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Memorandum

To	Jose Vernaza	Page 1
CC	Brenda Jamieson, Sheri Harmsworth, Stephen Schijns, Pranav Dave, Owen McGaughey	
Subject	City of Mississauga – Creditview Road EA Study – Road Safety Assessment of Existing Conditions (**Revised**)	
From	Hossein Zarei, P.Eng.	
Date	March 4, 2014	Project No. 60304588

As part of the Class Environmental Assessment (EA) Study, Schedule "C", this memorandum provides a summary of the findings from the road safety assessment of the existing conditions for the study corridor – Creditview Road between Bancroft Drive and Old Creditview Road. The information provided in this memorandum will be included in the Safety Performance Report.

The study adopts a methodology called "lines of evidence" approach to identify road safety issues within the study corridor. Where lines of evidence overlap and point to a common conclusion regarding a particular element of the roadway, that conclusion is strengthened. The adopted framework examined the road safety performance of the study corridor by using a couple of distinct examination methods as follows:

- Descriptive collision trend analysis: A review of the most recent historical collisions was undertaken to identify observed collision trends within the study corridor. This task also includes identification of high risk locations (for mid-block road sections as well as intersections) with higher than average collision rates, and over-represented collision characteristics (i.e. severity type, initial impact type, lighting conditions, and road surface conditions). This task includes preparation of collision diagrams for identified high-risk locations;
- Potential for safety improvement (PSI): For the purpose of this road safety assessment study, a rigorous safety analysis was also conducted in order to quantitatively measure safety performance of various roadway elements (intersections and mid-block road sections) within the study corridor. This was accomplished through adopting the Empirical Bayes (EB) methodology. Appropriate safety performance functions (SPFs) for various road elements were used to generate the predicted number of collisions. These predicted collision frequencies in combination with their respective observed collision frequencies were used to calculate the expected number of collisions and to obtain PSI values. The outcome of this task is identification of locations with potential for safety improvements; and

- Field investigation: The subject site was visited on October 10, 2013. The site visit was more focused on high-risk locations identified through the first two examination methods. In other words, the AECOM team closely examined the entire study corridor with special emphasis on locations with either potential for safety improvements, high collision rates, and / or over-represented collision characteristics. The outcome of this task is identification of potential hazards. As part of this task, various elements were looked into as potential contributing factors to past collision occurrences such as signage and pavement markings, horizontal and vertical alignments (sight distances), lane configuration and continuity, access management and corner clearance, vehicle speed, roadside hazards (clear zone requirements), street lighting, human factors considerations (road user operations and interactions) through conducting positive guidance reviews and conformance checks with Ontario Traffic Manual (OTM) Books as well as the Transportation Association of Canada (TAC) Canadian Road Safety Audit (RSA) Guide[1] and the Geometric Design Guide for Canadian Roads (GDGCR)[2].

The sections below describe the steps taken in conducting the road safety assessment of existing conditions.

Collision Data Preparation

The City of Mississauga provided an electronic collision database (as an Excel file) that spanned the period between January 2009 and December 2012[3]. The collision database included all collisions which occurred on the portion of Creditview Road between Britannia Road (south of Bancroft Drive) and Old Creditview Road. Attributes contained within the original database were:

- Collision ID Number
- Driver Conditions
- Collision Severity
- Date and Time of Collision
- Initial Impact Type
- Vehicle Direction of Travel and Manoeuvres
- Light Condition
- Environment Condition
- Traffic Control Type
- Road Surface Condition
- Names of Crossing Roadways
- Distance to adjacent Intersections (for mid-block collisions only)

A number of tasks were completed to prepare the collision data for analysis. As a first task a new "facility type" field was added to the collision database to differentiate between various road elements –mid-block road sections and intersections – at / on which the collisions were reported to occur. As part of the data preparation tasks, the following logical checks were undertaken:

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[1] Transportation Association of Canada (TAC), Canadian Road Safety Audit Guide, December 2001.
[2] Transportation Association of Canada (TAC), Geometric Design Guide for Canadian Roads, 1999.
[3] City of Mississauga also listed only one collision (Collision ID no. 13148298) which occurred in March 2013. This collision was removed from the collision database.

