

**ESTIMATION OF COLLISION REDUCTIONS  
RESULTING FROM THE RE-DEVELOPMENT OF THE  
NEW BRUNSWICK TRANS-CANADA HIGHWAY**

by

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Bachelor of Science in Civil Engineering, University of New Brunswick, 2014

A Report Submitted in Partial Fulfillment of  
the Requirements for the Degree of

**Master of Engineering**

in the Graduate Academic Unit of Civil Engineering

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This report is accepted by the Dean of Graduate Studies

THE UNIVERSITY OF NEW BRUNSWICK

April, 2017

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## Abstract

Between 1998 and 2007, the Trans-Canada Highway through New Brunswick underwent major re-development through the execution of two Public Private Partnership projects. The re-development involved both re-alignment of sections of the Trans-Canada Route 2, as well as upgrades to some of the existing 2-lane alignment (i.e. “twinning”). By 2007, the entire Route 2 was a fully access controlled, four-lane divided facility with a design speed of 120 km/h. Although it was believed that the safety performance of Route 2 had improved as a result of the upgrades, no analyses had been performed to quantify the net outcome. This research study undertook an analysis of collisions on Route 2 over 5-year periods before and after the major upgrade projects were performed.

The results of the research found that the rate of total collisions on Route 2 reduced from an average of 0.503 collisions per million-vehicle-kilometres (collisions/mvkm) to an average of 0.419 collisions/mvkm between the “before” and “after” study periods. The rate of injury and fatal collisions were significantly reduced from 0.137 collisions/mvkm to 0.089 collisions/mvkm and from 0.014 collisions/mvkm to 0.007 collisions/mvkm between the two study periods, respectively. The proportion of injury and fatal collisions reduced from 28 % to 22 % and from 3 % to 1 % between the two study periods, respectively. Annual reductions in injury and fatal collisions were estimated at 15 and 8 collisions per year, respectively. An economic analysis was also performed to estimate the safety benefits of the new facility. A cost savings rate of \$48,981 per million-vehicle-kilometres was estimated that equates to an average annual cost savings of \$44,438,000 per year.

## **Acknowledgments**

I would like to express my gratitude and appreciation to Dr. Eric D. Hildebrand, my supervisor, whose dedication, guidance and continuous support has enabled me to pursue and complete my graduate degree. I would like to thank the Department of Civil Engineering at the University of New Brunswick for allowing me the opportunity to complete not only my undergraduate degree, but also continue my studies through the graduate program. I would also like to thank John Baldwin and Veronica Pelkey with the New Brunswick Department of Transportation and Infrastructure who were incredibly helpful in providing the information and data required for the completion of this study. To my roommates, Katie and Adam: thank you for your continuous support and advice, and for acting as a backboard for me to bounce ideas off of. To my amazing family, mom, dad and Jason: I am eternally grateful for the endless amount of support, encouragement, and love that you have given me that have not only allowed me to complete the Master of Engineering program, but have made me the person I am today. I love you.

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## **Chapter 1: Introduction**

In 1998, the Government of New Brunswick began constructing a replacement highway to the largely two-lane, uncontrolled access Trans-Canada Highway Route 2 through the province. The new Route 2 was completed in phases as part of two separate Public Private Partnership (P-3) projects. The first P-3 project between Fredericton and Moncton was completed in 2001 by the Maritime Road Development Corporation (MRDC). The second P-3 project covered the western part of the province and was finished in 2007 by the Brun-Way Group. The new facility was primarily new build, with some incorporation of the existing alignment through the use of “twinning”. By 2007, the new highway was complete, with any remaining sections of the old route renumbered and reorganized. One major objective of this work was to improve safety on Route 2 by reducing collision rates. Although it had been assumed that the safety performance of the highway has improved, a study had not previously been performed to confirm or quantify any impacts. The purpose of this research project was to quantify the collision rates on the new Route 2 and compare them to those on the former alignment. This permitted an estimation of the net benefit in safety measured by reductions in annual collision frequencies and shifts in collision severities.

### **1.1 Background**

The upgrades undertaken on the above mentioned sections of highway were implemented in order to increase capacity and safety, and to facilitate the movement of commercial goods. Route 2 is a gateway between the provinces of Quebec, Prince Edward Island and Nova Scotia, as well as a major connector link for traffic to and from Newfoundland and Labrador, and, as a result, it has a high volume of heavy, commercial vehicles – nearly 20

% of all traffic on the highway in 1989 (Fiander-Good 1989). Formerly, Route 2 consisted of a primarily two-lane undivided facility that travelled through a number of communities throughout New Brunswick. From a safety perspective, this former alignment raised several concerns. For instance, nearly 5000 private driveways had direct access to the Highway (Fiander-Good 1989). This was a safety concern due to the frequent interruptions of traffic flow and hazardous movements of vehicles entering and exiting the highway. Additionally, collision rates had become a concern on the highway. Over a 3-year study period prior to 1989, on average, 767 collisions were recorded on the Route 2 annually, with approximately 28% involving fatal and injury collisions (Fiander-Good 1989). From a capacity perspective, it was projected that by 2008, the old alignment of Route 2 would operate at a level of service E (approaching capacity), with several sections reaching a level of service F (exceeding capacity) (Fiander-Good 1989).

Upgrades to Route 2 were performed in phases. The first phase, extending from Longs-Creek to Moncton, was upgraded between the winter of 1998 and the fall of 2001. This section, also known by the name “Fredericton-Moncton Highway”, was built as part of a P-3 between MRDC and the Province of New Brunswick. The new alignment between Longs-Creek and Moncton consists of 195 km of twinned highway and cost approximately \$576 million (Government of New Brunswick 2001). The remaining sections between Fredericton and the Quebec border were upgraded over the following years. Between 2000 and 2003, several small control sections underwent upgrades, some of which required realignments and some consisted simply of twinning existing sections of the former Route 2. By November 2007, the remaining 98 km section of Route 2 was twinned between Woodstock and Grand-Falls by Brun-Way Group under another P-3

with the Province of New Brunswick. This P-3 granted Brun-Way \$544 million to complete the remaining upgrades and perform necessary maintenance to the Highway between Longs-Creek and the Quebec border – approximately 275 km in length (Government of New Brunswick 2005). These two P-3 projects place nearly 90% of the maintenance of the 523 kilometers of Route 2 under MRDC and Brun-Way’s responsibility. Figures 1.1 and 1.2 show the new alignment of Route 2 operated by Brun-Way and MRDC, respectively. Also shown on these figures are locations of the sections of the former Route 2 alignment that were renumbered and reclassified, and that remained in operation following the re-development projects. The new alignment is shown in red and the old, in blue. The new Trans Canada Route 2 is a fully access controlled, four-lane divided highway with a posted speed limit of 110 km/h and a design speed of 120 km/h.

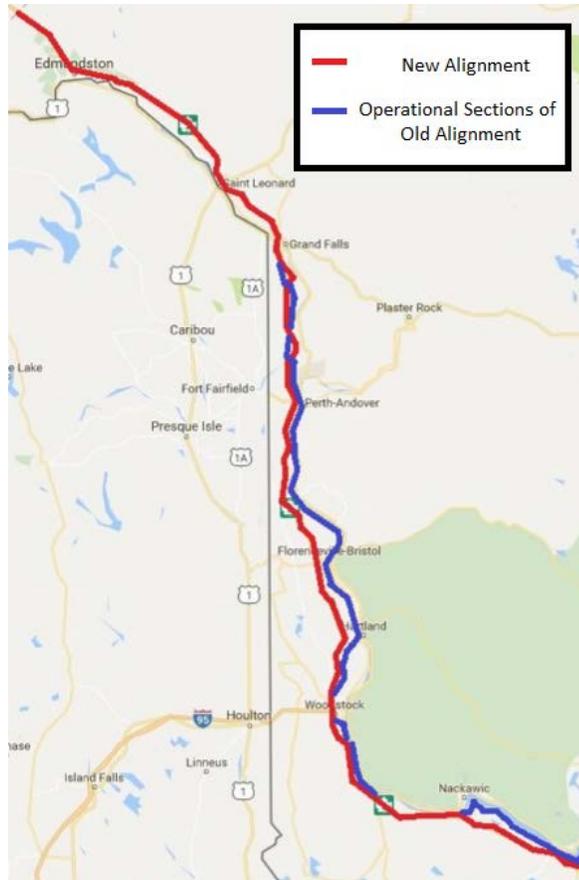


Figure 1.1 – Brun-Way Operated Section of Route 2

[Source: Google maps]

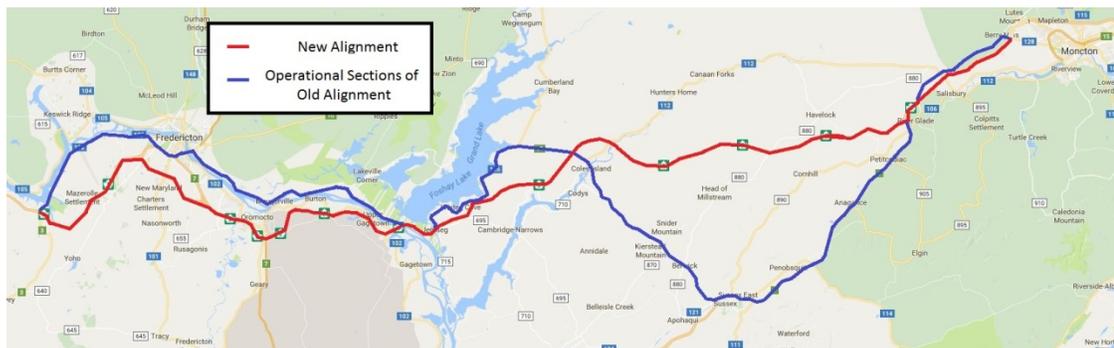


Figure 1.2 – MRDC Operated Section of Route 2

[Source: Google maps]

## **1.2 Problem Definition**

Sections of the Trans-Canada Highway Route 2 underwent major re-alignments and upgrading between 1998 and 2007. The upgrades were performed in order to facilitate movement of traffic through the province and to improve safety. This research project provides insight into the effect that these re-alignments have had on the safety performance of Route 2.

