BC MINISTRY OF TRANSPORTATION

SAFETY ANALYSIS OF COLLISION-PRONE LOCATIONS AND SECTIONS BRITISH COLUMBIA

FINAL REPORT

OPUS

BC MINISTRY OF TRANSPORTATION

SAFETY ANALYSIS OF COLLISION-PRONE LOCATIONS AND SECTIONS BRITISH COLUMBIA

Final Report

Opus Hamilton Consultants Ltd.

Prepared by:

Margaret Gibbs, P.Eng., PTOE
Senior Transportation Engineer

Kanny Chow, P.Eng, PTOE
Senior Transportation Engineer

Sany R. Zein, M.Eng., P.Eng.
Vice-President (Projects)

Reviewed by:

Sarah Rocchi, P.Eng., PTOE
Senior Project Manager

February 2009
H-80010.00

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

1.1 Background and Purpose

The British Columbia Ministry of Transportation's 2006 Provincial Highway System-Level Performance Analysis Annual Report lists 265 Collision Prone Locations (CPLs) and 164 Collision Prone Sections (CPSs) on the provincial numbered highway system. These sites were identified using the Ministry's Highway Accident System (HAS) that summarized collision data for the years 2000 to 2004 (or for some intersections, years 2001 to 2005). The purpose of identifying these CPLs and CPSs was to potentially determine the safety issues and identify mitigating measures to reduce the collision propensity. Many of these sites have already been analyzed or are currently in a project development phase because they are good candidates for capital improvements in the short- to mid-term period. However, there remain a number of sites that have not been analyzed in any detail. The Ministry has therefore initiated this study to perform detailed safety analyses on 22 of these sites - 11 CPLs and 11 CPSs.

1.2 Study Locations and Sections

The list of the selected CPLs and CPSs are summarized in TABLES 1.1 and 1.2, and are shown spatially in FIGURE 1.1.

TABLE 1.1 COLLISION PRONE LOCATIONS

CPL #	REGION	MUNICIPALITY	HIGHWAY *	CROSS STREET/LOCATION
1	Vancouver Island	Saanich	17	Sayward Rd
2	Vancouver Island	Saanich	1	Tillicum Rd
3	Vancouver Island	South of Nanaimo	1	Morden Rd
4	Lower Mainland	West Vancouver	1 (westbound)	Taylor Wy
5	Lower Mainland	West Vancouver	1 (eastbound)	Taylor Wy
6	Lower Mainland	West Vancouver	99	Lions Gate Bridge North Abutment
7	Southern Interior	Penticton	97	Penticton Chnl. Pkwy / Skaha Lake Rd
8	Northern Region	Prince George	97	Highway 16
9	Northern Region	Prince George	16	Cowart Rd./ Vance Rd
10	Northern Region	Prince George	16	Ferry Ave
11	Northern Region	Prince George	97	22nd Ave

* Site includes both directions if no direction specified

TABLE 1.2 COLLISION PRONE SECTIONS

CPS #	REGION	MUNICIPALITY	HIGHWAY *	DESCRIPTION
1	Vancouver Island	Saanich	17 (northbound)	1.2 km of freeway at the McKenzie Avenue Interchange including onramp
2	Vancouver Island	Lantzville	19	1.7 km of highway including Nanoose Rest Area
3	Lower Mainland	Delta and Richmond	99 (northbound)	3.2 km of freeway between Hwy 17 and Steveston Underpass
4	Lower Mainland	West Vancouver	1 (westbound)	1 km of freeway including onramp from Taylor Way
5	Lower Mainland	Abbotsford	1 (westbound)	1.6 km of freeway including Clearbrook Road Interchange on and off ramps
6	Lower Mainland	Agassiz	9	South end of Agassiz/Rosedale Bridge
7	Southern Interior	Approximately 14 km west of Princeton	3	1.8 km of rural 2-lane highway including Whipsaw Creek Bridge, and a number of pullouts and minor accesses
8	Southern Interior	Approximately 28 km west of Princeton	3	1.7 km of rural 2-lane highway including a stop controlled intersection
9	Southern Interior	Approximately 22 km west of Peachland	97C (westbound)	1.7 km of freeway including Brenda Mine Road Chain up area
10	Southern Interior	Approximately 10 km south of Merritt	5 (southbound)	1.1 km of freeway including Comstock Road Interchange
11	Southern Interior	Approximately 42 km north of Hope	5 (southbound)	3.6 km of freeway including Ottomite Bridge and the Great Bear Snowshed

