOTI	C	Sparwood	3	1470	4422	4809	4760	4809	4819	5356	5543	5906	5942	10	9	14	11	5	7	8	9	3
30	$20,900	2010	MOTI	C	Yahk	3	1440 - 1450	3249	3345	3436	3362	3260	3393	3408	3390	3389	15	9	19	20	11	11	10	10	6
31	$39,300	2010	MOTI	C	Keremeos	3A	1315	3559	3395	4955	5361	5936	6442	6937	7428	7928	14	13	5	15	15	9	8	16	11
32	$35,700	2010	MOTI	C	Cranbrook	93	2135	3395	3447	3592	3534	3487	3586	3610	3583	3629	11	3	15	8	4	4	0	0	1
33	$10,100	2010	MOTI	C	Coquihalla	5	2000 2005	4567	4636	4927	4864	5197	5532	5494	5411	5565	10	19	12	9	18	11	17	7	8
34	$61,800	2010	MOTI	E	Langford	14	370 - 371	12333	12298	12863	12822	13307	13809	13501	13308	13761	64	67	105	65	54	43	50	50	18
35	$68,600	2010	MOTI	B	Surrey	99	2912 2917	22753	22975	23470	22674	23308	24360	25171	25371	25570	83	82	78	73	60	59	48	60	71
36	$32,100	2010	MOTI	B	Chilliwack	1	534 535	17987	18408	18956	19061	19069	18972	18111	17692	17943	11	17	22	13	25	16	23	18	10
37	$71,300	2010	MOTI	E	Nanaimo	1	0452	12101	12222	12546	12158	12380	12706	12524	12413	12657	11	12	18	13	8	3	6	12	6
38	$63,500	2010	MOTI	E	Port Alberni	4	2350	1865	1906	1916	1937	1953	1969	1987	2003	2024	6	12	3	2	3	4	2	2	0
39	$40,900	2010	MOTI	B	Langley	10	3119	30922	30954	32314	32310	32314	31975	31975	31971	30022	10	7	8	8	8	3	7	3	4

A.5 Summary of Control Group Sites

Comparison sites were selected to ensure that they had similar traffic and environmental conditions as the treated sites.

To ensure that there was a similarity in the traffic conditions between treatment and comparison sites in an urban setting, the comparison site had to be a signalized intersection. In the rural setting, the comparison site had to have the same highway classification as the treatment site. The MOTI use a classification system that classify highways based on:

1) Urban (U) or Rural (R)
2) Arterial (A), Expressway (E) or Freeway (F)
3) Undivided (U) or Divided (D)
4) 2 Lanes (2) or More than 4 Lanes (4)

To ensure similar environmental conditions (e.g., weather, reporting practices) the proximity to the treatment site was the main criterion used for the selection of comparison group sites. The following tables show the geographic region,

Comparison Group	**Geographical Area**	**Description of Control Group**
Urban Area (Signalized intersections)	Greater Vancouver Region	1) 10 sites, all within the City of Vancouver
		2) 10 sites, 8 in Vancouver and 2 in Burnaby
		3) 10 sites, all within City of Vancouver
		4) 10 sites, 5 in City of North Van, 5 in District of North Van
		5) 10 sites, all within Maple Ridge
		6) 10 sites, 4 Coquitlam, 4 Port Coquitlam, 2 Burnaby
		7) 10 sites, all within Burnaby
	Fraser Valley Region	1) 6 Sites, all within Abbotsford
		2) 11 Sites, 6 in Langley and 5 in Langley Township
		3) 10 sites, all within Richmond
		4) 8 sites, all within Chilliwack
		5) 10 sites, all within Surrey
		6) 10 sites, all within Delta
	Southern Interior and Northern Regions	1) 10 Sites all within Kelowna
		2) 6 sites, all within Prince George
		3) 12 sites, all within Kamloops
Rural Area	Lower Mainland	1) 10 sites, located on Highways 1, 7, 17 91 and 99
	Fraser Valley	2) 10 sites, located on Highways 1, 10, 11 and 91
	Southern Interior	3) 10 sites, located on Highways 1, 3, 5, 8 and 22
	North/Central	4) 10 sites, located on Highways 16, 24, 26, 27, 35, 37, and 39
	Vancouver Island	5) 10 sites, located on Highways 1, 4, 14 and 19