## **1.3 Study Goal**

The main goal of this research was to quantify the safety benefits accrued from replacing the original two-lane, undivided, Route 2 alignment with a new, design-build-operate and maintain, four-lane, divided freeway alignment. In order to achieve this goal, the following objectives were carried out:

- development of collision history/profile of the former Route 2;
- development of collision history/profile of the new Route 2, including sections of the former Route 2 that remain in service;
- development of collision frequencies and rates for both the former and existing alignments of Route 2;
- development of collision frequencies and rates delineated by collision severity for both alignments; and
- estimation of economic savings resulting from the net reduction in collisions attributable to the Route 2 redevelopment.

## **1.4 Scope and Limitations**

The research encompassed in this report was limited to aggregate comparisons of collision rates before and after the complete re-alignment of Route 2. The project also included a comparison between the proportions of fatal, injury and property damage only collisions for the before and after periods. The analysis was limited to collisions occurring within five years prior to and following the major re-alignment projects (i.e. from 1992 to 1997 and 2008 to 2012). The safety analysis relied on police reported collisions only. The research omits the following:

- specific details regarding the exact upgrades that were performed on the highway and their associated safety benefits;
- comparisons with safety performance indicators such as collision prediction models (CPMs);
- specific details relating to collision configurations (e.g. head-on, rear-end, rollover, etc.); and
- the section of Route 2 between Moncton and the Nova Scotia border.

## **1.5 Literature Review**

The following sections provide a review of previous literature that discuss the relationship between roadway facility upgrades and safety performance. A review of collision costs is also provided in this section.

### **1.5.1 Previous Studies Quantifying Safety Benefits of Transportation Facility Upgrades**

There are numerous ways to upgrade a transportation facility to provide a safer environment for road users. These upgrades can vary widely, from simply widening the shoulder of the roadway, to adding extra traffic lanes, to providing a median between lanes of opposing directions of travel. Ahmed *et al.* (2015) evaluated the safety effectiveness of upgrading from a 2-lane facility to a 4-lane divided facility and concluded that safety improved significantly as a result. Research studies have also been performed on the safety effectiveness of performing other types of upgrades. Contrarily, studies have been performed on the negative safety implications of performing upgrades such as narrowing the roadway in order to increase capacity. The following sections summarize five key studies that were performed to evaluate these relationships.

#### **Safety benefits of road widening and raised medians**

Ahmed *et al.* (2015) used a number of statistical methods to evaluate the safety effects of adding a lane in each direction and a raised median simultaneously on a two-lane roadway. It was determined that the conversion was successful in reducing fatal and injury collisions by 63% and 45% in urban and rural areas, respectively. Collision modification factors of 0.341 and 0.712 were developed for all collision types for urban and rural roadways, respectively. It was also determined that the upgrades yielded greater reductions on roadways having a higher AADT (Average Annual Daily Traffic). It was noted that the data used in this study only included 2.5 years of crash data after the

upgrades were performed. It was recommended that further research be performed using more “after” data.

### **Narrow widening projects to improve safety**

Similar to Ahmed’s study, a before-and-after study was performed by Wu *et al.* (2015) on the safety effects of narrow pavement widening projects in Texas. In this case, narrow pavement widening refers to adding shoulders along roadways, increasing the width of shoulders and lanes, or both. The study found that total crashes were reduced by 31.5% and that significant reductions were found in run-off-the-road, head-on, and fatal and serious injury crashes.

### **Safety pitfalls of urban freeway narrowing**

Bauer *et al.* (2004) acknowledges a relationship between safety performance and road width. The study that was performed evaluated how safety diminished as a result of narrowing urban freeways in California in order to increase capacity. Narrowing in this instance involved maintaining the total width of the freeway while increasing the number of lanes, which resulted in narrower lanes and reductions in shoulder width. The before-and-after analyses that were performed showed increases of 10% to 11% in total crashes, with a larger concentration of fatal and injury accidents.

### **Safety benefits of Road Safety Audits**

Lougheed and Hildebrand (2016) investigated the safety benefits of performing road safety audits (RSA’s) on three design-build projects in New Brunswick. The safety implications of the use of RSAs throughout the different stages of the projects were

analyzed. The research involved comparing observed collision frequencies to those predicted by collision prediction models. It was determined that the RSAs allowed for significant reductions in collision frequencies on the three projects. The facilities experienced approximately 15% fewer collisions. Lougheed and Hildebrand (2016) also performed an analysis in order to understand the economic benefits of performing RSAs on design-build projects. An average benefit-cost ratio of 55:1 was calculated for the three projects.

### **Safety effects of adding median and increasing shoulder width**

Though a number of studies found that there is a correlation between safety performance and road characteristics, others were unable to support the notion. Roland and Oh (2004) were unable to prove that certain roadway upgrades have a positive effect on safety. In some instances, they even found a negative relationship between certain upgrades and safety. The analysis involved the use of linear regression to understand the effect that different roadway upgrades have on collision frequency. It was found that increasing the number of lanes, the width of the lanes, as well as the width of the shoulder resulted in increases in both collision frequency and severity and that there were no statistically significant reductions in collisions as a result of changes to median widths and horizontal and vertical profiles.

### **Collision reductions on Fredericton – Moncton Highway following re-alignment project**

As part of their safety analysis on the road safety audit performed as part of the major re-alignment project of Route 2 between Fredericton and Moncton, Gunter and Hildebrand

(2007) compared collision frequencies and rates on the new facility with those on the old alignment. It was determined that the average collision rate on the former alignment of Route 2 between Fredericton and Moncton was 0.896 collisions per million-vehicle-kilometres. The collision rate on the new alignment and sections of the old alignment still in operation was estimated at 0.637 collisions per million-vehicle-kilometres. This resulted in an estimated reduction in total collision rate of 0.259 collisions per million-vehicle-kilometres. It is important to note that Gunter and Hildebrand's study was limited to a section of the Trans-Canada Highway (Fredericton to Moncton) and that the before and after collision data that were used in their analyses were limited. The "before" data was obtained from the *Functional Planning Study for the Trans Canada Highway Fredericton to Moncton Background Report*, which was completed in 1992. The "after" data were limited to collisions occurring between 2002 and 2006.

### **1.5.2 Collision Costs**

When analyzing collision reductions, it can often be beneficial to quantify these from an economic standpoint. A monetary value can be associated to different types of collisions based on severity, i.e. property damage only (PDO), injury and fatal collisions. The cost of PDO collisions are generally based on the average cost associated with the repair and replacement of the vehicles and property that were involved in the collision. The cost of collisions resulting in injuries is usually generated based on the average costs of emergency and medical services, loss of productivity due to the injury, as well as the monetary value associated with the diminished quality of life. The cost of fatal collisions is typically evaluated using the willingness-to-pay method. There have been many studies performed in an attempt to evaluate the costs of collisions. In their research, Loughheed

and Hildebrand (2016) utilized collision costs from 6 different sources to develop collision costs for each severity level. Table 2.1 outlines these costs, which will be used in this study.

Table 2.1 – Collision Costs Based on Severity (2015 dollars)

Collision Severity	Collision Cost
PDO	\$15,000
Injury	\$150,000
Fatal	\$5,500,000

### 1.5.3 Literature Summary and Need for Further Research

Past research indicates that there is a correlation between certain roadway upgrades and safety. Though Ahmed *et al.* (2015) successfully quantified safety benefits related to converting a 2-lane roadway to a 4-lane divided facility, further research was necessary in order to verify these benefits. The traffic characteristics on the New Brunswick portion of the Trans-Canada Highway differ from those of the roadway evaluated in Ahmed’s analysis. The highway is used as a gateway to several neighbouring provinces, which means that a large proportion of traffic on the facility consists of out-of-province and commercial vehicles (20% of total traffic). No such study is known to have addressed roadways with these types of characteristics.

This study allowed for the quantification of the safety benefits associated with converting the Trans-Canada Route 2 from a 2-lane facility to a 4-lane divided highway through the Province of New Brunswick. With the use of collision cost data, an economic evaluation of the associated safety benefits could also be performed.

## **Chapter 2: Methodology**

### **2.1 Data**

This study involved the use of collision data for the current and previous alignments of the Trans-Canada Highway 2 between the Quebec border and Moncton. Traffic volume data were provided in terms of average annual daily traffic (AADT) over pre-defined control sections along the highway and were used to develop collision rates in terms of collisions per million vehicle kilometres for the “before” and “after” conditions. Collision data and traffic volume data were provided by the New Brunswick Department of Transportation and Infrastructure (NBDTI).

### **2.2 Non-Experimental Procedure**

The procedure for this research analysis involved the manipulation of NBDTI collision data in order to produce collision rates for time periods of 5 years before and after upgrades were performed on the Trans-Canada Highway Route 2 between the Quebec border and Moncton. First, collision data for the new and old sections were extracted from the data set provided. These data were sorted into different control sections based on where the collisions occurred. Control sections are defined as varying lengths of roadway that have relatively homogenous characteristics (e.g. geometry, traffic volumes, etc.). The control sections used in the analysis were pre-defined by NBDTI. All collision data between 1998 and 2007 were omitted because these represent the time periods during construction and between the construction of both phases (the Quebec border to Longs-Creek and Longs-Creek to Moncton) and would not represent a steady state environment on the highway. Collision data for the new alignment were combined with

those from the sections of the old alignment that remained operational in order to best represent the “after” state.

Once the collision data were sorted into their respective control sections and years, annual collision frequencies were developed. These were developed in terms of total collisions as well as based on collision severity. The collision frequencies were then converted into collision rates in terms of collisions per million-vehicle-kilometres. These rates were developed in order to normalize the data for varying control section lengths and traffic volumes and for growth of volumes over the 1993 to 2012 timeframe. AADTs from the year 1998 were used for the “before” condition because volume data were not available for the years included in the “before” study period. AADT data from 2008 to 2012 were used for the “after” condition. Collision rates were also separated into collision severity, namely property damage only, injury and fatal collisions.