- Based on information provided in the “crossing roadway name” and “distance to adjacent intersection” fields provided in the database, collisions reported to occur outside the study corridor were identified and removed from the analysis. As a result, Collision ID no. 10099962 was removed from the database. Note that this collision was reported to occur at a driveway located south of Bancroft Drive and basically outside of the study area.
- For all collision records, the reported “light conditions” data were verified against the corresponding reported “time” and “date” of collisions in order to identify any possible discrepancies. Two collision records were affected by this logical check. For Collision ID no. 11380933, the “time” of collision was reported at 3:56 AM whereas the “light condition” was reported as “daylight”. In addition, for Collision ID no. 11144682, the “time” of collision was reported as 5:00 AM and the “light condition” was reported as “daylight”. For both of these collisions the “time” and “light condition” fields were input as “unknown”.
- Collision ID no. 10218127 was recorded two times in the original collision database. Collision ID no. 09077446 and 10212172 were also recorded twice. To avoid any double counting, one of the two records was removed from collision database.
- Finally, based on thorough examination of all collision records, some adjustments were made to data presented in the “initial impact type” field of the following collision records:

  - For five collisions, namely Collision ID no. 11345966, 12033780, 11006201, 11380933, and 10212172, initial impact type was changed to “turning movement”; and
  - For two collisions, namely, Collision ID no. 11096988 and 11399389, initial impact type was changed to “rear-end”.

In addition, although Collision ID no. 10166280 was categorized as a “non-fatal injury” collision in the collision database, further discussion with the City staff and the area residents (during the PIC meeting) revealed that the person injured on site was transferred to hospital where they subsequently died as a result of the collision. This information was corroborated with an online news report. The collision record included in the collision database is a snap-shot of on-site events, and as such was not updated to change the original record to that of a fatality; however, this assessment considered this collision as “fatal” instead of the originally recorded “non-fatal injury”.

Summary of Collision Analysis

A review of the collisions was undertaken to identify observed collision trends within the study corridor. As indicated above, for the purpose of collision analysis, the study corridor was segmented into mid-block road sections and intersections.

At the completion of the collision data preparation tasks, a total of 69 reportable collisions[4] was included in the collision database for the study corridor over the period between January 1st, 2009 and December 31st, 2012. Of those,

- 1 collision was coded as “fatal”;
- 12 collisions were coded as “non-fatal injury”;
- 55 collisions were coded as “property damage only” (PDO); and
- Severity (noted as “accident classification” in the City’s collision database) for 1 collision was coded as “other

Figure 1 shows the yearly distribution of the total number of collisions (“blue” bars) and the number of fatal / injury (i.e. non fatal injury) collisions (“brown” bars) over the four-year study period (2009 – 2012). Figure 1 shows a notable increase in both total and fatal / injury collisions from 2009 to 2010 and onward - the annual number of total and injury collisions almost doubled as compared to numbers in 2009; for fatal / injury collisions, the total number tripled; however, this change represents an increase by two, from one fatal / injury collision to three. The increases may be attributable to the random nature of collision occurrences.