* Site includes both directions if no direction specified

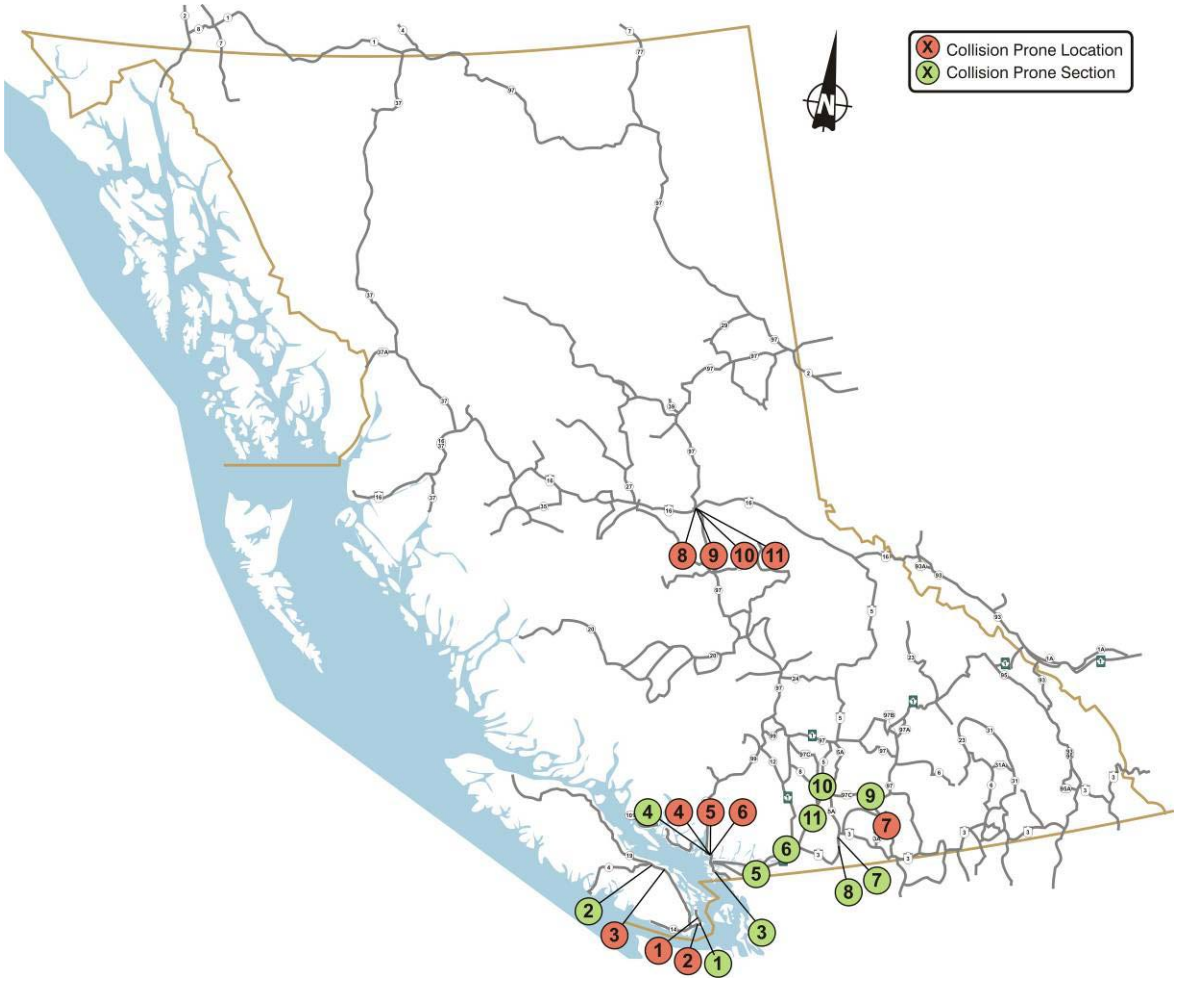


FIGURE 1.1 COLLISION PRONE SITES

1.3 Study Tasks

The overall objective of this assignment is to develop a prioritized list of feasible and economical safety mitigation measures that the Ministry can consider for implementation in order to reduce the risk of crashes at the selected 22 sites.

To achieve this objective, the following Tasks were completed:

1. Verify that the sites identified by HAS are indeed experiencing a high crash risk that warrants intervention;
2. Visit and analyze the sites and define what the problems and issues are, including thorough discussions with local stakeholders;
3. Develop mitigating measures for improving the safety performance of the sites;
4. Discuss the mitigating measures with the Ministry;
5. Evaluate the options, prepare cost estimates, conduct a benefit/cost evaluation, and recommend the optimal mitigation measures at each site; and,
6. Prioritize the mitigation measures from all the sites, and document the results of the analysis to facilitate future implementation.

2.0 METHOD

Analysis for all CPL's and CPS's consisted of the following items:

- Collision Analysis
- Site Visits
- Stakeholder Discussions
- Definition of Problems , Issues and Proposed Countermeasures

Summaries of the analyses of these items for each of the sites are provided in APPENDICES A through V.

All the necessary and available information to complete the above items have been obtained from the Ministry, including access to the latest HAS, traffic volumes, PhotoLog, and LKI sources and information. Also, the information and data used to generate the list of 22 collision prone locations and sections were reviewed and possible sources of error and uncertainty were discussed with the Ministry. Moreover, a list of relevant stakeholders and their contact information was obtained from the Ministry. The stakeholders mostly consisted of local police, ICBC, and Ministry (Regional and District) staff and highway maintenance contractor, and are shown in APPENDIX W.

2.1 Collision Analysis

A. Collision Data and Desktop Quality Check

The HAS data provided by the Ministry was used in the collision analysis. At least five complete years of collision data for each location (varying from 2000 to 2007) were provided, and included the following fields:

- highway number and direction;
- LKI;
- date and time;
- collision type;
- collision severity;
- contributing factors;
- surface condition; and,
- weather.

Using the available information on-hand and on-line, a desktop quality check of the provided HAS data was conducted to identify any significant errors, omissions, gaps in logic, incomplete / out of date data and inapplicable assumptions in the 2000-to-2004 (or 2001-to-2005) HAS analysis that may have contributed to sites being erroneously identified as collision prone. In verifying the magnitude of the safety problem at each CPL and CPS, various traditional benchmarks were used, including:

a. Provincial average collision rate
    i. By facility type and classification

b. Regional average collision rate (by facility and road class)
    i. South Coast Region
    ii. Vancouver Island Region
    iii. Northern Region
    iv. Southern Interior Region

Rates were calculated using vehicle volumes provided on-line by the Ministry and the 2000-to-2004 (or 2001-to-2005 where applicable) frequencies to maintain consistency with the 2006 Provincial Highway System-Level Performance Analysis Annual Report. To correspond to the HAS analysis, traffic volumes dated 2000 to 2005 were used where possible.

As a further check, Collision Prediction Models (CPMs) developed by Ministry staff in conjunction with the University of British Columbia were used to quantify expected safety performance. The CPMs are shown in APPENDIX X and the potential for improvement was measured by comparing the difference between the actual and predicted performance. True collision prone locations have higher-than-predicted crash frequencies. The desktop quality check indicated that all sites are collision prone.

B. Detailed Analysis

The provided HAS data was further reviewed by the available fields. Where possible, relevant collision characteristics were compared to British Columbia regional averages provided by the Ministry from 2000 to 2006. The monthly, collision type, surface type, and severity characteristics of each collision prone site were compared to the provincial averages of the respected region (Lower Mainland and Vancouver Island, Northern Region, Southern Interior) and notable findings were detailed. These detailed analyses are summarized in TABLE 2 for each site in APPENDICES A to V. A sample of the tables is shown in TABLE 2.1.

TABLE 2.1 EXAMPLE OF TABLES 1 AND 2 FROM APPENDICES A THROUGH V

(from APPENDIX B: Highway 17 and Tillicum Road Intersection – CPL #2)

COLLISION DATA CATEGORY	STUDY LOCATION		PREDICTED/AVERAGE	
	VALUE	SOURCE	VALUE	SOURCE
Collision Frequency	73 per 5 years	HAS, 2000-2004[1]	32 per 5 years	Collision Prediction Model[2]
Two-way AADT	27,360 (Hwy 17) 18,200 (Tillicum)	MOT, 2005	n/a	n/a
Collision Rate[3]	0.88 collisions/MEV	Calculated, HAS[4]	0.14 collisions/MEV	BC MOT Average Provincial Collision Rates (2000-2004) for Urban Expressway Divided 4 Lanes, at intersection, over 20,000 vpd

1 - Collision diagram shows collision frequency for 2000 to 2006 whereas TABLE B-1 uses collision frequency from 2000 to 2004 to match MOT rates time period

2 - Collision Prediction Model Used: Four-Leg Signalized Intersections

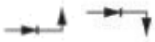
3 - Both Major and Minor Road AADT were used to estimate MEV and to calculate the collision rate

4 - Calculated using HAS data

TRENDS	STUDY LOCATION		PREDICTED/AVERAGE	
	VALUE	SOURCE	VALUE	SOURCE
Month	August (14%)	HAS, 2000-2006	August (9%)	MOT, Lower Mainland Region Statistics (2000-2006)
Collision Type	Rear End (58%)	HAS, 2000-2006	Rear End (28%)	MOT, Lower Mainland Region Statistics (2000-2006)
Road Surface	Wet, Ice (34%)	HAS, 2000-2006	Wet, Ice (41%)	MOT, Lower Mainland Region Statistics (2000-2006)
Severity	Injury (48%) PDO (52%)	HAS, 2000-2006	Fatal (1%) Injury (45%) PDO (54%)	MOT, Lower Mainland Region Statistics (2000-2006)

Using the site layout and the LKI information for each collision, a spatial collision diagram for each site was also prepared. The diagram indicates the location and direction of the collisions by type using the symbols summarized in TABLE 2.2. The severity of each collision is indicated by colour (green, red, and blue for fatal, injury, and property damage only, respectively). These collision diagrams are shown for each site in APPENDICES A to V.