In order to better understand the economic impact associated with the collision reductions identified in this study, collision costs were utilized. The collision costs identified in section 1.5.2 were used to calculate collision cost rates, expressed in terms of dollars per million-vehicle-kilometers. Actual collision costs were then developed to represent the annual cost of collisions before and after the upgrades. These were developed with the use of the collision frequencies and collision costs.

### **2.2.1 Statistical Analysis**

The primary statistical method that was used in the analysis of the data in this research project is a statistical test of difference between proportions. This type of analysis is used to test whether one proportion from a population is equal to a proportion of a different

population. In the case of this research project, the statistical test of difference between proportions was used to evaluate whether the proportion of fatal collisions before the upgrades is statistically greater than the proportion of fatal collisions after the upgrades. Similarly, the statistical test was also used to evaluate whether the proportion of injury collisions before the upgrades is statistically greater than the proportion of injury collisions after the upgrades.

A two-sample *t*-test for equal means was also performed as part of the data analysis. The test was used to evaluate if the average collision rates for the “before” and “after” study periods were statistically different.

## **Chapter 3: Results**

The following chapter presents a synthesis of the results of the research study. A discussion of the results is provided in Chapter 4.

### **3.1 Collision Frequencies**

Collision frequencies were developed for both the before and after conditions on the highway. As previously mentioned, data from 1993 to 1997 were used to describe the “before” condition and data from 2008 to 2012 were used to describe the “after” condition. Data from 1998 to 2007 were excluded from the analysis because the redevelopment of the highway took place in phases during this time. A total of 6,188 collisions were reported during the analysis period. The old alignment, which extended over approximately 493 kilometres, was separated into 39 north and southbound control sections of varying lengths and volumes. The new alignment, which extends over approximately 459 kilometres, was separated into 39 northbound and 39 southbound control sections also of varying lengths and volumes. Some sections of the old alignment were renumbered and remained operational following the re-alignment projects. These sections extend over a total of approximately 383 kilometres and were separated into 33 control sections. A breakdown of all the control sections used in the analysis is included in Appendix A.

The average annual collision frequency before the upgrades was found to be 571 collisions per year. The average annual collision frequency after the upgrades was 667 collisions per year for the new alignment and operational sections of the old alignment, and 488 collisions per year for the new alignment only. Tables 3.1, 3.2 and 3.3 synthesize

the collision frequencies for each year of the study, as well as an average collision frequency for each study period. Annual collision frequencies are also listed for each severity type. Figure 3.1 depicts the annual collision frequencies for each year of the study. Frequencies for the new alignment and sections of the old alignment that remained operational after the upgrades are depicted separately. Summary tables for collision frequencies are included in Appendix B.

Table 3.1 – Collision Frequencies, Old Alignment

<b>Year</b>	<b>PDO Collisions</b>	<b>Injury Collisions</b>	<b>Fatal Collisions</b>	<b>Total</b>
1993	420	163	11	594
1994	436	171	9	616
1995	457	172	20	649
1996	296	139	19	454
1997	366	155	20	541
Average Annual Frequency	395	160	16	571

Table 3.2 – Collision Frequencies, New Alignment and Operational Sections of Old Alignment Combined

<b>Year</b>	<b>PDO Collisions</b>	<b>Injury Collisions</b>	<b>Fatal Collisions</b>	<b>Total</b>
2008	497	140	8	645
2009	543	169	4	716
2010	525	143	11	679
2011	575	165	7	747
2012	429	109	9	547
Average Annual Frequency	514	145	8	667

Table 3.3 – Collision Frequencies, New Alignment Only

Year	PDO Collisions	Injury Collisions	Fatal Collisions	Total
2008	359	105	5	469
2009	385	119	2	506
2010	393	109	8	510
2011	427	122	4	553
2012	321	74	5	400
Average Annual Frequency	377	106	5	488

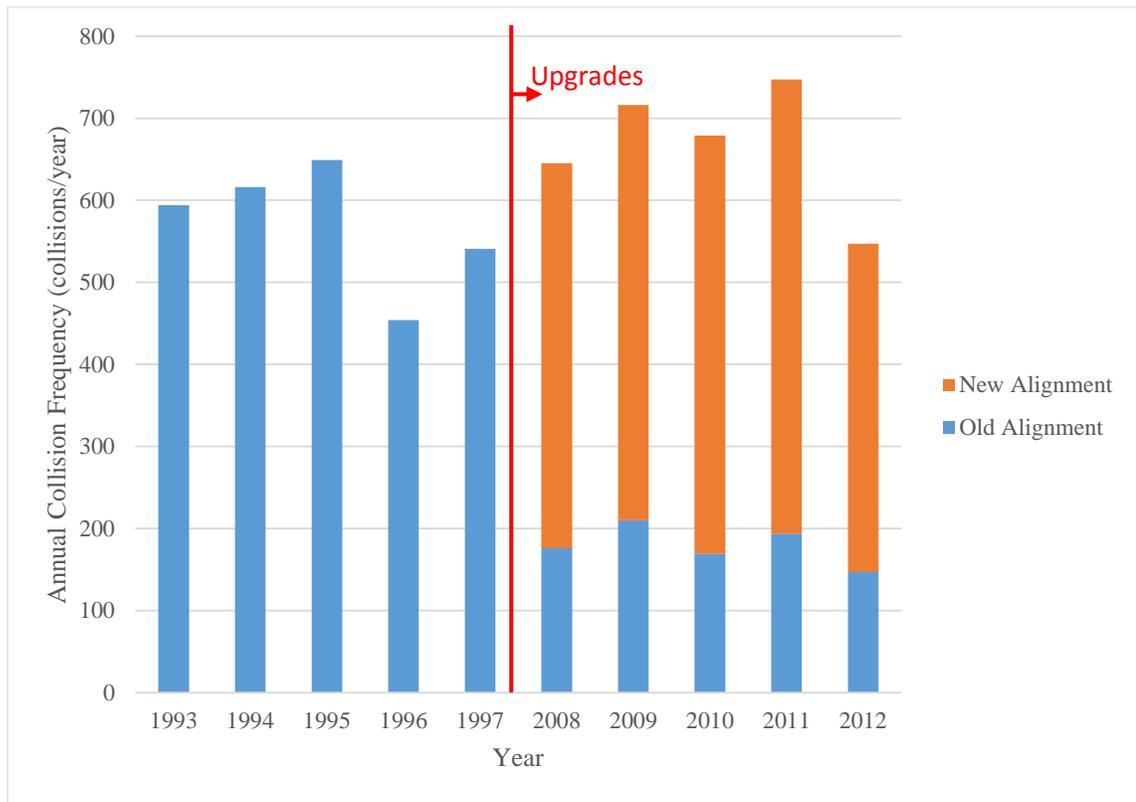


Figure 3.1 – Annual Collision Rates, New and Old Alignments

### 3.2 Collision Rates

In order to normalize the collision data for control section lengths, differing volumes, and for growth over the years of the study, collision rates were developed. This involved dividing the number of collisions for each control section (for each study year) by the

estimated annual volume on the control section and by the length. The results were then multiplied by one million in order to express the collision rates in terms of collisions per million-vehicle-kilometres. Table 3.4 provides an example of a summary table that was used to calculate the collision rates for each control section of the new alignment in 2008.

Table 3.4 – 2008 Collision Rate Calculation Summary Table, New Alignment Only

<b>CS</b>	<b>AADT</b>	<b>Length (km)</b>	<b>No. of Collisions</b>	<b>Collision Rate</b>
01	2933	14.301	7	0.457
02	4335	7.366	6	0.515
03	4750	17.606	12	0.393
04	3395	19.783	15	0.612
05	3040	10.005	6	0.540
06	2995	8.324	8	0.879
07	4295	4.973	3	0.385
08	2720	11.539	1	0.087
09	2720	11.114	3	0.272
10	2720	10.167	4	0.396
11	2030	18.286	1	0.074
12	2030	5.912	1	0.228
13	2760	13.895	5	0.357
14	2760	18.464	2	0.108
15	4510	12.161	6	0.300
16	4790	11.792	8	0.388
17	3453	13.526	8	0.469
18	3453	17.770	10	0.447
19	3453	8.088	2	0.196
20	3465	18.124	14	0.611
21	4060	18.216	14	0.519
22	4060	6.499	5	0.519
23	2565	13.926	4	0.307
24	9550	7.763	10	0.370
25	9550	6.120	5	0.234
26	3200	18.780	9	0.410
27	3200	14.400	3	0.178
28	3375	8.605	7	0.660
29	3375	5.556	0	0.000
30	3375	12.131	5	0.335
31	2920	7.171	4	0.523
32	2920	14.798	3	0.190
33	2920	8.298	3	0.339

34	2920	4.346	1	0.216
35	2920	11.072	9	0.763
36	2920	3.171	0	0.000
37	2920	13.187	2	0.142
38	7400	13.371	5	0.138
39	10240	18.711	21	0.300
61	10240	18.713	0	0.000
62	7400	13.343	10	0.277
63	2920	13.016	3	0.216
64	2920	3.145	0	0.000
65	2920	11.001	4	0.341
66	2920	4.401	3	0.640
67	2920	8.162	5	0.575
68	2920	14.872	7	0.442
69	2920	7.310	2	0.257
70	3375	12.026	8	0.540
71	3375	5.566	3	0.438
72	3375	8.611	4	0.377
73	3200	14.311	13	0.778
74	3200	18.818	18	0.819
75	9550	6.105	9	0.423
76	9550	7.941	8	0.289
77	2565	14.083	8	0.607
78	4060	6.562	2	0.206
79	4060	18.053	9	0.336
80	3465	18.228	8	0.347
81	3453	8.047	4	0.394
82	3453	17.723	16	0.716
83	3453	13.452	12	0.708
84	4790	11.865	7	0.337
85	4510	12.151	4	0.200
86	2760	18.490	8	0.429
87	2760	13.907	5	0.357
88	2030	5.857	2	0.461
89	2030	18.266	1	0.074
90	2720	10.196	5	0.494
91	2720	11.164	0	0.000
92	2720	11.606	1	0.087
93	4295	4.950	8	1.031
94	2995	8.362	2	0.219
95	3040	10.006	6	0.540
96	3395	19.775	7	0.286
97	4750	17.630	14	0.458
98	4335	7.379	5	0.428
99	2933	12.309	6	0.455

Once the collision rates were developed for each control section in the study, average collision rates were estimated for each study period by calculating the arithmetic mean of the collision rate data. The average collision rate for the “before” condition is 0.503 collisions per million-vehicle-kilometres. The average collision rate for the “after” condition, including both the new alignment and operational sections of the old alignment, is 0.419 collisions per million-vehicle-kilometres and only 0.385 for the new alignment only. Tables 3.5 and 3.6 outline the average collision rates for the “before” and “after” study periods, respectively. Summary tables for collision rates are included in Appendix B.

