# Quantifying the Benefits of Road Safety Audits

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## *Abstract*

Although the Road Safety Audit (RSA) process is gaining widespread application throughout North America, little is understood about the net benefits being derived for design-build projects. A better understanding of collision reduction and mitigation is necessary to allow an objective economic evaluation of the RSA process. This study attempted to quantify the benefits of RSAs through a retrospective case study of the first major design-build RSA that was conducted in Canada – the Fredericton-Moncton Highway project.

The Fredericton-Moncton Highway's safety performance since it has opened was contrasted against other collision rates considered to be representative of those expected for this type of facility. Any difference between observed and expected rates can, in part, be attributed to the RSA process. Expected collision rates were developed using data from five similar facilities within the region and the output of six collision prediction models. The comparison of average collision rates for similar facilities and the Fredericton-Moncton Highway indicated that applying RSAs contributed to an estimated 29 percent reduction in the overall collision rate. This represents a benefit-cost ratio of 9:1. Similarly, a comparison of the output from collision prediction models and the observed collision rates indicated a total reduction of 19 percent and a benefit-cost ratio of 16:1. While the improved safety performance of the Fredericton-Moncton Highway may not be solely attributed to the inclusion of the RSA process, the results of this study would suggest it has made a substantial contribution.

## *Résumé*

Même si le processus de vérification de la sécurité routière (VSR) est de plus en plus répandu en Amérique du Nord, on connaît très peu les avantages nets des projets de conception-construction. Il est nécessaire de mieux comprendre la réduction du nombre et des conséquences des collisions pour permettre une évaluation économique objective du processus de VSR. Ces travaux visaient à quantifier les avantages des VSR en faisant une étude de cas rétrospective de la première grande VSR de conception-construction qui a été effectuée au Canada – le projet d'autoroute Fredericton-Moncton.

Depuis son ouverture, on a comparé le niveau de sécurité de l'autoroute Fredericton-Moncton à d'autres taux de collisions qui devraient représenter les chiffres auxquels on peut s'attendre sur ce type d'infrastructure. Toute différence entre les taux observés et ceux prévus peut être attribuée, en partie, au processus de VSR. On a élaboré les taux de collisions prévus en utilisant les données de cinq infrastructures similaires dans la région et les résultats de six modèles de prévision des collisions. La comparaison des taux moyens de collisions d'infrastructures similaires et des taux de

l'autoroute Fredericton-Moncton montre que l'application des VSR a permis une réduction estimative de 29 % des taux de collisions moyens. Ceci représente un ratio coûts-avantages de 9:1. Par ailleurs, une comparaison des résultats des modèles de prévision des collisions et des taux de collisions observés montre une réduction totale de 19 % et un ratio coûts-avantages de 16:1. Même si le niveau de sécurité accru de l'autoroute Fredericton-Moncton n'est peut-être pas seulement attribuable au processus de VSR, les résultats de cette étude prouvent qu'il en a grandement profité.

# 1. Introduction

Engineers have traditionally addressed road safety problems through blackspot analysis by ranking dangerous sites and treating only those considered high on a priority list. This method is reactive and can only be applied to existing road systems with an established history of collisions. Road Safety Audits (RSAs) were introduced to North American authorities in the mid-1990s as a more proactive approach used to identify problems earlier in the planning, design or construction stages [1]. Unfortunately, little is understood regarding the economic efficiency of RSAs when applied specifically to design-build projects. The benefits of applying RSAs to existing roads (sometimes referred to as In-Service Safety Reviews) have been extensively documented in the literature through before-and-after type analyses [2-10]. This study undertook a retrospective analysis of the benefits and costs associated with the first RSA conducted on a major design-build project in Canada; namely, the Fredericton-Moncton Highway (FMH) project.

The Transportation Association of Canada (TAC) defines an RSA as "a formal and independent safety performance review of a road transportation project by an experienced team of safety specialists, addressing the safety for all road users" [11]. The RSA is a tightly structured process that helps to ensure that all safety issues are addressed and that every opportunity to incorporate cost-effective improvements, beyond compliance with minimum design code, is taken. RSAs can be performed at one or more stages of a new roadway project including feasibility (planning), draft (preliminary/layout) design, detail design, pre-opening, and post-opening for new roadway projects.