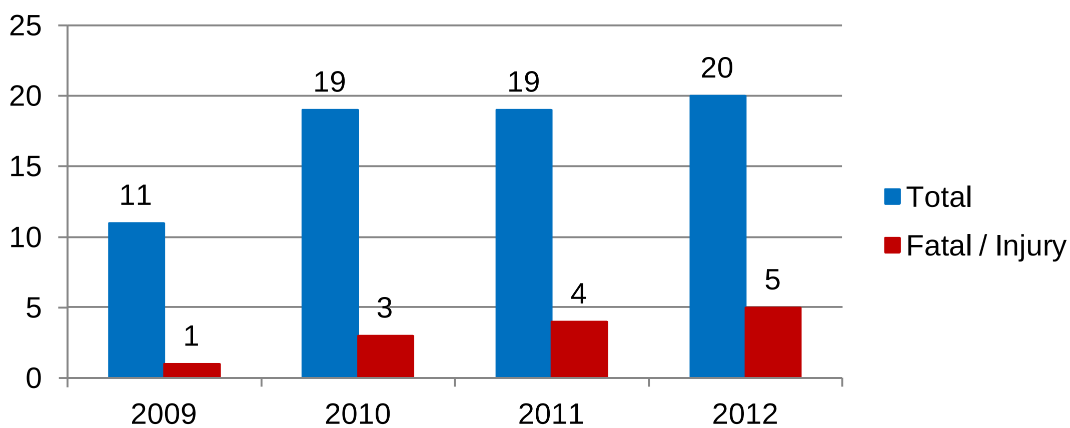

Figure 1: Yearly Distribution of Total and Fatal / Injury Collisions (2009 – 2012)

In addition, as indicated above, the entire study corridor was further segmented into basic road elements (mid-block road sections and intersections) and the related facility type information stored in a new field (names as “facility type”) in the collision database. The following intersections and mid-block road sections along Creditview Road were analyzed as part of the road safety assessment.

Creditview Road intersections at:

- Bancroft Drive (Sir Monty’s Drive);
- Velebit Court;

[4] *Collision ID no. 9227018 was reported as “non-reportable” collision in the database provided by the City*

- Kenninghall Boulevard;
- River Gate Place;
- Falconer Drive;
- Argentia Road; and
- Old Creditview Road.

Mid-block road sections along Creditview Road between:

- Bancroft Drive (Sir Monty's Drive) and Velebit Court;
- Velebit Court and Kenninghall Boulevard;
- Kenninghall Boulevard and River Gate Place;
- River Gate Place and Falconer Drive;
- Falconer Drive and Argentia Road; and
- Argentia Road and Old Creditview Road.

Descriptive Collision Trends Analysis

The various collision characteristics for each of the road elements (i.e. mid-block road sections and intersections) were examined in terms of the following characteristics:

- Collision severity including property damage only, injury and fatal;
- Collision initial impact type;
- Lighting condition;
- Road surface condition; and
- Environment condition.

Table 1 and Table 2 summarize the observed number of collisions for intersections and mid-block road sections respectively over the study period (January 2009 to December 2012). Intersections and mid-block road sections that had no reported collisions over the study period (highlighted in grey in Table 1 and Table 2) were excluded from any further analysis. As can be seen in Table 1 and Table 2, the majority of collisions (80.3% for intersections and 75.0% of mid-block road sections) were property-damage-only collisions. As can be seen in Table 1, in comparison with other intersections within the study corridor, the two intersections of Creditview Road / Bancroft Drive and Creditview Road / Argentia Road experienced a higher number of severe (fatal / injury) collisions.

Table 1: Observed Number of Collisions Classified by Severity at Intersections along Creditview Road from 2009 to 2012

Creditview Road Intersection at:	Fatal	Non-Fatal Injury	Property Damage Only	Unknown / Other	Total
Bancroft Drive (Sir Monty's Drive)	0	5	17	0	22

Velebit Court	0	0	0	0	0
Kenninghall Boulevard	1	0	7	0	8
River Gate Place	0	0	1	0	1
Falconer Drive	0	1	4	0	5
Argentia Road	0	3	9	0	12
Old Creditview Road	0	1	11	1	13
Total	**1**	**10**	**49**	**1**	**61**

Table 2: Observed Number of Collisions Classified by Severity on Mid-Block Road Sections along Creditview Road from 2009 to 2012

Creditview Road Mid-Block Road Section between:	Non-Fatal Injury	Property Damage Only	Total
Bancroft Drive (Sir Monty's Drive) and Velebit Court	1	1	2
Velebit Court and Kenninghall Boulevard	0	2	2
Kenninghall Boulevard and River Gate Place	0	0	0
River Gate Place and Falconer Drive	0	1	1
Falconer Drive and Argentia Road	0	2	2
Argentia Road and Old Creditview Road	1	0	1
Total	**2**	**6**	**8**

As can be seen in Table 1, the following intersections have the largest number of collisions in the study corridor:

- Bancroft Drive (Sir Monty's Drive);
- Old Creditview Road; and
- Argentia Road.