TABLE 2.2 COLLISION TYPE DIAGRAM SYMBOLS

COLLISION TYPE	SYMBOL
Rear-End	
Head-On	
Sideswipe	
Left/Right Rear-End	
Overtaking	
Off Road Left/Right	
Angle	
Left-Turn Opposing	
Left/Right Crossing	
Involving Animal	

It is not possible to show all the collisions on the crash diagrams as some collisions do not have adequate location or direction information. The collisions on the intersection collision diagrams represent collisions located 100 metres on either side of the intersection, and the collisions on the sections collision diagrams contain collisions located within the LKI specified by the Ministry for each section.

2.2 Site Visits

Each CPL and CPS site was visited by at least one senior member of Opus Hamilton staff to understand the physical and traffic characteristics at each location. At each site visit, the following tasks were conducted:

- Conducted drive-throughs;
- Walked the site;
- Observed traffic conditions;
- Recorded geometric, roadside and operational features that affect safety performance; and,
- Took photographs.

The on-site observations are shown for each site in APPENDICES A to V.

Prior to site visits, Ministry staff and local stakeholder representatives from the police and ICBC were also invited to join Opus Hamilton staff at the sites.

2.3 Stakeholder Discussions

To provide further insight for each site, local stakeholders (consisting of Ministry staff at the Regional and District level, local police, municipal staff where appropriate, ICBC representatives, and highway maintenance contractors) were invited to meet with Opus Hamilton staff. These stakeholder discussions took place around the same time as the site visits, at either a pre-arranged location or on the sites. If possible, information summarized by Opus Hamilton such as collision details, collision diagrams, traffic volumes, and basic site layout photos were presented at these meetings. Stakeholders that were unable to attend were invited to provide comments.

The stakeholders were specifically asked the following:

- What they know locally and from first hand knowledge about the site;
- Whether the site is locally perceived as a high risk location;
- Details of any specific incidents or crashes that the stakeholders are aware of, as well as non-reported incidents and near-misses;

- What road safety problems and issues have been previously identified or discussed;
- What safety solutions have been (or should be) considered; and,
- The local context of the site, including constraints and opportunities for improvement.

The stakeholders' comments are summarized for each site in APPENDICES A to V.

2.4 Identification of Problems, Issues, and Mitigating Measures

The results obtained from the previous sections were used to prepare the identification of problems, issues, and mitigating measures at each site.

The problems and issues are categorized as follows:

- Geometric: for example, horizontal alignment; vertical alignment; lane width; pedestrian / bike facilities.
- Operational: for example, congestion; queuing; traffic control.
- Roadside: for example, clear-zone; access driveways, fixed-objects.
- Environmental: for example, severe winter weather conditions; wild-life; sun glare.

In many cases, a combination of factors resulted in more pronounced problems and issues. The combinations contributing to crash causation were identified. The definition of problems and issues were summarized for each site and are presented in APPENDICES A to V.

Based on the identified safety issues, mitigating measures that are appropriate for short term, medium term, and longer term were identified for each site. The solution options clearly link the problems and issues. The solution options are presented in APPENDICES A to V.

2.5 Evaluation of the Options and Preparation of Cost Estimates

After discussing the identified mitigating measures for each CPL and CPS with the Ministry staff, the options were evaluated based on the following criteria:

Safety effectiveness
The safety effectiveness was evaluated based on the assumed collision reduction factors for the proposed countermeasure. Collision reduction factors were from the reports Desktop Reference for Crash Reduction Factors, (FHWA, September 2007) and The Canadian Guide to In-service Road Safety Reviews (Transportation Association of Canada, January 2004). For unique countermeasures not addressed by either the FHWA or TAC documents, engineering judgement was used to estimate the collision reduction factor for the countermeasure based on a review of the site conditions and collision patterns. For example, if an access were be closed, it would be assumed that all collisions related to that access would be reduced by 100 percent. If collisions were assessed to be caused by unusual intersection configuration, engineering judgement was used to estimate the impact on collisions by providing diagrammatic signage. Although some collision reduction factors may be higher than expected for site-specific locations, for this study the collision reduction was estimated as accurately as practicable.

The types of collisions that may be reduced by the suggested mitigating measures are also identified. The suggested options were then ranked based on their collision reduction factors on a scale of 1 to 5 where 1 represents countermeasures that reduce total collisions by less than 5 percent and 5 represents countermeasures which reduce total collisions by 20 or more percent.

Impact on traffic efficiency
The impact of each option on traffic efficiency was estimated by experienced traffic engineers based on their site observations and review of traffic volumes. This was also ranked on a scale of 1 to 5 where 1 means decreased efficiency, 3 means no impact, and 5 means improved efficiency. For example, providing additional lanes are expected to improve efficiency, providing protected-only phasing is expected to reduce efficiency, and reducing driver confusion is expected to improve efficiency.

Impact on right-of-way

All the medium and long term options were evaluated based on their impacts on land right-of-way and ranked on a scale of 1 to 5 with 1 representing significant impact (significant property acquisition or impact on adjacent businesses expected) and 5 representing no impact on right-of-way (no property acquisition expected). Short term options were not evaluated based on their impacts on right-of-way since they generally have no impacts.

Constructability/ jurisdictional issues

Medium and long term options were ranked based on their constructability or jurisdictional issues on a scale of 1 to 5 with 1 having major issues and 5 having no issues. Jurisdictional issues were considered to occur for any countermeasure that would require co-ordination with another road authority or agency. Constructability issues included issues relating to water crossing, challenging terrain, or significant cut/fill. Short term options were not evaluated based on their constructability/ jurisdictional issues since they are generally easy to implement or install.

Cost

The primary source used to determine the unit cost of implementing each option was the *Ministry of Transportation Construction and Rehabilitation Cost Guide* (June 2007). However, not all the unit costs were available in the guide and therefore, some of the estimated costs are based on standard industry unit costs at the time of the study from various publications, internet websites, or industry sales enquires. The unit costs are merely an estimate and may not include cost of right-of-way, traffic management, labour and engineering designs. A more detailed cost evaluation of each option is beyond the scope of this study.

After determining a cost estimate, each medium-term and long-term mitigating measure was ranked on a scale of 1 to 5 with 1 representing the highest cost and 5 representing the lowest cost. The cost assigned to each scale is site specific.

Detailed evaluations of the options are presented in TABLE 5 for short-term options and TABLE 6 for medium-term and long-term options. Sample of tables are shown in TABLE 2.3 and TABLE 2.4.