A unique aspect of this study was its approach to quantify the residual benefits of the audit process by comparing actual collision rates with those *expected* of this facility. Expected rates were developed using two independent methods. Empirical collision rates were gathered from similar facilities within the region and contrasted to the FMH, while the second approach relied on the output from several collision prediction models (CPM) developed specifically for freeways.

The Fredericton-Moncton Highway project was completed in 2001 and included the construction of a 196-kilometre four-lane divided, controlled access highway from Jewetts Cove (west of Fredericton) to Magnetic Hill (near Moncton). The FMH has a design speed of 120 km/h and a posted speed limit of 110 km/h.

A total of 24 audits were conducted between February 1998 and October 2001. The approximate engineering cost of conducting the audits was $142,000. During the RSA process, the audit team determines and prioritizes improvement recommendations based on experience and capital expenditure available. The estimated cost of implementing the accepted recommendations was approximately $2,801,000 [12]. The bulk of these additional costs were associated with changes to guiderail, barriers, signing and grading. The total construction cost of the Fredericton-Moncton Highway project was in excess of $584,000,000; therefore, the total RSA cost only represented an incremental expenditure of less than ½ percent.

## 2. Background

A literature review was conducted to gain a better understanding of the development of RSA practice in the United Kingdom (U.K.), Australia, New Zealand, United States of America (U.S.A.), and Canada [13]. The literature identified the U.K. and Australia as the continued leaders in implementing RSA techniques. RSAs are now mandatory in the U.K. for all trunk roads and freeways (for both new and existing facilities). Australia and New Zealand have put into practice policies and regulations ensuring that a percentage of projects receive RSAs. North America has not initiated the same level of practice as the U.K. or Australia and New Zealand; however, the use of RSAs continues to grow particularly for larger private-public-partnership projects.

Ten previous studies were identified that attempted to quantify the benefits of RSAs [13]. Results are extremely varied as the projects reviewed varied greatly in size and type. Most of the studies evaluated the outcome of RSAs targeted to existing facilities and failed to evaluate the benefits of RSAs for the construction of new projects. What little work exists for design-build projects often focuses on a single design stage and fails to quantify the overall benefits of the entire process.

## 3. Methodology

The collision rates for the Fredericton-Moncton Highway were calculated for each severity level, (property damage only, injury or fatality) based on the observed frequencies since opening in 2001, average annual daily traffic volumes (AADT), and length of study sections. This provided collision rates for each type of crash as well as an average overall collision rate for the FMH. Rates were developed separately for mainline and interchange related collisions.

In order to isolate the benefits associated with having undertaken a series RSA reviews, the observed collision rates noted above were contrasted against rates to be expected for this type of facility. To that end, a two-pronged approach was taken where collision rates for similar facilities and those derived from collision prediction models (CPM) were used.

Collision rates for five similar existing facilities in New Brunswick, Nova Scotia, and Maine were developed. A premise of this study was that collision rates for facilities that were not exposed to RSAs would differ from those that received RSAs. Care was taken to select existing highways that are nearby to normalize for regional differences (e.g., driver behaviour, weather, etc.) and with similar traffic and design characteristics (volumes, composition, operating/design speeds, etc.). All facilities selected are 4-lane, controlled access highways with either 110 km/h, 100 km/h or 65 mph speed limits. Accident reporting thresholds ($1,000 minimum property damage) were consistent as well.

Estimated collision frequency and subsequent collision rates were developed using CPMs for comparison purposes. Again, the study hypothesized that collision rates developed using CPMs would differ from a project that was subjected to an RSA process. A comparison of CPMs and the observed FMH collision rates was conducted to highlight the benefits of RSAs.

A synthesis of average collision costs was developed from various transportation agencies. The values were normalized to a common year (2006) and currency to allow for a direct comparison. The data in Table 1 indicate the collision cost estimates per year developed for New Brunswick highways based on severity [13]. These values incorporate a weighted average of the cost

components valued by different provinces and territories for use in benefit-cost analyses of highway projects [14].

The total cost associated with conducting the Fredericton-Moncton Highway RSA and implementing the recommendations was $2,943,000. Annualizing these costs over a 30-year project life, the annual worth of the costs associated with the RSA was calculated to be $191,000 per year.