In Appendix "A", Figures A1 – A3 present the collision diagrams pertaining to these three intersections over the study period (2009 – 2012).

<u>Initial impact type</u>: Table B1 and Table B2 (in Appendix "B") present observed number of collision occurrences classified by initial impact type for intersections and mid-block road sections respectively along the study area. As shown in Table B1, rear-end collisions followed by angle collisions and turning-movement collisions were reported as the most prevalent types of collisions at intersections within the study area and altogether constitute 72.1% of total collisions. As presented in Table B2, the predominant initial impact type for collisions on mid-block road sections was found to be rear-end reported as initial impact type for 87.5% of total collisions.

<u>Lighting conditions</u>: Table B3 and Table B4 show observed number of collisions classified by lighting conditions for intersections and mid-block road sections

respectively along the study area. The majority of collisions (70.4% for intersections and 62.5% for mid-block road sections) occurred during daylight conditions.

Road surface conditions: Table B5 and Table B6 show the observed number of collision occurrences classified by road surface conditions for intersections and mid-block road sections respectively along the study area from 2009 to 2012. It was found that the majority of collisions (72.1% for intersections and 62.5% for mid-block road sections) occurred during ideal conditions when the road surface was dry.

Environment conditions: Table B7 and Table B8 show observed number of collisions classified by environment conditions for intersections and mid-block road sections respectively along the study area from 2009 to 2012. It was found that the majority of collisions (78.7% for intersections and 87.5% for mid-block road sections) occurred during ideal (clear) weather conditions.

Potential for Safety Improvement (PSI)

In order to identify the locations with the highest potential for safety improvements, it is vital that a sound procedure be used to screen the study area. A location with potential for safety improvement is defined as any location that exhibits a collision potential that is significantly high when compared with some normal collision potential derived from a group of similar locations. Evaluating the potential for safety improvement (PSI) for the study area involved the following steps:

- Use SPFs developed for City of Mississauga, for similar type of roadway and intersections, to predict yearly number of severe collisions (fatal and injury) and minor collisions (property damage only) for the intersections and mid-block road sections within the study area.
- Use the Empirical Bayes (EB) technique to calculate the expected number of collisions by combining the predicted yearly number of fatal and injury (FI) and property damage only (PDO) collisions and the observed number of FI and PDO respectively.
- Calculate the potential for safety improvement at each location which is the difference between the expected and predicted number of collisions. This methodology is depicted graphically in Figure 2.

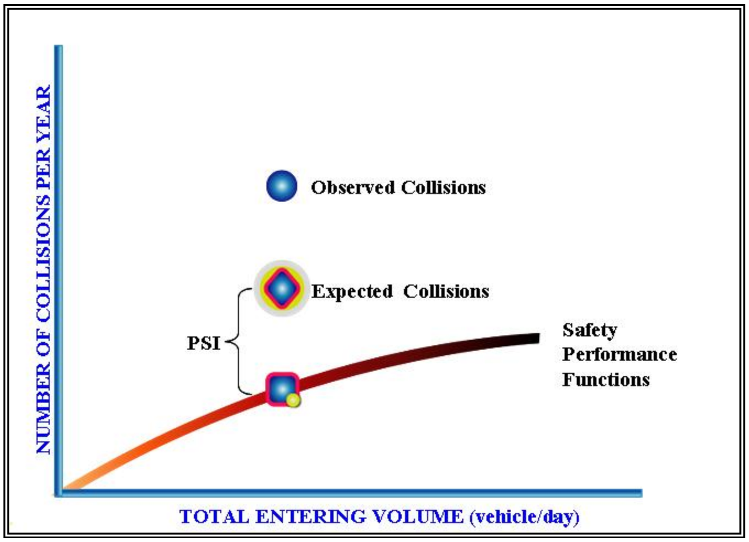

Figure 2: Potential for Safety Improvement (PSI)

The intersection and mid-block road section characteristics for the entire study area used in the analysis are detailed below in Table 3 and Table 4.