TABLE 2.3 EXAMPLE OF TABLE 5 FROM APPENDICES A THROUGH V

(from APPENDIX C: Highway 1 and Morden Road Intersection – CPL #3)

PROPOSED MITIGATING MEASURES	ASSUMED COLLISION REDUCTION FACTOR/ COLLISION TYPE REDUCED	SAFETY EFFECTIVENESS RATING (1 = little reduction (<5%) 5 = significant reduction (>20%))	IMPACT ON TRAFFIC EFFICIENCY (1= decrease efficiency 3= no impact 5= improved efficiency)	OVERALL SCORE	COST	UNIT COST SOURCE
Review the channelization, laning, and pavement marking at the Morden / Schoolhouse intersection to improve the compactness of the intersection.	10% by FHWA[1], 2007/all collisions	3	5	8	$2,000	Standard Industry Cost[2]
Consider observing drivers behaviour at the intersection for a short period of time at Morden Road and Schoolhouse Road. The wide pavement may be used by large vehicles, but confirm if the expanse of the pavement could be reduced.	10% by site observations[1]/all collisions	3	5	8	$5,000	Standard Industry Cost
Provide higher overhead north/south left turn signal heads	7% by FHWA, 2007/ Rear ends, LTO and LTC	2	3	5	$15,000	Standard Industry Cost
Upgrade all secondary signals to 300 mm diameter lenses with backplates.	7% by FHWA, 2007/all collisions	2	3	5	at least 10 and $4,000/each	Standard Industry Cost
Improve the signing to the pedestrian underpass from all four corners of the intersection	7% by FHWA, 2007/ all pedestrian related collisions	2	3	5	$1,000	Standard Industry Cost

1- Please refer to section 2.5 in the report for more details.

2- The unit costs in this table merely represent standard industry unit costs at the time of this report. However, Ministry of Transportation Construction and Rehabilitation Cost Guide (2007) was used whenever the costs were available.

TABLE 2.4 EXAMPLE OF TABLE 6 FROM APPENDICES A THROUGH V

(from APPENDIX B: Highway 1 and Tillicum Road Intersection – CPL #2)

PROPOSED MITIGATION MEASURE	ASSUMED COLLISION REDUCTION FACTOR/ COLLISION TYPE REDUCED	SAFETY EFFECTIVENESS RATING (1 = little reduction (<5%) 5 = significant reduction (>20%))	IMPACT ON TRAFFIC EFFICIENCY*	COST[1] (5= <$50,000 1=>$10,000,000)	IMPACT ON RIGHT-OF-WAY**	CONSTRUCT-ABILITY/ JURISDICTIONAL ISSUES***	TOTAL
MEDIUM TERM OPTIONS							
Improve pavement friction	25% by FHWA, 2007/ all collisions	5	3	5 ($15,000) ($12.5/metre)	5	5	23
Provide better access management	25% by Collision Analysis/ collisions related to Gas station accesses (Rear ends on Hwy 1 EB), 10% reduction of all collisions	3	3	5 ($5,000)	5	5	21
Provide acceleration lanes for the northbound and southbound right-turn	10% by Collision Analysis/ NB and SB Right Turn Collisions and some Rear end collisions on east and west legs, less than 5% reduction of all collisions	1	5	3 ($180,000)	3	3	15
LONG TERM OPTIONS							
Construct an interchange	85% Collision Analysis/all collisions	5	5	1 ($18,000,000)	1	1	13

1- The unit costs in this table merely represent standard industry unit costs at the time of this report. However, Ministry of Transportation Construction and Rehabilitation Cost Guide (2007) was used whenever the costs were available.

*Impact on Traffic Efficiency
1= decrease efficiency
3= no impact
5= improved efficiency

**Impact on Right-of-Way
5 = no impact
1= significant impact

***Constructability/ Jurisdictional issues
5= no issue
1= significant issue

2.6 Benefit/Cost Evaluation of the Options and Prioritization of the Mitigating Measures

In order to prioritize the proposed medium-term and long-term options, a benefit/cost evaluation was conducted for each option using the Ministry Shortben Spreadsheet. Worked examples of the Shortben Spreadsheet for CPL 2 and CPS 7 are presented in APPENDIX Y. The benefit/ cost ratio of each medium-term and long-term option was a determining factor on whether or not the suggested improvements should be implemented or not. The analysis conducted on the proposed improvements was based on the following factors:

- Annual traffic growth rate of 2 percent (confirmed by the Ministry);
- Truck volume of 5 percent;
- Discount rate of 6 percent (suggested by the Ministry);
- Length of each segment;
- Analysis period of 2 or 5 for short term and medium-term improvements and 25 years for long-term improvements(as requested by the Ministry), taking into account time-related items such as Net Present Value;
- Benefit in future years are related to the changes in traffic volumes in 2007;
- Cost of PDO collision ($7,342), cost of injury collision ($99,999) and cost of fatal collision ($5,693,954)

It is noted that a fatal collision is generally infrequent and random. Inclusion of fatal collision costs into the analysis may potentially skew the economic evaluations. Therefore, unless a fatal collision trend is apparent, all fatal collision costs will be analyzed with the same value as injury collisions.

In general, due to the relatively low cost and ease of implementation of the short-term options, short-term options were excluded from the Shortben Analysis and are ranked number 1 in the ranking table. This means that the short-term options can be implemented as soon as possible.

It is noted that the dollar values of both the collision benefits and the implementation cost are discounted values representing the present value of future benefits and costs.

The results from the Shortben analysis are summarized in TABLE 7 in each of the appendices. A sample of the summary table is shown in TABLE 2.5.

TABLE 2.5 EXAMPLE OF TABLE 7 FROM APPENDICES A THROUGH V

(from APPENDIX C: Highway 1 and Morden Road Intersection – CPL #3)

PROPOSED MITIGATION MEASURE	ASSUMED COLLISION REDUCTION	PROJECT LIFE (YEARS)	COLLISION REDUCTION	COST	B/C RATIO	CONSIDER FOR IMPLEMENTATION?
MEDIUM-TERM OPTIONS						
Improve pavement friction	25% by FHWA, 2007/ all collisions	2	$151,000	$15,000	11	Yes
Review access management to the Gas Station on the northwest corner (Consider closing gas station access on Highway1)	25% by Collision Analysis/ collisions related to Gas station accesses (rear ends), less than 5% reduction of all collisions	5	$71,000	$5,000	15	Yes
LONG-TERM OPTIONS						
Construct an interchange	85% Collision Analysis/all collisions	25	$4,264,000	$18,000,000	0.3	No

2.7 Prioritization of the Mitigating Measures

After all the suggested mitigating measures were evaluated and were considered for implementation by benefit/cost analysis, they were ranked by their scores to determine their priority with respect to the other measures. Short-term options are ranked as the most urgent and need to be implemented as soon as possible. The medium-term and long-term options were then ranked based on their scores in the evaluation process. The ranking results are summarized in TABLE 8 in each of the appendices and a sample of the ranking table is shown in TABLE 2.6.

TABLE 2.6 EXAMPLE OF TABLE 8 FROM APPENDICES A THROUGH V

RANK	PROPOSED MITIGATION MEASURE
1	Short-term options
2	Improve pavement friction
3	Review access management to the Gas Station on the northwest corner

3.0 SUMMARY AND RECOMMENDATIONS

A summary of the issues, organized by the applicable safety category, for each of the collision-prone intersections and sections is shown in TABLE 3.1 and TABLE 3.2, respectively.