Table 3.5 – Average Collision Rates, Old Alignment

<b>Year</b>	<b>Average Total Collision Rate (collisions/mvkm)</b>
1993	0.504
1994	0.567
1995	0.549
1996	0.400
1997	0.492
Average, 1993-1997	0.503

Table 3.6 – Average Collision Rates, New Alignment and Operational Sections of Old Alignment

<b>Year</b>	<b>New Alignment</b>	<b>Old Alignment</b>	<b>New and Old Combined</b>
2008	0.377	0.462	0.405
2009	0.404	0.546	0.450
2010	0.397	0.497	0.430
2011	0.423	0.592	0.479
2012	0.323	0.348	0.331
Average, 2009-2012	0.385	0.489	0.419

### 3.2.1 Two-Sample *t*-Test for Equal Means

A *t*-test was performed to determine if the average collision rates for the before and after conditions are statistically different. The null hypothesis for this test is that the sample mean for the “before” data is statistically equal to the sample mean for the “after” data. The data in Table 3.7 synthesize the results of the analysis.

$$H_0 : \mu_1 = \mu_2$$

$$H_a : \mu_1 \neq \mu_2$$

$$\text{Test Statistic: } t_{\text{calculated}} = \frac{\bar{Y}_1 - \bar{Y}_2}{\sqrt{\frac{s_1^2}{N_1} + \frac{s_2^2}{N_2}}}$$

Table 3.7 – Two-Sample *t*-Test for Equal Means

	<b>Before</b>	<b>After</b>
Year 1	0.5038	0.4051
Year 2	0.5674	0.4503
Year 3	0.5494	0.4302
Year 4	0.4000	0.4785
Year 5	0.4920	0.3314
Average (Y)	0.5025	0.4191
N	5	5
Variance ( s )	0.0043	0.0031
Deg. of Freedom	8	
Critical value	1.86	
$t_{\text{calculated}}$	35.30	> 1.86

The results of the two-sample *t*-test indicate that the null hypothesis can be rejected. This confirms that the average collision rates for both study periods are statistically different.

### 3.2.2 Measures of Central Tendency

The collision rates above were developed by averaging collision rates for individual control sections along the highway. In order to better understand the distribution of the data, measures of central tendency were determined. Tables 3.8, 3.9 and 3.10 outline the mean, maximum, minimum and standard deviation to the mean for the old alignment, new alignment combined with the operational sections of the old alignment, and the new alignment only.

Table 3.8 – Measures of Central Tendency, Old Alignment

	<b>PDO Collisions (collision/mvkm)</b>	<b>Injury Collisions (collision/mvkm)</b>	<b>Fatal Collisions (collision/mvkm)</b>	<b>All Collisions (collision/mvkm)</b>
<b>Mean</b>	0.352	0.137	0.014	0.503
<b>Max</b>	1.144	0.705	0.353	1.763
<b>Min</b>	0.000	0.000	0.000	0.052
<b>St Dev</b>	0.208	0.110	0.034	0.280

Table 3.9 – Measures of Central Tendency, New Alignment and Operational Sections of Old Alignment Combined

	<b>PDO Collisions (collision/mvkm)</b>	<b>Injury Collisions (collision/mvkm)</b>	<b>Fatal Collisions (collision/mvkm)</b>	<b>All Collisions (collision/mvkm)</b>
<b>Mean</b>	0.324	0.089	0.006	0.419
<b>Max</b>	2.919	1.288	0.665	3.284
<b>Min</b>	0.000	0.000	0.000	0.000
<b>St Dev</b>	0.318	0.128	0.036	0.371

Table 3.10 – Measures of Central Tendency, New Alignment Only

	<b>PDO Collisions (collision/mvkm)</b>	<b>Injury Collisions (collision/mvkm)</b>	<b>Fatal Collisions (collision/mvkm)</b>	<b>All Collisions (collision/mvkm)</b>
<b>Mean</b>	0.297	0.083	0.004	0.385
<b>Max</b>	1.398	0.433	0.213	1.678
<b>Min</b>	0.000	0.000	0.000	0.000
<b>St Dev</b>	0.184	0.086	0.021	0.223

### 3.3 Severity of Collisions

The collision data were used to calculate average collision rates for each severity level (i.e. property damage only, injury and fatal collisions). Tables 3.11, 3.12 and 3.13 outline the number of collisions and the average collision rates for each severity for the “before” and “after” conditions, respectively, over the sample years. The proportion of injury to total collisions is 0.280 for the “before” condition and 0.218 for the “after” condition. The proportion of fatal to total collisions is 0.028 for the “before” condition and 0.012 for the “after” condition. Figures 3.2 and 3.3 depict the number of collisions and collision rates for both study periods, respectively.

Table 3.11 – Distribution of Collisions and Rates by Severity, Old Alignment

	<b>Total Collisions</b>	<b>PDO Collisions</b>	<b>Injury Collisions</b>	<b>Fatal Collisions</b>
<b>Number of Collisions</b>	2854	1975	800	79
<b>Proportion of Total Collisions</b>	1.000	0.692	0.280	0.028
<b>Collision Rate (collisions/mvkm)</b>	0.503	0.352	0.137	0.014

Table 3.12 – Distribution of Collisions and Rates by Severity, New Alignment and Operational Sections of Old Alignment Combined

	<b>Total Collisions</b>	<b>PDO Collisions</b>	<b>Injury Collisions</b>	<b>Fatal Collisions</b>
<b>Number of Collisions</b>	3334	2569	726	39
<b>Proportion of Total Collisions</b>	1.000	0.771	0.218	0.012
<b>Collision Rate (collisions/mvkm)</b>	0.419	0.324	0.089	0.006

Table 3.13 – Distribution of Collisions and Rates by Severity, New Alignment Only

	<b>Total Collisions</b>	<b>PDO Collisions</b>	<b>Injury Collisions</b>	<b>Fatal Collisions</b>
<b>Number of Collisions</b>	2438	1885	529	24
<b>Proportion of Total Collisions</b>	1	0.773	0.217	0.010
<b>Collision Rate (collisions/mvkm)</b>	0.385	0.298	0.083	0.004

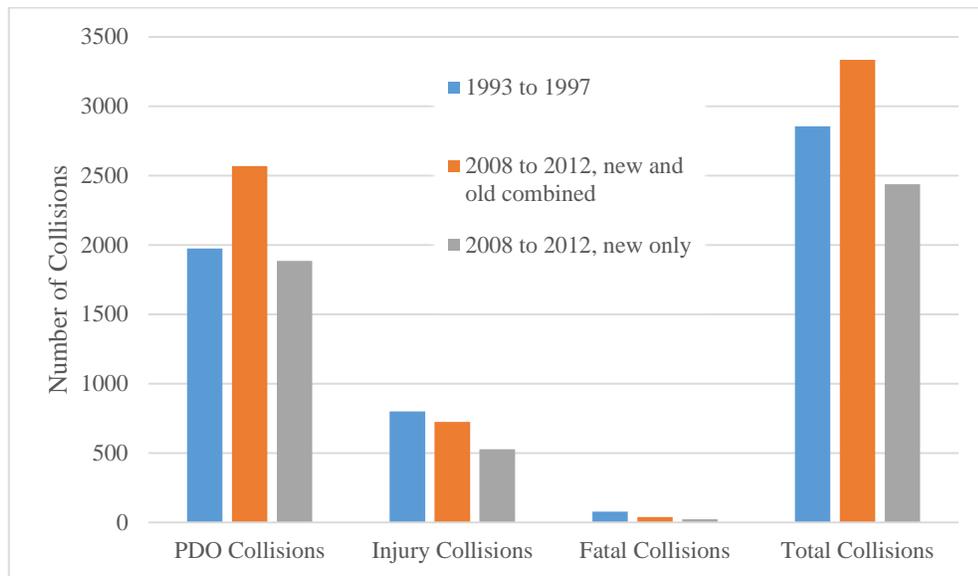


Figure 3.2 – Number of Collisions Based on Severity, Before and After Upgrades

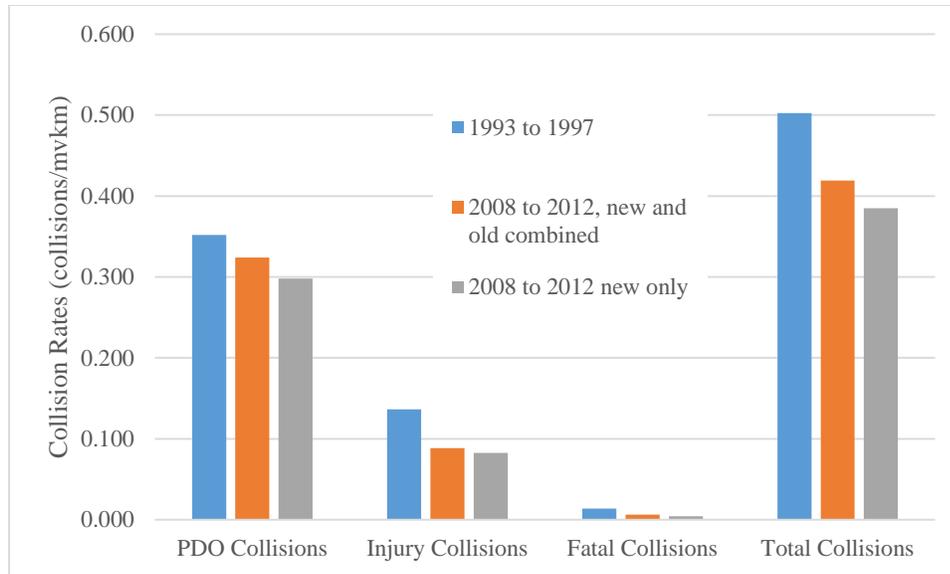


Figure 3.3 – Collision Rates Based on Severity, Before and After Upgrades

The distributions of collision severities for both study periods were calculated and are outlined in Table 3.14. This data is depicted in Figure 3.4.