**Table 1: Collision Costs Estimates for New Brunswick Highways**
(normalized to 2006 Canadian Dollars)

| Severity | Cost Estimate ( per person) |
|---|---|
| Total | $69,112 |
| Severe* | $199,476 |
| Fatality | $ 4,337,361 |
| Injury | $ 59,612 |
| PDO | $ 6,142 |

* weighted average of fatalities and injuries.

## 4. Results

Separate analyses were undertaken to develop the expected collision rates for the FMH based on observations from similar facilities and CPMs. These results were then utilized to conduct a financial review of the benefits derived from the RSA process. The following sections synthesize these findings.

## 4.1 Comparison to Similar Facilities

The observed collision rates on the FMH were compared to those of other similar facilities. These facilities included sections of Highway 1 and 15 in New Brunswick, sections of Highway 102 and 104 in Nova Scotia, and the northern portion of Interstate 95 in Maine. As noted, they were specifically selected to normalize for design standards, traffic, and regional characteristics. A comparison of the FMH with other similar facilities that have not received RSAs should delineate some of the benefit of conducting RSAs.

The data in Table 2 indicate the development of average collision rates for the similar facilities during the same time-frame that the FMH has been open for service. The data in Table 3 and Figure 1 provide a comparison between the Fredericton-Moncton Highway and average collision rate for similar facilities.

Values found to be statistically different (based on *t*-tests and level of significance of 5%) than those for the FHM are shown in italics. Note that statistical analysis could not be performed on the I-95 data based on the configuration of the data provided.

## Table 2: Average Collision Rates of Similar Facilities

| | NB Highway 1 | NB Highway 15 | NS Highway 102 | NS Highway 104 | ME Interstate 95 | Average Collision Rate |
|---|---|---|---|---|---|---|
| **Severity** | **collision / mvkm** | **collision / mvkm** | **collision / mvkm** | **collision / mvkm** | **collision / mvkm** | **collision / mvkm** |
| PDO | ***0.361*** | ***0.564*** | ***0.220*** | ***0.206*** | 0.431 | 0.327 |
| Injury | ***0.163*** | ***0.241*** | ***0.114*** | ***0.112*** | 0.208 | 0.159 |
| Fatality | 0.006 | 0.012 | 0.002 | 0.005 | 0.003 | 0.004 |
| Severe* | ***0.169*** | ***0.253*** | ***0.116*** | ***0.117*** | 0.211 | 0.163 |
| Total | ***0.531*** | ***0.817*** | 0.336 | ***0.323*** | 0.643 | 0.490 |
| **Length** | 144 km | 27 km | 103 km | 166 km | 190 km | |

*fatalities plus injuries.
Values statistically different than FHM are shown in ***italics***. (Note: statistical analysis could not be performed on the I-95 data based on configuration of the data provided).

## Table 3: Comparison of FMH with Similar Facilities

| | Avg. of Similar Facilities | | Fredericton-Moncton | | Difference | |
|---|---|---|---|---|---|---|
| **Severity** | **Collision Rate (collisions / mvkm)** | **Equivalent Collisions / yr** | **Collision Rate (collisions /mvkm)** | **Collisions / yr** | **Collisions / yr** | **Cost Savings / yr** |
| PDO | 0.327 | 177.1 | 0.249 | 134.8 | 42.4 | $ 260,000 |
| Injury | 0.159 | 85.9 | 0.093 | 50.3 | 35.6 | $ 2,123,000 |
| Fatality | 0.004 | 2.4 | 0.005 | 2.5 | -0.1 | -$ 585,000 |
| Severe* | 0.163 | 88.2 | 0.097 | 52.8 | 35.5 | $ 1,538,000 |
| Total | 0.490 | 265.4 | 0.346 | 187.5 | 77.9 | $ 1,798,000 |

*fatalities plus injuries.