TABLE 3.1 SUMMARY OF FINDINGS AT COLLISION-PRONE LOCATIONS

CPL #	Highway #	Cross Street / Location	Operational	Signs and Pavement Markings	Geometric	Access Mgmt.	Speed	Site Specific/ Other
1	17	Sayward Road	✓	✓	✓	✓	✓	
2	1	Tillicum Road	✓	✓	✓	✓	✓	
3	1	Morden Road	✓	✓	✓	✓	✓	
4	1 (westbound)	Taylor Way			✓		✓	
5	1 (eastbound)	Taylor Way			✓		✓	
6	99	Lions Gate Bridge - North Abutment	✓		✓	✓	✓	
7	97	Penticton Chnl. Parkway / Skaha Lake Rd.	✓	✓	✓	✓	✓	
8	97	Highway 16	✓		✓		✓	
9	16	Cowart Rd./ Vance Rd.			✓	✓	✓	
10	16	Ferry Avenue			✓		✓	
11	97	22nd Avenue	✓	✓	✓	✓	✓	✓

✓ indicates that an issue associated to the category was identified by the analysis

TABLE 3.2 SUMMARY OF FINDINGS AT COLLISION-PRONE SECTIONS

CPS #	Highway #	Signs	Geometric	Speed	Site Specific/ Other
1	17 (northbound)		✓	✓	
2	19		✓	✓	
3	99 (northbound)		✓		✓
4	1 (westbound)		✓	✓	✓
5	1 (westbound)		✓	✓	✓
6	9		✓	✓	✓
7	3	✓	✓	✓	✓
8	3	✓	✓	✓	✓
9	97C (westbound)		✓	✓	✓
10	5 (southbound)		✓	✓	✓
11	5 (southbound)		✓	✓	✓

✓ indicates that an issue associated to the category was identified by the analysis

Based on the identified issues, various mitigating measures were identified and scored, as summarized in APPENDIX A through V. The scoring incorporates the feasibility and effectiveness of the measures, and prioritizes the suggested measures by site. Based on the scoring, the recommended implementation priority by region was determined by determining which locations had a high number of effective short-term improvements, high-scoring improvements, and higher number of favourable improvements. The results are shown in TABLE 3.3.

TABLE 3.3 RECOMMENDED IMPLEMENTATION PRIORITY

RECOMMENDED PRIORITY RANK	SITE #	SITE DESCRIPTION
Lower Mainland		
1	CPS#5	Hwy 1 (westbound) for 1.6 km of freeway including Clearbrook Road Interchange on and off ramps, Abbotsford
2	CPS#6	Hwy 9 at South end of Agassiz/Rosedale Bridge, Agassiz
3 (concurrently)	CPL#4	Hwy 1 (westbound) at Taylor Wy, West Vancouver
	CPL#5	Hwy 1 (eastbound) at Taylor Wy, West Vancouver
	CPS#4	Hwy 1 (westbound) for 1 km of freeway including onramp from Taylor Way, West Vancouver
4	CPL#6	Hwy 99 at Lions Gate Bridge North Abutment, West Vancouver
5	CPS#3	Hwy 99 (northbound) for 3.2 km of freeway between Hwy 17 and Steveston Underpass, Delta and Richmond
Northern Region		
1	CPL#11	Hwy 97 at 22nd Ave., Prince George
2	CPL#9	Hwy 16 at Cowart Rd./ Vance Rd., Prince George
3	CPL#8	Hwy 97 at Hwy 16, Prince George
4	CPL#10	Hwy 16 at Ferry Ave., Prince George
Southern Interior		
1	CPS#7	Hwy 3 for 1.8 km of rural 2-lane highway including Whipsaw Creek Bridge, and a number of pullouts and minor accesses, Approximately 14 km west of Princeton
2	CPS#11	Hwy 5 (southbound) for 3.6 km of freeway including Ottomite Bridge and the Great Bear Snowshed, Approximately 42 km north of Hope
3	CPL#7	Hwy 97 at Penticton Ch. Pkwy / Skaha Lake Rd, Penticton
4	CPS#8	Hwy 3 for 1.7 km of rural 2-lane highway including a stop controlled intersection, Approximately 28 km west of Princeton
5	CPS#10	Hwy 5 (southbound) for 1.1 km of freeway including Comstock Road Interchange, Approximately 10km south of Merritt
6	CPS#8	Hwy 97C (westbound) for 1.7 km of freeway including Brenda Mine Road Chain up area, Approximately 22 km west of Peachland
Vancouver Island		
1	CPL#2	Hwy 1 at Tillicum Rd, Saanich
2	CPS#1	Hwy 17 (northbound) for 1.2 km of freeway at the McKenzie Avenue Interchange including onramp, Saanich
3	CPS#2	Hwy 19 for 1.7 km of highway including Nanoose Rest Area, Lantzville
4	CPL#1	Hwy 17 at Sayward Rd, Saanich
5	CPL#3	Hwy 1 at Morden Rd, South of Nanaimo

THIS PAGE WAS INTENTIONALLY LEFT BLANK.

APPENDIX A
COLLISION PRONE LOCATION 1
HIGHWAY 17 AND SAYWARD ROAD

Study Location Number: 1
Intersection Description: Highway 17 and Sayward Road
LKI: Segment 304/307, km 10.1/17.8
Traffic Control: Signalized Intersection

A. Physical Characteristics/Site Layout

FIGURE A-1 SITE LAYOUT

- Intersection of Sayward Road and Hamsterley Road is located about 60 metres to the west of Sayward Road and Highway 17 intersection. Hamsterley Road has a curved approach to Sayward Road.
- There are two gas station developments located on the northwest and southwest corners of the intersection, each with multiple accesses to Sayward Road and Highway 17.
- One bus stop is located on the southbound approach (immediately north of the intersection on the west side) and another one is located on the northbound exit leg (immediately north of the intersection on the east side).
- Raised medians are provided on northbound and southbound legs.
- Protected-only phasing is provided for north-south left turn movements. Permitted left-turn phasing is provided for east-west movements.

- Primary signal heads provide 300 mm lenses with backplates. Highway 17 southbound and northbound has two primary signal heads, and Sayward Road eastbound and westbound has one primary signal head.
- Secondary signal heads provide 200 mm lenses.
- Advanced warning flashers are located on the Highway 17 northbound and southbound approaches.
- The intersection is equipped with red-light cameras.
- Speed limit along the highway is 80 kilometres per hour.
- Land use is a mix of commercial and residential. A Petro Canada gas station is located on the northwest corner and a Shell gas station is located on the southwest corner of the intersection.
- Laning configuration is shown in Figure A-1.

B. Traffic Characteristics

PM Peak hour turning movement volumes are provided in FIGURE A-2. North-south through volumes are the dominant movement.