Table 3: Selected Characteristics of Intersections

Creditview Road Intersection at:	Number of Legs - Traffic Control Type	Total Entering AADT on Major Road	Total Entering AADT on Minor Road
Bancroft Drive (Sir Monty's Drive)	Four – Traffic Signal	11,374	1,953
Kenninghall Boulevard	Four – Traffic Signal	14,079	1,071
River Gate Place	Three – No Control	-	-
Falconer Drive	Three – Stop Sign	12,495	541
Argentia Road	Three – Traffic Control	11,308	5,052
Old Creditview Road	Four – Traffic Signal	8,231	2,312

Table 4: Selected Characteristics of Mid-Block Road Sections

Creditview Road Mid-Block Road Section between:	Type – No. of Lanes	Section Length (m)	AADT
Bancroft Drive (Sir Monty's Drive) and Velebit Court	Urban - 2	410	5,650
Velebit Court and Kenninghall Boulevard	Urban - 2	200	7,371
River Gate Place and Falconer Drive	Urban - 2	150	6,386
Falconer Drive and Argentia Road	Urban - 2	310	6,154
Argentia Road and Old Creditview Road	Urban - 2	750	4,818

The SPF model forms and parameters used to determine the predicted numbers of collisions for the three-legged and four-legged intersections are presented in Table 5 and Table 6 respectively. Due to the very low number of historical collisions along mid-block road sections along Creditview Road, it was assumed that there is no potential for safety improvement for mid-block road sections and that they have been experiencing fewer numbers of collisions in comparison to similar roadways in the City. In addition, the City of Mississauga currently does not have any SPFs developed for intersections with no traffic control device. Therefore the uncontrolled three-legged intersection of Creditview Road and River Gate Place (highlighted in grey in Table 3) as well as all mid-block road sections were excluded from the PSI analysis.

Table 5: Safety Performance Functions for Three-legged Intersections

Traffic Control Type	Model Form and Parameters	Collision Classification	
		Fatal and Injury	Property Damage Only
Signalized	Model Form	$a (F_1)^b (F_2 / (F_1+F_2))^c$	
	Ln(a)	-6.7111	-7.1172
	b	0.6060	0.8422
	c	0.3382	0.4217
	Pearson Chi-Square	0.9893	0.9348
	k	1.1451	0.7491
Stop-Controlled	Model Form	$a (F_1)^b (F_2 / (F_1+F_2))^c$	
	Ln(α)	-13.3843	-11.1226
	b	1.3362	1.3123
	c	0.6523	0.7337
	Pearson Chi-Square	1.0087	1.0404
	k	0.2970	0.7693

Note: F_1 = Total Entering AADT for Major Road
F_2 = Total Entering AADT for Minor Road

Table 6: Safety Performance Functions for Four-legged Intersections

Traffic Control Type	Model Form and Parameters	Collision Classification	
		Fatal and Injury	Property Damage Only
Signalized	Model Form	$a (F_1)^b (F_2 / (F_1+F_2))^c$	
	Ln(a)	-12.0015	-12.0953
	b	1.2137	1.3955
	c	0.4897	0.5655
	Pearson Chi-Square	0.9790	0.9299
	k	0.4918	0.4439

Note: F_1 = Total Entering AADT for Major Road
F_2 = Total Entering AADT for Minor Road

The study team obtained the potential for improvements for both FI (severe) and PDO collisions in terms of number of collisions by simply obtaining the differences between “predicted numbers of FI collisions” and “expected number of FI collisions” and the difference between corresponding PDO values. Table 7 presents the PSI values for the intersections within the study corridor. Appendix “C” contains a complete description of the methodology and a sample calculation to obtain overall potential for safety improvement.