Table 3.14 – Collision Severity Distributions, Before and After Upgrades

Sev.	1993 to 1997		2008 to 2012 (combined)		2008 to 2012 (new only)	
	Number of Collisions	Severity Distribution	Number of Collisions	Severity Distribution	Number of Collisions	Severity Distribution
PDO	1975	69%	2569	77%	1885	77%
Injury	800	28%	726	22%	529	22%
Fatal	79	3%	39	1%	24	1%
Total	2854	100%	3334	100%	2438	100%

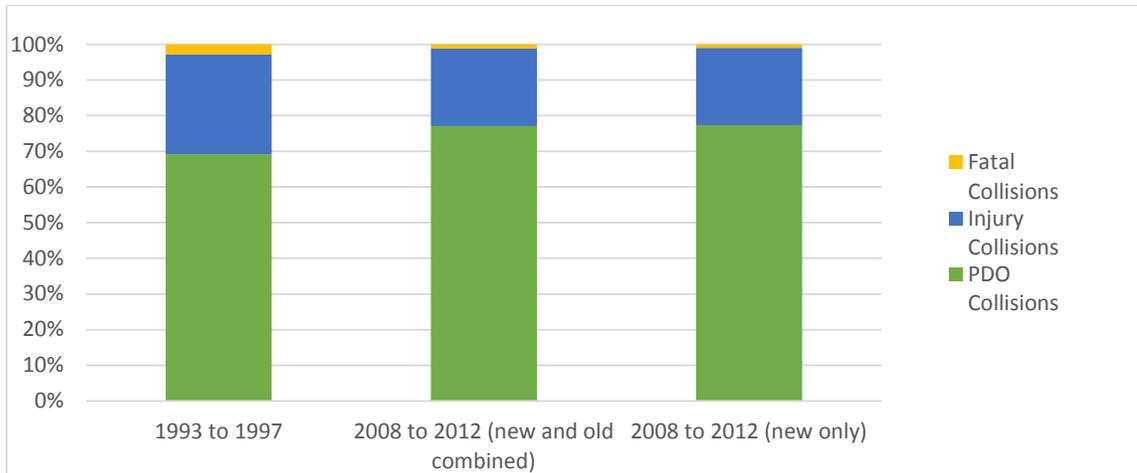


Figure 3.4 – Severity Distributions, Before and After Upgrades

### 3.3.1 Statistical Test of Difference Between Proportions

A statistical test of difference between proportions was conducted in order to determine if the proportion of injury to total collisions and fatal to total collisions is statistically different between the two study periods. The null hypothesis for this analysis is that these proportions are not statistically different to one another. Tables 3.12 and 3.13 outline the results of the analysis.

$$H_0 : p_1 = p_2$$

$$H_a : p_1 \neq p_2$$

$$\text{Test Statistic: } z = \frac{(\hat{p}_1 - \hat{p}_2) - 0}{\sqrt{\hat{p}(1-\hat{p})\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

$$\text{Where: } \hat{p} = \frac{Y_1 + Y_2}{n_1 + n_2}$$

Table 3.15 – Statistical Analysis: Total Number of Collisions

Sample Years	Total Collisions		PDO Collisions		Injury Collisions		Fatal Collisions	
	Collisions	Prop.	Collisions	Prop.	Collisions	Prop.	Collisions	Prop.
1993-1997	2854	1.00	1975	0.69	800	0.28	79	0.03
2008-2012	3334	1.00	2569	0.77	726	0.22	39	0.01

Table 3.16 – Statistical Test of Difference Between Proportions

	Injury	Fatal
Y <sub>1</sub>	800	79
Y <sub>2</sub>	726	39
n <sub>1</sub>	2854	2854
n <sub>2</sub>	3334	3334
p <sub>1</sub> (old)	0.280	0.028
p <sub>2</sub> (new)	0.218	0.012
p	0.247	0.019
z	5.690	4.583
Accept H <sub>0</sub> ?	No	No

The results of the statistical analysis indicate that the null hypothesis can be rejected. As a result, we can say that the proportion of injury to total collisions and fatal to total collisions between the two study periods are statistically different thereby confirming the new facility has reduced collision severities.

### 3.4 Cost of Collisions

In order to better understand the impact of the reductions in collision rates of each severity type, an cost analysis was performed. Recalling the collision costs outlined in section 2.2 of this report, associated collision cost rates in terms of dollars per million-vehicle-kilometres were developed for each collision severity. Table 3.17 provides a

breakdown of the costs associated with the highway development. The total cost saved is dependent on the volumes on the highway. The total cost savings is \$42,408 per million-vehicle-kilometres.

Table 3.17 – Collision Cost Rates

<b>Severity</b>	<b>Collision Cost (\$/collision)</b>	<b>Collision Rate "Before" (collisions/mvkm)</b>	<b>Collision Cost "Before" (\$/mvkm)</b>	<b>Collision Rate "After" (Collisions/mvkm)</b>	<b>Collision Cost "After" (\$/mvkm)</b>	<b>Cost Savings (\$/mvkm)</b>
PDO	\$15,000	0.352	\$5,279	0.338	\$5,063	\$216
Injury	\$150,000	0.137	\$20,485	0.092	\$13,787	\$6,699
Fatal	\$5,500,000	0.014	\$77,127	0.008	\$41,633	\$35,494
					Total	\$42,408

An analysis of the average annual collision costs before and after the upgrades was performed. Table 3.18 outlines these costs. The average annual cost savings is \$44,438,000 per year.

Table 3.18 – Actual Annual Costs of Collisions

<b>Severity</b>	<b>Collision Cost (\$/collision)</b>	<b>Average Annual Collisions "Before"</b>	<b>Collision Cost "Before"</b>	<b>Average Annual Collisions "After"</b>	<b>Collision Cost "After"</b>	<b>Average Annual Cost Savings</b>
PDO	\$15,000	395	\$5,925,000	514	\$7,707,000	-\$1,782,000
Injury	\$150,000	160	\$24,000,000	145	\$21,780,000	\$2,220,000
Fatal	\$5,500,000	16	\$86,900,000	8	\$42,900,000	\$44,000,000
					Total	\$44,438,000

## **Chapter 4: Discussion**

The results presented in the previous section allow for a better understanding of the safety performance of Route 2 before and after the major re-alignment and upgrade projects. Collision rates, frequencies, severities and costs were presented so that comparisons could be made between the two study periods. This chapter provides a summary of findings, recommendations, suggested future research, as well as research limitations associated with this study.

### **4.1 Collision Rates vs. Frequencies**

In order to better understand the safety performance of the highway during both study periods, collision data were presented in terms of collision frequencies and rates.

Collision frequencies were developed in terms of number of collisions per year. The average frequencies were 571 collisions per year for the “before” period and 667 collisions per year for the “after” period. These data would suggest on the surface that collisions have increased following the upgrades on Route 2; however, the “after” condition includes 383 kilometres of the old route that have remained in service. The average collision frequency of the new alignment only was found to be 488. Another short-coming of only examining collision frequencies is that any growth in traffic volumes over the study period is neglected.

Collision rates were developed so that the collision data could be normalized with respect to section lengths and volumes for the two study periods. When comparing collision rates for the “before” and “after” study periods, it is seen that rates from 2008 to 2012 average 0.419 collisions per million-vehicle-kilometres. Rates from 1993 to 1997 average to

0.503 collisions per million-vehicle-kilometres. This results in a collision rate reduction of 0.083 collisions per million-vehicle-kilometres between the “before” study period and the “after” study period. The collision rate calculated for the “before” study period is less than the collision rate of 0.896 collisions per million-vehicle-kilometres that was developed in Gunter and Hildebrand’s study in 2007. This is likely due to the fact that the 2007 study evaluated collisions that only occurred on the MRDC section of Route 2. This would suggest that the former alignment between Longs-Creek and Moncton experienced a higher collision rate than the former section between the Quebec Border and Longs-Creek.

A two-sample *t*-test for equal means was performed to evaluate if the average collision rates for the “before” and “after” study periods were statistically different. The results of the *t*-test indicate that they are statistically different, further supporting the notion that the safety performance of Route 2 has improved as a result of the major re-alignment and upgrade projects.

As previously mentioned, the “after” data included collisions occurring on both the new alignment and sections of the old alignment that remained operational after the upgrades. When comparing the collision rates on these two, it is seen that the collision rates on the operational sections of the old alignment are higher than the rates on the new alignment (average of 0.489 collisions per million-vehicle-kilometres on the old versus 0.385 collisions per million-vehicle-kilometres on the new). This indicates that the collisions occurring on the operational sections of the old alignment are inflating the collision rates for the “after” period. For this reason, it can be said that the new alignment’s safety performance is even better than the collision rate for the “after” period would suggest.

When comparing the average collision rate for the “before” and “after” periods without taking into account the operational sections of the old alignment, a collision reduction of 0.118 collisions per million-vehicle-kilometres is found.

#### **4.1.1 Collision Rates: Measures of Central Tendency**

Measures of central tendency were developed for both study periods. These allowed for a better understanding of the distribution of the collision rate data. When comparing the minimum, maximum and standard deviations to the mean for both study periods, we see that the collision rates for the “after” study period vary more than those for the “before” period. The standard deviation for the “after” period is 0.371 collisions per million-vehicle-kilometres, Table 3.9, whereas the standard deviation for the “before” period is 0.280 collisions per million-vehicle-kilometres, Table 3.8. When comparing the measures of central tendency between the new alignment only to those for the new alignment combined with the operational sections of the old alignment, we see that the data for the new alignment only vary much less. The standard deviation for the new alignment only is 0.223 collisions per million-vehicle-kilometres, a difference of 0.149 collisions per million-vehicle-kilometres from the standard deviation for the entire “after” period. The high variability in the “after” study period data is therefore due to the fact that these data are from both the new alignment and the sections of the old alignment that remain operational.