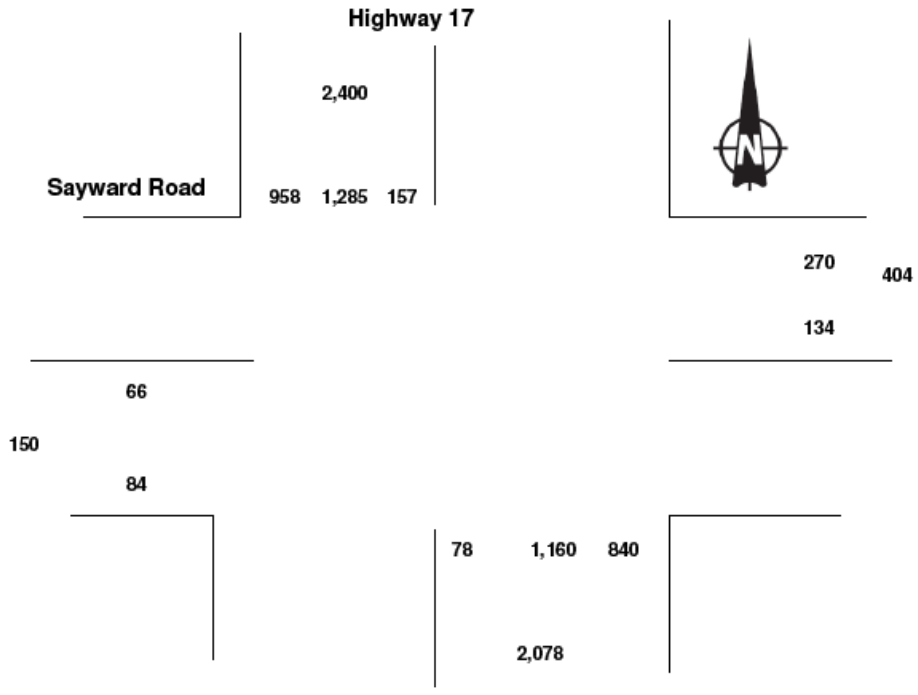


FIGURE A-2 PM PEAK HOUR VOLUME (SEPTEMBER 2005)

C. Collision Characteristics

The HAS system reported 149 collisions occurring at this intersection between 2000 and 2007 (77 collision between 2000 and 2004), and is shown in FIGURE A-3. A summary of the collision-prone review and a summary of the collision trends based on the HAS data are summarized in TABLE A-1and TABLE A-2 respectively. The following trends were noted:

- There is a concentration of rear-end collisions on the northbound approach.
- 16 percent of the collisions are occurring in September.
- 68 percent of the collisions are happening when the road surface is dry.
- The primary contributing factor to the collisions as reported by the police is driving without due care (34 percent) and following too closely (22 percent).
- 50 percent of the collisions involve injuries.
- 121 out of the 149 collisions are shown on the collision diagram, as some had insufficient information in the collision report to correctly illustrate the collision.

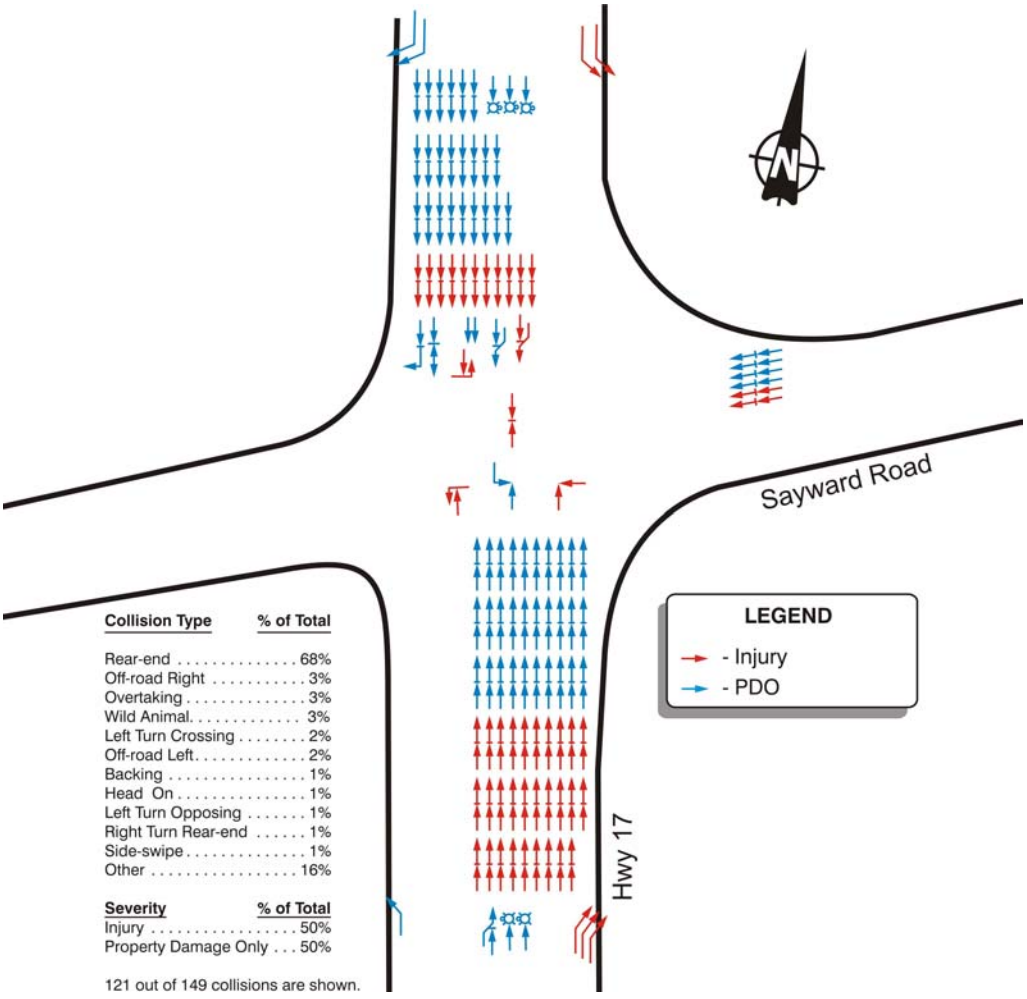


FIGURE A-3 COLLISION DIAGRAM (2000-2007)

TABLE A-1 COLLISION-PRONE REVIEW

COLLISION DATA CATEGORY	STUDY LOCATION		PREDICTED/AVERAGE	
	VALUE	SOURCE	VALUE	SOURCE
Collision Frequency	77 per 5 years	HAS, 2000-2004[1]	25 per 5 years	Collision Prediction Model[2]
Two-way AADT	44,780 (Hwy 17) 2,840 (Sayward)	MOT, 2005 (Survey Number: 100398)	n/a	n/a
Collision Rate[3]	0.89 collisions/MEV	Calculated, HAS[4]	0.14 collisions/MEV	BC MOT Average Provincial Collision Rates (2000-2004) for Urban Expressway Divided 4 lanes, at intersection, over 20,000 vpd

1 - Collision diagram shows collision frequency for 2000 to 2007 whereas TABLE A-1 uses collision frequency from 2000 to 2004 to match MOT rates time period