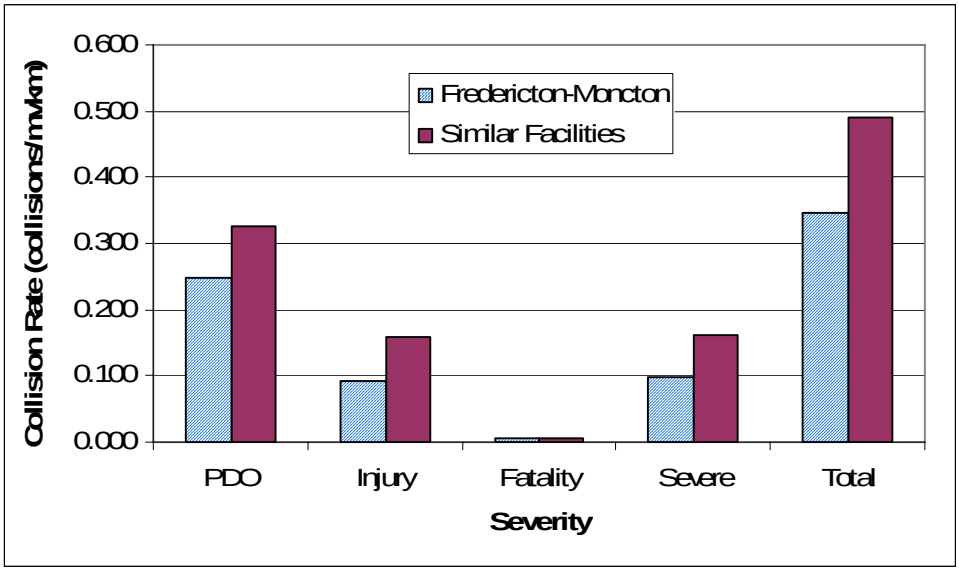


**Figure 1: Collision Rates of Similar Facilities**

Overall, the similar facilities yielded an average collision rate greater than the FMH for four of the five severity ratings. The FMH experiences slightly more fatal collisions than the calculated average for the similar facilities, however, the results are based on very small frequencies and are not statistically different. Larger data sets or longer observation periods may provide differences in fatalities more consistent with what was observed with the property damage and injury collision categories. The overall collision rate for the FMH is shown to be nearly 29% lower than the average of similar facilities. This translates into a benefit of nearly 78 fewer collisions per year on this facility.

It is interesting to note that injury collisions show a 42% reduction compared to 24% for property-damage collisions. This would suggest that not only has the overall frequency been reduced, but the severity mitigated as well.

## 4.2 Comparison to Collision Prediction Models

Estimated collision frequencies developed using CPMs were compared with observed collision rates for the FMH. This effectively provided another approach to contrast the FMH collision rates with what are essentially comparable averages for similar facilities. Comparisons between CPMs and the FMH were conducted for both mainline and interchange crashes. The literature review identified six collision prediction models developed to estimate crash frequency on rural four-lane divided highways. Limited research in this area hindered the ability to compare the FMH collision rates with the output from numerous CPMs. Much more extensive research has been completed to develop CPMs for two-lane undivided highways.

Four different mainline CPM models were taken from work by Hadi [15], Persaud and Dzbik [16], Wang [17], and the Texas Transport Institute [18]. Similarly, five CPMs used to develop estimates separately for the interchanges were based on models developed by Khorashadi , Bauer and Harwood , and the Texas Transport Institute [13,15 and 18].

Figures 2 and 3 depict the differences between model-predicted values for mainline and interchanges, respectively, against the collision rates actually observed on the FMH. CPM outputs from different models were averaged and then plotted. Note that some models explicitly predict collisions for the “severe” category rather than delineate injury and fatal collisions separately. Consequently the values depicted in the figures for CPM rates for injury and fatal collisions do not necessary sum to those values shown for the “severe” group. The magnitude of the differences between the CPM predictions and those observed are striking, particularly for interchanges which show large discrepancies across all severity categories. Interestingly, the overall difference depicted in Figure 2 for just the mainlines is relatively small (about 15%); however, the FMH has experienced proportionately fewer severe collisions again suggesting that collision consequence has been mitigated more than collision frequency.

An average collision rate based on severity was developed for the four different types of mainline CPMs and five different types of interchange CPMs. The data in Table 4 provide a composite comparison of the average collision rates for all crashes developed using CPMs contrasted against the collision experience observed on the FMH.

The results indicate that the FMH has experienced over 19% fewer collisions than what the CPMs suggest would be expected from this facility. This translates into an overall benefit of 45 fewer collisions per year for this highway project. Observed rates are lower across all severity categories with the most marked reductions for collisions involving casualties. Injury collisions are 44% less than what the CPMs predict, while property-damage are only 7% less.