Table 7: Intersections PSI Values

Creditview Road Intersection at:	Number of Legs - Traffic Control Type	Potential for Safety Improvement for FI Collisions	Potential for Safety Improvement for PDO Collisions	Overall Potential for Safety Improvement	Rank
Bancroft Drive (Sir Monty’s Drive)	Four – Traffic Signal	0.4616	2.5825	4.4935	1
Kenninghall Boulevard	Four – Traffic Signal	0.0284	0.7270	0.8445	4
Falconer Drive	Three – Stop Sign	0.0363	0.3867	0.6090	5
Argentia Road	Three – Traffic Control	0.2481	0.8015	2.2479	2
Old Creditview Road	Four – Traffic Signal	0.0334	1.4825	1.6207	3

As can be seen in Table 7, all intersections were found to have positive PSI values. This indicates that all intersections within the study corridor have a potential for safety improvement; the larger the positive value, the greater the potential. It is essential to note the PSI ranking presented in Table 7 pertains strictly to the study area and has no bearing on the overall City of Mississauga’s intersections’ safety performance.

As can be seen in Table 7, the three following Creditview Road intersections have the largest PSI values.

- Bancroft Drive (Sir Monty’s Drive);
- Argentia Road; and
- Old Creditview Road.

These findings, similar to the findings of descriptive collision trends analysis as presented earlier in this memorandum, identify the three above-noted intersections as the intersections in greater need of safety improvements with higher than average collisions as compared to similar types of roadways. This also implies the need for a thorough safety investigation to identify the potential reasons for relatively high prevalence of collisions at these intersections.

In addition, two (at Bancroft Drive and Argentia Road) of these three intersections were identified as intersections with significantly higher than average number of severe collisions. This was concluded based on their relatively large PSI values with respect to severe collisions (refer to the third column from left of Table 7).

Field Investigations

The subject site was visited on Thursday, October 10, 2013. Table 8 provides a summary of identified road safety issues in existing conditions along the study corridor. For road safety issue related to pedestrians / transit users and cyclists as well as Accessibility for Ontarians with Disability (AODA) requirements, please refer to the "Active Transportation and Transit Review" memorandum that was also completed as part of the Creditview Road EA Project. Appendix "D" provides photos associated with identified road safety issues that were presented in Table 8.

A speed study was conducted by the City of Mississauga on November 2, 2012. Vehicles travel speeds were measured for 24 hours straight at a station located on Creditview Road between Bancroft Drive and Velebit Court. The 85th-percentile speeds of vehicles for the southbound and northbound directions of travel were measured at 66 km/h and 74 km/h respectively. There were clear indications of posted speed limit violations in particular by southbound vehicles with 70% of the southbound vehicles travelling at speeds in excess of the posted speed limit (which is 60 km/h).

A separate speed study was also conducted on May 11, 2010 by the City of Mississauga at a location on Creditview Road between Highway 401 Bridge and Old Creditview Road. Similarly, this speed study also revealed the speeding issue for both directions of travel along that section. The average travel speeds were calculated at 63 km/h and 66 km/h for northbound and southbound directions respectively. At the intersections of Creditview Road / Bancroft Drive and Creditview Road / Argentia Road, the identified vehicle speeding issues coupled with the unavailability of the necessary sight distances on the north approaches (to the intersections) may be causal factors behind the relatively high prevalence of collisions in general and severe collisions in particular.