2 - Collision Prediction Model Used: Four-Leg Signalized Intersections

3 - Both Major and Minor Road AADT were used to estimate MEV and to calculate the collision rate

4 - Calculated using HAS data

TABLE A-2 COLLISION TRENDS

TREND	STUDY LOCATION		PREDICTED/AVERAGE	
	VALUE	SOURCE	VALUE	SOURCE
Month	September (16%)	HAS, 2000-2007	September (8%)	MOT, Lower Mainland Region Statistics (2000-2006)
Collision Type	Rear End (78%)	HAS, 2000-2007	Rear End (28%)	MOT, Lower Mainland Region Statistics (2000-2006)
Road Surface	Wet and Ice (28%)	HAS, 2000-2007	Wet and Ice (41%)	MOT, Lower Mainland Region Statistics (2000-2006)
Severity	Injury (50%) PDO (50%)	HAS, 2000-2007	Fatal (1%) Injury (45%) PDO (54%)	MOT, Lower Mainland Region Statistics (2000-2006)

Based on the collision frequency, collision rate and collision severity obtained from Desktop Quality Check, the intersection of Highway 17 and Sayward Road is confirmed to be a Collision-Prone Location.

D. Site Observations

- The visit was undertaken on Tuesday, April 15 at 0900 hours. Weather: partly cloudy
- Major issues identified on site are shown in TABLE A-3. Additional details are provided in section E.

TABLE A-3 SUMMARY OF MAJOR ISSUES NOTED ON SITE

	
Southbound approach on Hwy 17: Vehicles slowing down in the right-turn lane cause confusion since it is not clear whether they intend to make a right turn to Sayward Road or the Petro Canada gas Station.	Southbound approach on Hwy 17: Bus stop on the Hwy 17 southbound shoulder lacks an accessible designated waiting area for transit users.
	
Eastbound approach on Sayward Road: Vehicles exiting Petro Canada left onto Sayward Road have a very limited distance to complete the turn prior to the Highway 17 / Sayward intersection, and these vehicles often interfere with the eastbound queues and block the lanes on the west side of the intersection.	Eastbound approach on Sayward Road: The sharp horizontal curve before the intersection minimizes the sight distance to (1) the Highway 17 / Sayward intersection, and (2) to vehicles turning left out of the Petro Canada access.

Hwy 17 Southbound, south of the intersection: Shell gas station accesses to Hwy 17 southbound are located close to the intersection.

Hwy 17 Northbound approach: There is no designated right- turn lane from Hwy 17 to Sayward road; however, there is a paved triangle that may be used for right turns.

Hwy 17 northbound approach: there is no sidewalk adjacent to the northbound approach lanes. There is strong evidence of a pedestrian desire lane behind the barriers adjacent to the northbound lanes.

In addition, the following issues were also noted at the intersection:

- The secondary signal heads provide 200 mm lenses without backplates.
- The pedestrian crosswalk markings were faded at the time of the site visit.
- The pedestrian signal phases are generally short and require attentiveness and relatively brisk walking.

E. Stakeholder Input

Background/Issues

- The Ministry receives many complaints on this site.
- High traffic volumes contribute to the collisions (high exposure).
- Ministry staff mentioned two fatalities at this intersection (in 2003 and 2007); however, the fatalities did not appear to be reported in HAS data. There are at least two memorial shrines at the intersection.
- Signal heads visibility is not adequate. They are also not in coordination with adjacent intersections.
- Long queue lengths occur around peak hours.
- Efforts have been made in the past to better manage the access points to the Shell gas station.
- The left-turn movement onto Sayward from the Petro Canada station causes capacity and safety concerns.
- The horizontal curve on the Sayward Road west leg and the long queue lengths may limit the intersection sight distance.
- There is no acceleration lane on Hwy 17 for the eastbound to southbound movement.
- More housing developments south of the intersection may have direct access to Hwy 17 in future.
- A detailed study by McElhanney done on this intersection suggests :
    - Constructing a mini interchange including an overpass of Highway 17- south of existing intersection- Connecting to Brookleigh Road west of the Highway 17.
    - Constructing an interchange with an overpass slightly north of the existing intersection with at-grade connections to Hamsterly Road and Alderley Road on the east and west sides of the highway.
    - The last option consists of a partial diamond interchange with a tight loop on-ramp on the west side.

- *Potential Solutions*
- Construct a median on Sayward Road west leg to restrict the left turn movement from the Petro Canada gas station access onto Sayward Road. Provide a location on Hamsterley Road for vehicles to make a U-turn (possibly via a roundabout) to head eastbound.
- Relocated the Bus Stops on Hwy 17 southbound and northbound to locations further away from the intersection.
- Provide better access management for the gas stations.
- Long-term: consider an interchange.

F. Summary of Safety Issues

Based on the collision analysis, site visit and input from stakeholders, issues were identified and countermeasures proposed. These are summarized in TABLE A-4.

TABLE A-4 SAFETY ISSUES AND POTENTIAL COUNTERMEASURES

SAFETY ISSUES	COLLISION CAUSES	COUNTERMEASURES
• Multiple accesses from developments onto the highway • Curved eastbound approach • Heavy traffic volume • Confusion while using Hwy 17 southbound right-turn lane • Bus stops on highway 17 northbound and southbound • Lack of sidewalk on Hwy 17 northbound	• Congestion and queuing which may be unexpected at a major intersection along a relatively high speed highway may cause vehicles to brake suddenly, resulting in rear end collisions. • Turn movements into and out-of multiple access points on the west side of the intersection, exacerbated by the horizontal curve, result in a higher risk of rear-end, left-turn opposing, and left-turn crossing collisions. • Drivers are travelling too fast for the conditions and need to brake more heavily, resulting in rear end and off-road collisions. • The relative inconspicuity of the signals result in motorists either braking suddenly and resulting in rear end collisions, or not stopping for the red phase and increasing the risk for angle collisions.	Short Term • Provide backplates and 300 mm lens diameters for the secondary signal heads • Review and clarify the northbound to eastbound right-turn lane availability / markings • Review pedestrian • crossing times and adjust timing, Install countdown signal heads for pedestrian crossings. • Consider protected phases for the eastbound and westbound left-turn movements • Refresh all pavement markings including the crosswalks Medium Term • Provide an eastbound to southbound right-turn acceleration lane • Improve the pavement friction along the northbound and southbound approaches • Construct a median on Sayward Road eastbound to restrict the left turn movement from the Petro Canada gas station, and provide a U-Turn • Provide improved access management for all the gas station driveways (consider constructing a backage road) • Relocate the bus stops, in particular on the southbound side • Consider the needs of pedestrians adjacent to the northbound lanes. Long Term • Provide grade separation to remove the need for high-speed traffic on Highway 17 to stop at this intersection

G. Evaluation

The options shown in TABLE A-4 were evaluated based on the following criteria.

- Safety Effectiveness, including evaluating the potential reduction in collisions by severity level;
- Impact on Traffic Efficiency (all relevant modes);
- Impact on land right-of-way and any existing residences and businesses;
- Order of Magnitude Costs; and,
- Feasibility / Constructability.