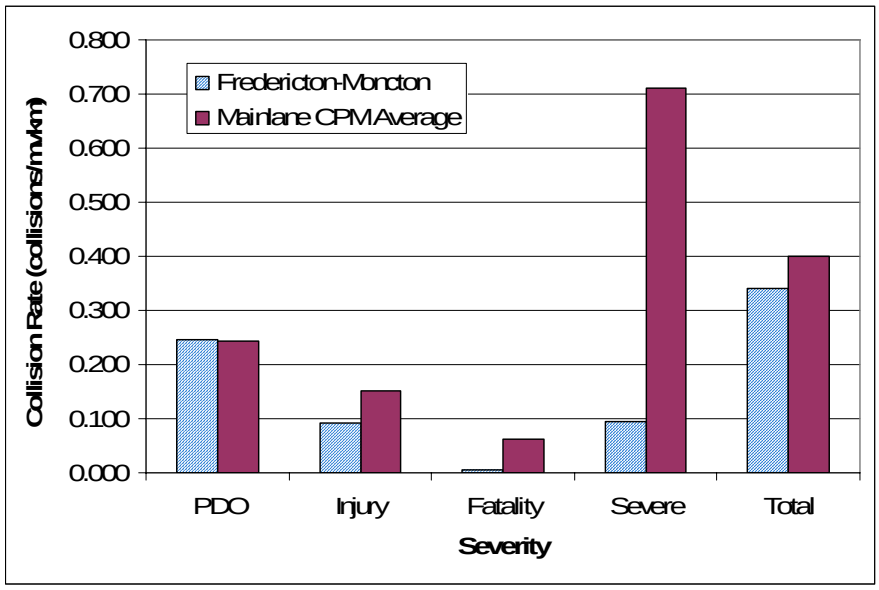


**Figure 2: Mainline CPM Rates vs. FMH Observed**

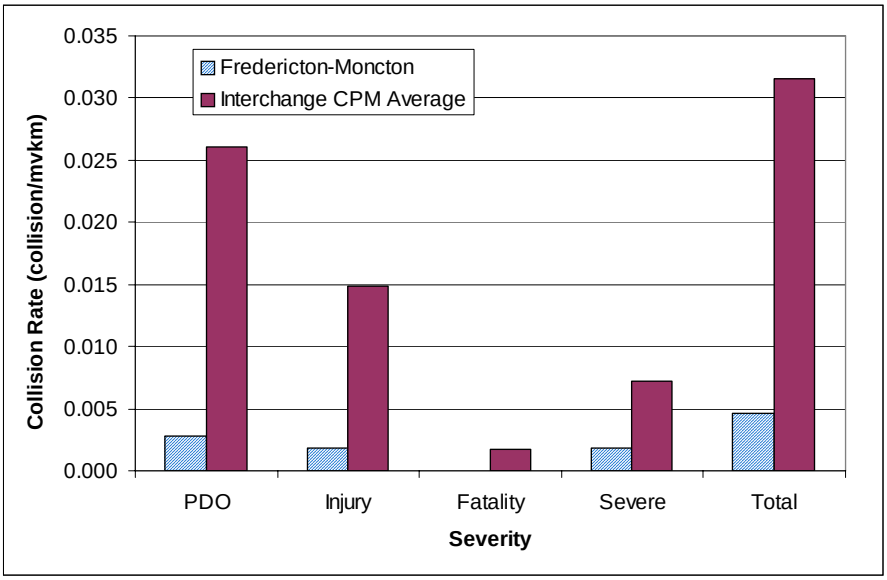


**Figure 3: Interchange CPM Rates vs. FMH Observed**

**Table 4: Collision Prediction Models Comparison**

| Severity | Collision Prediction Models | | Fredericton-Moncton | | Difference | |
|---|---|---|---|---|---|---|
| | Average Collision Rate (collision / mvkm) | Estimated Collisions / year | Collision Rate (collision / mvkm) | Observed Collisions / year | Collisions / year | Cost Savings / yr |
| PDO | 0.268 | 145 | 0.249 | 135 | 10 | $ 65,000 |
| Injury | 0.166 | 90 | 0.093 | 50 | 40 | $ 2,349,000 |
| Fatality | 0.064 | 35 | 0.005 | 3 | 32 | $ 139,373,000 |
| Severe* | 0.719 | 390 | 0.098 | 53 | 337 | $ 67,160,000 |
| Total** | 0.431 | 233 | 0.347 | 188 | 45 | $ 3,151,000 |

*weighted average of fatalities plus injuries.
**average of all sources (growthed to total where necessary).