#### **4.2 Collision Severities**

In order to better understand the distribution of collision types, collision data were separated into three different collision severities; property damage only (PDO), injury

and fatal. Both collision rates and total number of collisions were evaluated. We see that the total number of PDO collisions is greater for the “after” study period, but that the total number of injury and fatal collisions is greater for the “before” study period. The collision rates for all three severity types are lesser for the “after” period. Collision severity distributions were also developed in order to understand the proportions of each collision severity. It was determined that the percentage of PDO collisions increased from 69 % to 77 % from the “before” to the “after” study periods. The percentage of injury collisions reduced from 28 % to 22 % when comparing the “before” to the “after” study periods. The percentage of fatal collisions reduced from 3 % to 1 % between the two periods. This shows that the proportion of injury and fatal collisions have reduced, resulting in an increase in the proportion of PDO collisions. These results suggest that the overall severity of collisions occurring on Route 2 has reduced as a result of the upgrades.

#### **4.2.1 Collision Costs**

Collision costs were developed as a means of describing the collision data from a cost impact standpoint. Costs were expressed in terms of dollars saved per million-vehicle-kilometres, as well as average annual dollars saved. A cost savings rate of \$48,981 per million-vehicle-kilometres was estimated. The actual cost savings is dependent on the volumes. For example, looking at Control Section 1 on the new alignment in 2012 (length of 14.301 km and average annual daily traffic of 3135 vehicles per day), we can calculate a cost savings of \$801,538 per year for that section alone.

Evaluating the difference in collision costs for the “before” and “after” study periods, an average annual cost savings of \$44,438,000 was calculated. The cost of PDO collisions

saw an average increase of \$1,782,000 annually; however this was more than offset by the annual cost reductions in injury collisions alone. It is important to note, however, that this comparison does not take into account traffic volumes on the highway. It was previously determined that, due to volumes for the “after” period being higher than the “before” period, using the total number of collisions and/or collision frequencies results in an underestimation of the safety performance of the new facility. For this reason, it can be assumed that the average annual cost savings between the two study periods would be greater than \$44,438,000. It is also noteworthy that the vast majority of cost savings is attributed to an estimated reduction of an average of 8 fatalities per year.

#### **4.2.2 Statistical Test of Difference Between Proportions**

A statistical test of difference between proportions was performed in order to determine if the proportion of injury to total collisions and fatal to total collisions differ statistically between the two study periods. It was determined that the proportions for both injury and fatal collisions are statistically different. This further supports the notion that collision severities have reduced as a result of the highway upgrades.

#### **4.3 Recommendations**

The recommendations that follow are derived from this research project.

##### **4.3.1 Promotion of Findings for Validation of Future Projects**

It is recommended that, when considering future highway upgrade projects, the use of findings from this study be promoted in order to estimate potential economic benefits attributed to collision reductions.

### **4.3.2 Standard for Reporting of Collisions**

This research project relied on collision data from collision reports that were completed by hand by the police officers who responded to the collisions, consequently, the collision data are not reported in a consistent way and discrepancies between the data are likely to exist. In order to reduce inconsistencies and human error, it is recommended that collision reports be completed digitally. This would allow for collision locations to be populated using GPS coordinates, therefore, eliminating the possibility of errors with respect to collision locations. It would also eliminate the need for collision data to be processed manually by a third party, thus reducing risk of additional human error.

### **4.3.3 Public Encouragement to Use New Facility**

It was determined that collision rates on the new facility are less than those on the sections of the old alignment that remain in service today. In an attempt to reduce the number of collisions occurring on the remaining sections of the old alignment, it is recommended that a program be implemented to encourage road users to make use of the new facility, when possible, in place of the old alignment.

## **4.4 Future Research**

The following is a list of future research areas that are recommended as a result of this study:

- Additional research should be performed to better understand the configurations of the collisions before and after the re-alignment projects. This would allow for researchers to see how collision configurations have changed as a result of the

upgrades. This would also allow for a better understanding of the distribution of collisions that occur on the highway.

- Further research into the locations of collisions is recommended. It was determined when evaluating the measures of central tendency that collisions for the “after” study period varied more than during the “before” period. It is recommended that additional research be conducted in order to determine locations where there is a higher concentration of collisions so that measures can be implemented in order to reduce collision rates in these locations.
- It would be useful to compare the actual collision rates on the highway to the expected collision rates using collision prediction models (CPMs). This would allow for a better understanding of how the highway is performing from a safety perspective and whether collision rates are similar to what would be expected for this type of facility.

## **4.5 Research Limitations**

### **4.5.1 Missing Collisions**

Although the majority of severe collisions are reported to the police, a number of minor collisions go unreported. These usually involve property damage only collisions where there is minimal damage to vehicles and they are driven away from the scene without notification to the police; consequently, it is likely that property damage only collisions are underestimated. For the purposes of this study, this issue would have existed during both study periods and, therefore, was ignored.

#### **4.5.2 Non-Linearity of Collision Frequencies**

It is recognized that it is known that there is a non-linear relationship between collision frequency and increasing traffic volumes. Essentially, the expected collision frequency diminishes somewhat in proportion to increases in traffic volume. The consequence is that collision rates are expected to decrease for road segments that have higher traffic volumes. This relationship was ignored by the analysis undertaken in this study because the variation in AADT by control section is relatively small throughout the project boundaries.

#### **4.6 Conclusions**

The research project has allowed for an understanding of the safety performance of Route 2 before and after the major re-alignment and upgrade projects performed between 1998 and 2007. It was determined that collision rates have reduced as a result of the upgrades and collision severities have shifted toward less severe categories. Collision cost savings resulting from the upgrading of the Trans-Canada Highway of \$44,438,000 per year were calculated between the two study periods and are largely due to an estimated reduction of 8 fatalities per year. It can therefore be stated that, according to data used in the analysis, the overall safety performance of Route 2 has improved as a result of the re-alignment projects.

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## **Appendix A**

### **New Brunswick Department of Transportation and Infrastructure Applicable Control Sections and Annual Average Daily Traffic**

## Route 2: Control Sections and AADTs, Old Alignment

CS	Length (km)	AADT (1998)
1	14.319	5560
2	7.366	5850
3	18.404	8127
4	18.211	7605
5	16.81	8420
6	1.057	7350
7	4.016	5500
8	11.773	5500
9	11.489	4750
10	8.928	4050
11	17.597	4130
12	7.508	3990
13	15.729	4200
14	17.588	6135
15	15.819	7370
16	12.772	6437
17	12.468	6150
18	16.445	5550
19	15.98	5880
20	14.494	6080
21	16.395	7300
22	11.581	11667
23	9.235	16850
24	4.33	8500
25	17.383	7150
26	12.316	6205
27	12.277	5450
28	11.161	4750
29	11.812	4750
30	11.366	5370
31	12.714	3250
32	7.336	3250
33	12.394	4400
34	18.438	8810
35	12.957	8140

36	8.669	8000
37	10.304	8957
38	14.808	11020
39	18.711	11310

**Route 2: Control Sections and AADTs, New Alignment**

CS	Length (km)	AADT (2008)	AADT (2009)	AADT (2010)	AADT (2011)	AADT (2012)
01	14.301	2932.5	2880	3198	2960	3135
02	7.366	4335	4335	4370	4370	4365
03	17.606	4750	4750	4930	4930	4930
04	19.783	3395	3395	3655	3655	3480
05	10.005	3040	3040	3165	3165	2875
06	8.324	2995	2995	3225	3225	2845
07	4.973	4295	4295	4205	4205	4135
08	11.539	2720	2705	2705	2765	2765
09	11.114	2720	2705	2705	2765	2765
10	10.167	2720	2705	2705	2765	2765
11	18.286	2030	2030	2195	2140	2160
12	5.912	2030	2030	2195	2140	2160
13	13.895	2760	2825	2825	2850	2850
14	18.464	2760	2825	2825	2850	2850
15	12.161	4510	4350	4350	4445	4445
16	11.792	4790	5023	5023	5238	5238
17	13.526	3452.5	3633	3633	3778	3778
18	17.77	3452.5	3633	3633	3778	3778
19	8.088	3452.5	3633	3633	3778	3778
20	18.124	3465	3615	3735	3710	3670
21	18.216	4060	4180	4260	4205	4210
22	6.499	4060	4180	4260	4205	4210
23	13.926	2565	2565	2775	2775	2880
24	7.763	9550	10000	10300	10315	10245
25	6.12	9550	10000	10300	10315	10245
26	18.78	3200	3200	3465	3465	3475
27	14.4	3200	3200	3465	3465	3475
28	8.605	3375	3375	3560	3560	3650
29	5.556	3375	3375	3560	3560	3650
30	12.131	3375	3375	3560	3560	3650
31	7.171	2920	3090	3200	3175	3180
32	14.798	2920	3090	3200	3175	3180
33	8.298	2920	3090	3200	3175	3180
34	4.346	2920	3090	3200	3175	3180