Short-term improvements tend to be easily implemented options, and were therefore not evaluated based on right-of-way impacts or feasibility. The results of the evaluation are summarized in TABLE A-5 for short-term improvements, and TABLE A-6 for medium-term and long-term improvements. A benefit-cost review was conducted for the medium-term and long-term improvements, and is summarized in TABLE A-7. The ranking of suggested options is shown in TABLE A-8.

TABLE A-5 EVALUATION OF SHORT-TERM OPTIONS

PROPOSED MITIGATING MEASURES	ASSUMED COLLISION REDUCTION FACTOR/ COLLISION TYPE REDUCED	SAFETY EFFECTIVENESS RATING (1 = little reduction (<5%) 5 = significant reduction (>20%))	IMPACT ON TRAFFIC EFFICIENCY (1= decrease efficiency 3= no impact 5= improved efficiency)	OVERALL SCORE	COST[1]	UNIT COST SOURCE
protected phases for the eastbound and westbound left-turn movements	30% by FHWA[2], 2007/ EB and WB LTO and LTC, less than 5% reduction of overall collisions	1	5	6	$8,000	Standard Industry Unit cost
Refreshing all pavement markings including the crosswalks	25% by FHWA, 2007/ all collisions	5	3	8	$1,000	Standard Industry Unit cost
Review pedestrian crossing times and adjust timing, Install countdown signals for pedestrian crossings	8% by FHWA, 2007/ Pedestrian related collisions, less than 5% reduction of all collisions	1	5	6	At least 4 and $2,500/each	Standard Industry Unit cost
Clarify the northbound to eastbound right-turn lane availability / markings	4% by site observations[2] /Some NB rear end collisions	1	3	4	$10,000	Standard Industry Unit cost
Backplates and 300 mm lens diameters for the secondary signal heads	7% by FHWA, 2007/all collisions	2	3	5	at least 10 and $4,000/each	Standard Industry Unit cost

1- The unit costs in this table merely represent standard industry unit costs at the time of this report.

2- Please refer to section 2.5 in the report for more details.

TABLE A-6 EVALUATION OF MEDIUM-TERM AND LONG-TERM OPTIONS

PROPOSED MITIGATION MEASURE	ASSUMED COLLISION REDUCTION FACTOR/ COLLISION TYPE REDUCED	SAFETY EFFECTIVENESS RATING (1 = little reduction (<5%) 5 = significant reduction (>20%))	IMPACT ON TRAFFIC EFFICIENCY*	COST (5= <$50,000 1=>$10,000,000)	IMPACT ON RIGHT-OF-WAY**	CONSTRUCT-ABILITY/ JURISDICTIONAL ISSUES***	TOTAL
MEDIUM TERM OPTIONS							
Improve the pavement friction along the northbound and southbound approaches	25% by FHWA, 2007/all collisions	5	3	5 ($12,000)	5	5	23
Provide an eastbound to southbound right-turn acceleration lane	20% by collision analysis[1] / SB rear end collisions, less than 5% reduction of all collisions	1	5	4 ($90,000)	5	2	17
Consider the needs of pedestrians adjacent to the northbound lanes.	10% by site observation/ pedestrian related collisions, less than 5% reduction of all collisions	1	3	4 ($50,000) ($50/m^2)	5	2	15
Construct a median on Sayward Road eastbound to restrict the left turn movement from the Petro Canada gas station, and provide a U-Turn	10% by collision analysis/ collisions on EB Sayward Rd and some rear ends on Hwy 17 SB, less than 10% reduction of all collisions	2	3	5 ($7,000) ($140/m)	2	5	17
Provide improved access management for all the gas station driveways/ consider constructing a backage Rd	30% by collision analysis/ rear end, backing up, right-turn rear end collisions on Hwy 17 SB, 10% reduction of all collisions	3	3	3 ($150,000)	2	2	13
Relocate the bus stops, in particular on the southbound side	10% by site observation/ rear end collisions on Hwy 17 SB, less than 5% reduction of all collisions	1	3	5 ($3000)	5	3	17
LONG TERM OPTIONS							
Provide grade separation to remove the need for high-speed traffic on Highway 17 to stop at this intersection	85% by FHWA, 2007/ all collisions	5	5	1 ($18,000,000)	1	1	13

1- Please refer to section 2.5 in the report for more details.

*Impact on Traffic Efficiency
1 = decrease efficiency
3 = no impact
5 = improved efficiency

**Impact on Right-of-Way
5 = no impact
1 = significant impact

***Constructability/ Jurisdictional issues
5 = no issue
1 = significant issue

TABLE A-7 BENEFIT COST REVIEW (MEDIUM-TERM AND LONG-TERM OPTIONS)

PROPOSED MITIGATION MEASURE	ASSUMED COLLISION REDUCTION	PROJECT LIFE (YEARS)	COLLISION REDUCTION	COST	B/C RATIO	CONSIDER FOR IMPLEMENTATION?
MEDIUM TERM OPTION						
Improve the pavement friction along the northbound and southbound approaches	25% by FHWA, 2007/all collisions	2	$391,000	$12,000	35	Yes
Provide an eastbound to southbound right-turn acceleration lane	20% by collision analysis / SB rear end collisions, less than 5% reduction of all collisions	25	<$649,000	$90,000	7.6	Yes
Consider the needs of pedestrians adjacent to the northbound lanes.	10% by site observation/ pedestrian related collisions, less than 5% reduction of all collisions	5	<$185,000	$50,000	3.9	Yes
Construct a median on Sayward Road eastbound to restrict the left turn movement from the Petro Canada gas station, and provide a U-Turn	10% by collision analysis/ collisions on EB Sayward Rd and some rear ends on Hwy 17 SB, less than 10% reduction of all collisions	5	<$370,000	$7,000	More than 50	Yes
Provide improved access management for all the gas station driveways/ consider constructing a backage Rd	30% by collision analysis/ rear end, backing up, right-turn rear end collisions on Hwy 17 SB, 10% reduction of all collisions	5	$370,000	$150,000	2.6	Yes
Relocate the bus stops, in particular on the southbound side	10% by site observation/ rear end collisions on Hwy 17 SB, less than 5% reduction of all collisions	5	<$185,000	$3,000	More than 50	Yes
LONG TERM OPTION						
Provide grade separation to remove the need for high-speed traffic on Highway 17 to stop at this intersection	85% by FHWA, 2007/ all collisions	25	$11,025,000	$18,000,000	0.65	No

TABLE A-8 RANKING OF OPTIONS

RANK	PROPOSED MITIGATION MEASURE
1	Short term options
2	Improve the pavement friction along the northbound and southbound approaches
3	Provide an eastbound to southbound right-turn acceleration lane
4	Relocate the bus stops, in particular on the southbound side
5	Construct a median on Sayward Road eastbound to restrict the left turn movement from the Petro Canada gas station, and provide a U-Turn
6	Consider the needs of pedestrians adjacent to the northbound lanes.
7	Provide improved access management for all the gas station driveways/ consider constructing a frontage Rd