## 4.3 Financial Considerations

A comparison of the costs and subsequent benefits derived from the RSA process was undertaken on the basis that the estimated collision reductions represent the benefit of the process.

A comparison of the overall average collision cost for the FMH versus the average of similar facilities indicated that applying RSAs contributed to an estimated total cost savings of $1,798,000 per year for the FMH. The bulk of these benefits are associated with reductions in injury producing-collisions. When the annualized cost to undertake and implement the RSAs is considered, a benefit-cost ratio of approximately 9:1 is realized.

Contrasting the overall average collision costs based on the mainline CPMs with those observed for the FMH indicated that applying RSAs contributed to an estimated total cost savings of $2,142,000 per year. A similar comparison with the interchange collisions on the FMH versus those estimated using CPMs indicted that applying RSAs contributed to an estimated total cost savings of $1,009,000 per year. Overall, the average total cost savings (total mainline CPM cost savings plus total interchange CPM cost savings) for CPM estimates equals $3,151,000 per year. The corresponding benefit-cost ratio derived using CPMs to estimate the net benefits was determined to be 16:1.

Either approach used to estimate cost savings indicates a strong positive economic benefit associated with the application of an RSA for a design-build project.

## 5. Discussion

This study has attempted to isolate the net safety benefit associated with the implementation of an RSA process throughout the planning, design and construction stages of a major highway project. A premise has been that the difference between observed collision rates versus estimates of *expected* rates would be solely attributed to the RSA process. This is not a conservative assumption. Collision Prediction Models are not without error and it is impossible to capture

experience from existing similar facilities that have identical operational or design characteristics. Nevertheless, the values of benefit-cost ratios developed in this study should serve as a reasonable guidepost when considering the financial implications of instituting an RSA study.

One mitigating consideration is that there are inherently other financial benefits that are derived through the inclusion of the RSA process. For example, there should be fewer blackspots develop during operation that would require (often expensive) post-construction remediation. Further, there should be fewer omissions or errors made at the design stage that are not caught until late in the build process.

Another mitigating factor is the 30-year time-frame used for the development of benefit-cost ratios. It is quite reasonable to assume that the safety benefits will be reaped well beyond the 30-year window used to annualize RSA costs.

Most of the estimates for benefit-cost ratios reported in the literature associated with RSAs have been developed for upgrade projects for existing highways and generally range from 10 to 20:1 (Gunter, 2007). While these cannot be directly compared to the benefit-cost ratios developed in this study for a design-build project, it is noteworthy that they are at least similar in magnitude.

## 6. Conclusions

The following conclusions were drawn from the various collision rate comparisons completed as part of this research:

- The FMH exhibited a collision rate that was 0.144 collisions per million-vehicle-kilometres lower than the average rate observed for similar facilities within the region. Based on this comparison, it was inferred that applying RSAs contributed to a 29 percent reduction in the overall collision rate. Furthermore, a comparison of collision rates by severity indicated that applying RSAs contributed to a reduction in PDO and injury crashes of 24 and 42 percent, respectively. No statistical difference was noted between the rate of fatal collisions between the Fredericton-Moncton Highway and similar facilities.

- The Fredericton-Moncton Highway exhibited a collision rate that was 0.084 collisions per million-vehicle-kilometres lower than the combined collision rates estimated using mainline and interchange collision prediction models (CPMs). This finding suggests that applying RSAs contributed to an estimated reduction in the overall collision rate of 19 percent. The output of the models indicate that actual mainline collisions are over 14 percent lower, while interchange collisions are nearly 84 percent lower than predicted.

- The implementation of RSAs when comparing the safety performance of the Fredericton-Moncton Highway with similar facilities in the region resulted in an estimated benefit-cost ratio of 9:1.

- The implementation of RSAs when comparing the safety performance of the Fredericton-Moncton Highway with CPMs resulted in an estimated benefit-cost ratio of 16:1.

Although the resulting benefit-cost ratios derived from the two approaches are quite different, both suggest a very strong economic argument for the inclusion of RSAs in design-build projects. It is likely that the true benefit-cost ratio is closer to that found for the comparison of similar regional facilities (9:1) since CPMs would not account for characteristics intrinsic to the Atlantic Canada

highway system. Nevertheless, the estimated payback for RSAs undertaken on design-build projects was found to be between 1 to 2 years.

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