35	11.072	2920	3090	3200	3175	3180
36	3.171	2920	3090	3200	3175	3180
37	13.187	2920	3090	3200	3175	3180
38	13.371	7400	7750	8000	7880	7820
39	18.711	10240	10240	10810	10810	11355
61	18.713	10240	10240	10810	10810	11355
62	13.343	7400	7750	8000	7880	7820
63	13.016	2920	3090	3200	3175	3180
64	3.145	2920	3090	3200	3175	3180
65	11.001	2920	3090	3200	3175	3180
66	4.401	2920	3090	3200	3175	3180
67	8.162	2920	3090	3200	3175	3180
68	14.872	2920	3090	3200	3175	3180
69	7.31	2920	3090	3200	3175	3180
70	12.026	3375	3375	3560	3560	3650
71	5.566	3375	3375	3560	3560	3650
72	8.611	3375	3375	3560	3560	3650
73	14.311	3200	3200	3465	3465	3475
74	18.818	3200	3200	3465	3465	3475
75	6.105	9550	10000	10300	10315	10245
76	7.941	9550	10000	10300	10315	10245
77	14.083	2565	2565	2775	2775	2880
78	6.562	4060	4180	4260	4205	4210
79	18.053	4060	4180	4260	4205	4210
80	18.228	3465	3615	3735	3710	3670
81	8.047	3452.5	3633	3633	3778	3778
82	17.723	3452.5	3633	3633	3778	3778
83	13.452	3452.5	3633	3633	3778	3778
84	11.865	4790	5023	5023	5238	5238
85	12.151	4510	4350	4350	4445	4445
86	18.49	2760	2825	2825	2850	2850
87	13.907	2760	2825	2825	2850	2850
88	5.857	2030	2030	2195	2140	2160
89	18.266	2030	2030	2195	2140	2160
90	10.196	2720	2705	2705	2765	2765
91	11.164	2720	2705	2705	2765	2765
92	11.606	2720	2705	2705	2765	2765
93	4.95	4295	4295	4205	4205	4135
94	8.362	2995	2995	3225	3225	2845
95	10.006	3040	3040	3165	3165	2875
96	19.775	3395	3395	3655	3655	3480
97	17.63	4750	4750	4930	4930	4930
98	7.379	4335	4335	4370	4370	4365
99	12.309	2932.5	2880	3198	2960	3135

**Operational Sections of Former Route 2: Route Numbers, Control Sections and  
AADTs**

RTE	CS	Length (km)	AADT (2008)	AADT (2009)	AADT (2010)	AADT (2011)	AADT (2012)
130	3	10.735	1650	1650	1650	1650	1650
130	4	12.626	2000	2000	2000	2000	2000
130	5	12.934	1330	1330	1330	1330	1330
130	6	14.685	850	850	880	880	840
130	7	7.508	850	850	880	880	840
130	8	13.417	1030	1240	1240	1240	1330
130	9	19.075	2410	2800	2800	2685	2570
130	10	5.779	3000	3000	3000	3000	3000
590	1	10.889	1790	1790	1845	1900	1920
165	1	4.358	1010	1010	1010	1010	1010
165	2	14.566	1095	1095	1180	1225	1225
102	2	12.111	520	490	620	620	620
102	3	12.979	1000	1000	1000	1000	1000
102	4	6.314	1840	1840	1840	1840	1840
102	5	11.674	1800	1800	1770	1740	1740
102	6	11.521	10320	10320	10180	10040	10040
8	1	11.276	12762	12328	11894	12451	13008
8	99	11.276	7445	7325	7205	7333	7460
105	1	11.819	360	360	360	360	360
105	2	14.98	260	260	275	290	290
105	3	12.277	890	890	845	800	800
105	4	17.896	2760	2905	3050	3150	3250
105	5	11.793	3220	3220	3220	3220	3220
105	6	4.317	5290	5600	5910	5885	5860
10	10	11.366	1200	1200	1240	1280	1280
10	11	12.714	1610	1720	1710	1730	1700
10	12	7.336	2430	2430	2430	2430	2430
10	13	13.011	3410	3455	3500	3485	3470
1	17	18.479	6730	7707	7793	7020	7607
1	18	12.957	5498	5670	5670	5670	5670
1	19	8.669	5498	5670	5670	5670	5670
1	20	10.731	5498	5670	5670	5670	5670
1	80	8.949	3705	3700	3700	3700	3700
1	81	8.669	3705	3700	3700	3700	3700
1	82	12.966	3705	3700	3700	3700	3700
1	83	18.474	5035	5350	5350	5095	4840
Homestead Rd	N/A	18.5	3000	3000	3000	3000	3000
128	1	3.546	9250	9250	9250	9250	9250

## **Appendix B**

### **Collision Report Summaries**

## Route 2 Collision Frequency Summaries, Old Alignment

CS	Total Collisions (collisions/year)	PDO Collisions (collisions/year)	Injury Collisions (collisions/year)	Fatal Collisions (collisions/year)
01	17.2	10.6	5.8	0.8
02	17.4	13.0	3.8	0.6
03	39.0	27.0	11.0	1.0
04	25.0	16.4	7.8	0.8
05	22.4	14.4	6.8	1.2
06	2.8	1.6	1.0	0.2
07	4.4	4.0	0.4	0.0
08	11.4	8.4	2.2	0.8
09	21.0	14.4	6.2	0.4
10	8.4	6.6	1.6	0.2
11	12.0	9.8	1.8	0.4
12	5.0	3.4	1.4	0.2
13	8.0	6.8	1.2	0.0
14	14.8	10.8	4.0	0.0
15	20.8	13.0	7.2	0.6
16	15.8	9.2	5.6	1.0
17	11.4	7.6	3.6	0.2
18	12.4	9.2	2.8	0.4
19	12.0	9.2	2.4	0.4
20	9.6	6.6	2.6	0.4
21	20.4	17.2	3.0	0.2
22	27.2	18.0	9.0	0.2
23	22.8	15.4	7.4	0.0
24	9.8	7.0	2.8	0.0
25	20.6	14.8	5.6	0.2
26	7.0	2.8	4.0	0.2
27	9.6	6.8	2.6	0.2
28	4.0	2.4	1.6	0.0
29	12.6	8.8	3.8	0.0
30	9.8	7.0	2.8	0.0
31	10.2	7.2	2.6	0.4
32	5.2	4.0	1.0	0.2
33	11.0	8.4	2.4	0.2
34	24.2	16.8	6.2	1.2
35	10.4	7.4	2.8	0.2

36	4.8	3.6	1.2	0.0
37	16.4	10.4	5.8	0.2
38	26.4	17.0	8.2	1.2
39	27.6	18.0	8.0	1.6
Total	14.6	10.1	4.1	0.4

### Route 2 Collision Frequency Summaries, New Alignment

CS	Total Collisions (collisions/year)	PDO Collisions (collisions/year)	Injury Collisions (collisions/year)	Fatal Collisions (collisions/year)
01	9.2	6.8	2.0	0.4
02	5.4	5.0	0.4	0.0
03	8.2	6.8	1.2	0.2
04	14.8	10.4	4.2	0.2
05	5.0	3.6	1.4	0.0
06	3.6	3.2	0.4	0.0
07	1.6	1.6	0.0	0.0
08	3.0	2.4	0.6	0.0
09	5.8	5.0	0.8	0.0
10	5.8	4.4	1.2	0.2
11	4.0	3.2	0.8	0.0
12	1.0	0.8	0.2	0.0
13	4.0	3.6	0.4	0.0
14	5.2	4.0	1.2	0.0
15	7.0	5.4	1.4	0.2
16	7.4	6.2	1.0	0.2
17	3.8	3.2	0.6	0.0
18	9.0	7.0	2.0	0.0
19	4.0	3.2	0.8	0.0
20	8.8	7.0	1.6	0.2
21	12.0	9.6	2.4	0.0
22	3.2	2.8	0.4	0.0
23	6.4	4.0	2.2	0.2
24	7.6	6.4	1.2	0.0
25	6.6	4.8	1.6	0.0
26	8.8	5.8	3.0	0.0
27	5.0	3.8	1.0	0.2
28	4.2	3.0	1.2	0.0
29	1.2	1.2	0.0	0.0
30	5.2	4.0	1.2	0.0
31	5.0	3.8	1.2	0.0
32	4.0	3.4	0.4	0.2
33	2.4	2.2	0.2	0.0

34	1.8	1.4	0.4	0.0
35	6.2	3.8	2.4	0.0
36	1.6	1.4	0.2	0.0
37	6.8	5.6	1.0	0.2
38	7.8	6.4	1.4	0.0
39	20.0	14.4	5.4	0.2
61	10.6	7.8	2.8	0.0
62	9.0	7.0	2.0	0.0
63	4.2	3.8	0.4	0.0
64	0.8	0.6	0.2	0.0
65	3.2	2.2	1.0	0.0
66	2.4	1.8	0.4	0.2
67	3.0	2.4	0.6	0.0
68	4.4	2.8	1.6	0.0
69	3.8	2.6	1.2	0.0
70	5.8	4.8	1.0	0.0
71	4.0	3.0	1.0	0.0
72	4.8	4.0	0.8	0.0
73	9.0	6.4	2.6	0.0
74	10.0	7.0	3.0	0.0
75	11.4	8.4	2.8	0.2
76	9.0	6.4	2.6	0.0
77	7.2	5.6	1.6	0.0
78	4.4	2.8	1.4	0.2
79	11.6	8.8	2.8	0.0
80	9.2	8.0	1.2	0.0
81	3.2	2.8	0.2	0.2
82	13.6	10.8	2.6	0.2
83	8.6	5.8	2.4	0.4
84	9.4	8.4	1.0	0.0
85	7.0	6.0	1.0	0.0
86	6.0	4.2	1.6	0.2
87	4.6	3.4	1.2	0.0
88	2.6	1.6	0.8	0.2
89	3.6	2.8	0.8	0.0
90	7.0	5.6	1.2	0.2
91	2.2	1.6	0.6	0.0
92	3.0	2.2	0.8	0.0
93	3.6	3.0	0.6	0.0
94	3.2	2.4	0.8	0.0
95	6.0	3.8	2.0	0.2
96	15.2	12.6	2.6	0.0
97	12.2	10.2	2.0	0.0
98	7.2	5.2	2.0	0.0
99	9.4	7.8	1.6	0.0
Total	6.3	4.8	1.4	0.1

## Route 2 Collision Frequency Summaries, Operational Sections of Old Alignment

RTE	CS	Total Collisions	PDO Collisions	Injury Collisions	Fatal Collisions
130	3	2.0	1.4	0.6	0.0
130	4	1.2	0.2	0.4	0.6
130	5	4.2	3.4	0.8	0.0
130	6	2.2	2.2	0.0	0.0
130	7	0.4	0.4	0.0	0.0
130	8	4.0	3.2	0.8	0.0
130	9	10.0	8.2	1.6	0.2
130	10	4.2	3.0	1.2	0.0
590	1	0.4	0.4	0.0	0.0
165	1	0.0	0.0	0.0	0.0
165	2	4.2	2.8	1.2	0.2
102	2	6.4	5.8	0.6	0.0
102	3	3.8	3.6	0.2	0.0
102	4	1.2	1.2	0.0	0.0
102	5	10.0	8.8	1.0	0.2
102	6	16.4	12.4	3.6	0.4
8	1	7.2	5.0	2.2	0.0
8	99	1.4	0.8	0.6	0.0
105	1	1.2	0.6	0.6	0.0
105	2	1.6	0.8	0.6	0.2
105	3	1.2	0.8	0.4	0.0
105	4	6.0	4.4	1.6	0.0
105	5	9.4	7.0	2.4	0.0
105	6	4.6	3.0	1.6	0.0
10	10	3.8	3.0	0.8	0.0
10	11	5.4	4.0	0.8	0.6
10	12	3.2	2.2	0.8	0.2
10	13	7.8	6.0	1.8	0.0
1	17	7.0	4.8	2.2	0.0
1	18	3.6	2.2	1.2	0.2
1	19	3.4	2.4	1.0	0.0
1	20	2.8	2.4	0.4	0.0
1	80	4.4	3.4	0.8	0.2
1	81	1.6	1.6	0.0	0.0
1	82	3.8	1.8	2.0	0.0
1	83	7.8	6.8	1.0	0.0
Homestead Rd	N/A	19.6	15.4	4.2	0.0
128	1	1.8	1.4	0.4	0.0
Total		4.7	3.6	1.0	0.1

## Route 2 Collision Rate Summaries, Old Alignment

CS	Total Collisions (collisions/ mvkm)	PDO Collisions (collisions/ mvkm)	Injury Collisions (collisions/ mvkm)	Fatal Collisions (collisions/ mvkm)
1	0.5919	0.3648	0.1996	0.0275
2	1.1063	0.8265	0.2416	0.0381
3	0.7144	0.4946	0.2015	0.0183
4	0.4946	0.3244	0.1543	0.0158
5	0.4336	0.2787	0.1316	0.0232
6	0.9874	0.5642	0.3527	0.0705
7	0.5458	0.4961	0.0496	0.0000
8	0.4823	0.3554	0.0931	0.0338
9	1.0543	0.7229	0.3113	0.0201
10	0.6365	0.5001	0.1212	0.0152
11	0.4524	0.3694	0.0679	0.0151
12	0.4573	0.3109	0.1280	0.0183
13	0.3318	0.2820	0.0498	0.0000
14	0.3758	0.2742	0.1016	0.0000
15	0.4888	0.3055	0.1692	0.0141
16	0.5266	0.3066	0.1866	0.0333
17	0.4073	0.2715	0.1286	0.0071
18	0.3722	0.2762	0.0841	0.0120
19	0.3499	0.2683	0.0700	0.0117
20	0.2985	0.2052	0.0808	0.0124
21	0.4670	0.3937	0.0687	0.0046
22	0.5515	0.3650	0.1825	0.0041
23	0.4014	0.2711	0.1303	0.0000
24	0.7295	0.5211	0.2084	0.0000
25	0.4541	0.3262	0.1234	0.0044
26	0.2510	0.1004	0.1434	0.0072
27	0.3931	0.2784	0.1065	0.0082
28	0.2067	0.1240	0.0827	0.0000
29	0.6153	0.4297	0.1856	0.0000
30	0.4399	0.3142	0.1257	0.0000
31	0.6763	0.4774	0.1724	0.0265
32	0.5975	0.4596	0.1149	0.0230
33	0.5526	0.4220	0.1206	0.0100
34	0.4082	0.2834	0.1046	0.0202

35	0.2702	0.1922	0.0727	0.0052
36	0.1896	0.1422	0.0474	0.0000
37	0.4869	0.3087	0.1722	0.0059
38	0.4432	0.2854	0.1377	0.0201
39	0.3573	0.2330	0.1036	0.0207
Average	0.5025	0.3519	0.1366	0.0140

### Route 2 Collision Rate Summaries, New Alignment

CS	Total Collisions (collisions/ mvkm)	PDO Collisions (collisions/ mvkm)	Injury Collisions (collisions/ mvkm)	Fatal Collisions (collisions/ mvkm)
01	0.584	0.430	0.128	0.025
02	0.461	0.427	0.034	0.000
03	0.262	0.218	0.038	0.006
04	0.580	0.408	0.165	0.008
05	0.452	0.328	0.125	0.000
06	0.391	0.349	0.042	0.000
07	0.208	0.208	0.000	0.000
08	0.260	0.208	0.052	0.000
09	0.520	0.448	0.071	0.000
10	0.571	0.433	0.118	0.020
11	0.281	0.226	0.055	0.000
12	0.220	0.177	0.043	0.000
13	0.280	0.252	0.029	0.000
14	0.273	0.210	0.063	0.000
15	0.357	0.275	0.072	0.010
16	0.339	0.284	0.046	0.009
17	0.214	0.180	0.034	0.000
18	0.380	0.295	0.084	0.000
19	0.371	0.297	0.074	0.000
20	0.369	0.292	0.068	0.009
21	0.432	0.345	0.087	0.000
22	0.325	0.284	0.041	0.000
23	0.464	0.290	0.161	0.014
24	0.267	0.225	0.042	0.000
25	0.292	0.213	0.070	0.000
26	0.388	0.256	0.132	0.000
27	0.285	0.218	0.057	0.011
28	0.389	0.277	0.112	0.000
29	0.171	0.171	0.000	0.000
30	0.335	0.258	0.077	0.000
31	0.613	0.464	0.149	0.000
32	0.237	0.202	0.024	0.012

33	0.255	0.234	0.021	0.000
34	0.363	0.282	0.081	0.000
35	0.498	0.303	0.195	0.000
36	0.444	0.388	0.056	0.000
37	0.449	0.369	0.067	0.013
38	0.205	0.168	0.037	0.000
39	0.276	0.198	0.075	0.003
61	0.145	0.107	0.038	0.000
62	0.238	0.185	0.053	0.000
63	0.284	0.257	0.027	0.000
64	0.219	0.164	0.055	0.000
65	0.257	0.177	0.080	0.000
66	0.482	0.360	0.082	0.040
67	0.327	0.263	0.064	0.000
68	0.263	0.168	0.095	0.000
69	0.456	0.313	0.143	0.000
70	0.381	0.315	0.066	0.000
71	0.559	0.418	0.141	0.000
72	0.436	0.363	0.073	0.000
73	0.518	0.367	0.151	0.000
74	0.441	0.309	0.132	0.000
75	0.506	0.373	0.124	0.009
76	0.308	0.219	0.089	0.000
77	0.522	0.405	0.117	0.000
78	0.436	0.279	0.138	0.020
79	0.420	0.319	0.102	0.000
80	0.380	0.330	0.050	0.000
81	0.302	0.264	0.019	0.019
82	0.578	0.458	0.111	0.008
83	0.484	0.326	0.135	0.023
84	0.427	0.382	0.045	0.000
85	0.360	0.309	0.051	0.000
86	0.316	0.221	0.084	0.011
87	0.321	0.238	0.083	0.000
88	0.568	0.352	0.173	0.043
89	0.255	0.197	0.057	0.000
90	0.688	0.549	0.119	0.020
91	0.198	0.144	0.054	0.000
92	0.258	0.189	0.069	0.000
93	0.469	0.390	0.078	0.000
94	0.345	0.261	0.084	0.000
95	0.537	0.339	0.181	0.017
96	0.595	0.495	0.100	0.000
97	0.391	0.327	0.064	0.000
98	0.614	0.443	0.170	0.000
99	0.686	0.570	0.116	0.000
Average	0.385	0.298	0.083	0.004

## Route 2 Collision Rate Summaries, Operational Sections of Old Alignment

RTE	CS	Total Collisions (collisions/ mvkm)	PDO Collisions (collisions/ mvkm)	Injury Collisions (collisions/ mvkm)	Fatal Collisions (collisions/ mvkm)
130	3	0.309	0.217	0.093	0.000
130	4	0.130	0.022	0.043	0.065
130	5	0.669	0.542	0.127	0.000
130	6	0.477	0.477	0.000	0.000
130	7	0.172	0.172	0.000	0.000
130	8	0.683	0.547	0.136	0.000
130	9	0.545	0.448	0.086	0.011
130	10	0.664	0.474	0.190	0.000
590	1	0.052	0.052	0.000	0.000
165	1	0.000	0.000	0.000	0.000
165	2	0.676	0.453	0.193	0.031
102	2	2.550	2.303	0.247	0.000
102	3	0.802	0.760	0.042	0.000
102	4	0.283	0.283	0.000	0.000
102	5	1.328	1.169	0.133	0.026
102	6	0.383	0.290	0.084	0.009
8	1	0.140	0.098	0.042	0.000
8	99	0.046	0.026	0.020	0.000
105	1	0.773	0.386	0.386	0.000
105	2	1.037	0.526	0.378	0.133
105	3	0.320	0.215	0.106	0.000
105	4	0.301	0.223	0.078	0.000
105	5	0.678	0.505	0.173	0.000
105	6	0.520	0.334	0.186	0.000
10	10	0.737	0.579	0.158	0.000
10	11	0.690	0.514	0.100	0.076
10	12	0.492	0.338	0.123	0.031
10	13	0.474	0.365	0.109	0.000
1	17	0.141	0.097	0.044	0.000
1	18	0.136	0.083	0.045	0.008
1	19	0.190	0.134	0.056	0.000
1	20	0.126	0.108	0.018	0.000
1	80	0.364	0.281	0.066	0.017
1	81	0.137	0.137	0.000	0.000
1	82	0.217	0.103	0.114	0.000
1	83	0.225	0.197	0.029	0.000
Homestead Rd	N/A	0.968	0.760	0.207	0.000
128	1	0.150	0.117	0.033	0.000
Average		0.489	0.377	0.101	0.011

## **Curriculum Vitae**

Candidate's full name: Jillian DeMerchant

University Attended: University of New Brunswick  
Bachelor of Science in Civil Engineering, BScE  
2010-2014