Table 8: Identified Road Safety Issues during Field Investigations

Location Description	Road Safety Issues
Credit River Bridge	Incorrect installation and connection of W-beam steel guiderails to bridge barrier on both approaches to the Credit River bridge (Figure D1 and Figure D2);
	Improper repair of barrier curb on both sides of the bridge (Figure D3);
	Improper W-beam steel guiderail end treatment (buried) on north approach to the bridge (Figure D4);
	W-beam steel guiderail not in good state of repair on both approaches to the bridge (Figure D5);
Mid-Block Road Section between Bancroft Drive and Credit River Bridge	Steep grade (1V:2H or steeper) on the side of the road immediately behind the east sidewalk is considered a fall hazard for pedestrians (especially for children and those with visual impairment). Pedestrians are likely to be engaged in conversations and go off-track from the sidewalk and onto the steep side slope and subsequently fall into the ditch (Figure D6);
Creditview Road and Bancroft Drive Intersection	Hidden “NO TURNS” sign on north approach to intersection of Creditview Road and Bancroft Drive (Figure D7);
	Insufficient clear sightline distances (due to vertical alignments and some sightline obstructions) to/from eastbound right-turning vehicles at the intersection from/to southbound traffic along Creditview Road. This is of greater issue when southbound right-turning traffic are present (Figure D8);
Creditview Road and River Gate Place Intersection	Improperly located “INTERSECTION” sign on north approach to uncontrolled intersection of Creditview Road and River Gate Place (Figure D9);
Creditview Road and Falconer Drive Intersection	Insufficient clear sightline distances (due to vertical alignments to/from eastbound right-turning vehicles at the intersection from/to southbound traffic along Creditview Road (Figure D10);
Creditview Road and Argentia Road Intersection	Hidden “INTERSECTION” sign on south approach to intersection of Creditview Road and Argentia Road (Figure D11);
Creditview Road and Old Creditview Road Intersection	Worn out “BICYCLE ROUTE” sign on north approach (from Old Creditview Road) to the intersection (Figure D12);
	Worn out pavement marking for “RIGHT TURN ONLY” arrow (Figure D13);
Multiple Locations	Although there is a “NO HEAVY TRUCKS” sign on the south and north ends of the study corridor, trucks were seen travelling along study corridor during the site visit (Figure D14);

Summary of Findings

The study adopts a methodology called "lines of evidence" approach to identify road safety issues. Where lines of evidence overlap and point to a common conclusion regarding a particular element of the roadway, that conclusion is strengthened. The adopted framework examined the road safety performance of the study corridor by using a couple of distinct examination methods as follows:

- Descriptive collision trend analysis;
- Potential for safety improvement; and
- Field investigations.

The signalized Creditview Road intersections at Bancroft Drive, Argentia Road, and Old Creditview Road were identified as locations with relatively high potential for safety improvement and a higher number of total and severe collisions. Past speed studies completed by the City of Mississauga and recent field investigations conducted by the study team identified speeding and potential sightline issues (due to the vertical alignment) on the north approaches to the intersections of Creditview Road / Bancroft Drive and Creditview Road / Argentia Road as potential causal factors behind the prevalence of historic collisions at these two intersections.

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APPENDIX “A” – COLLISION DIAGRAMS AT HIGH RISK INTERSECTIONS

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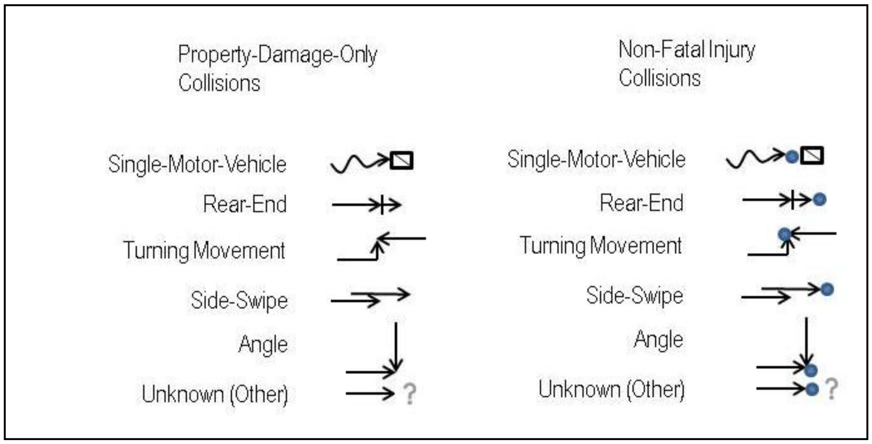

Legend for Collision Diagrams

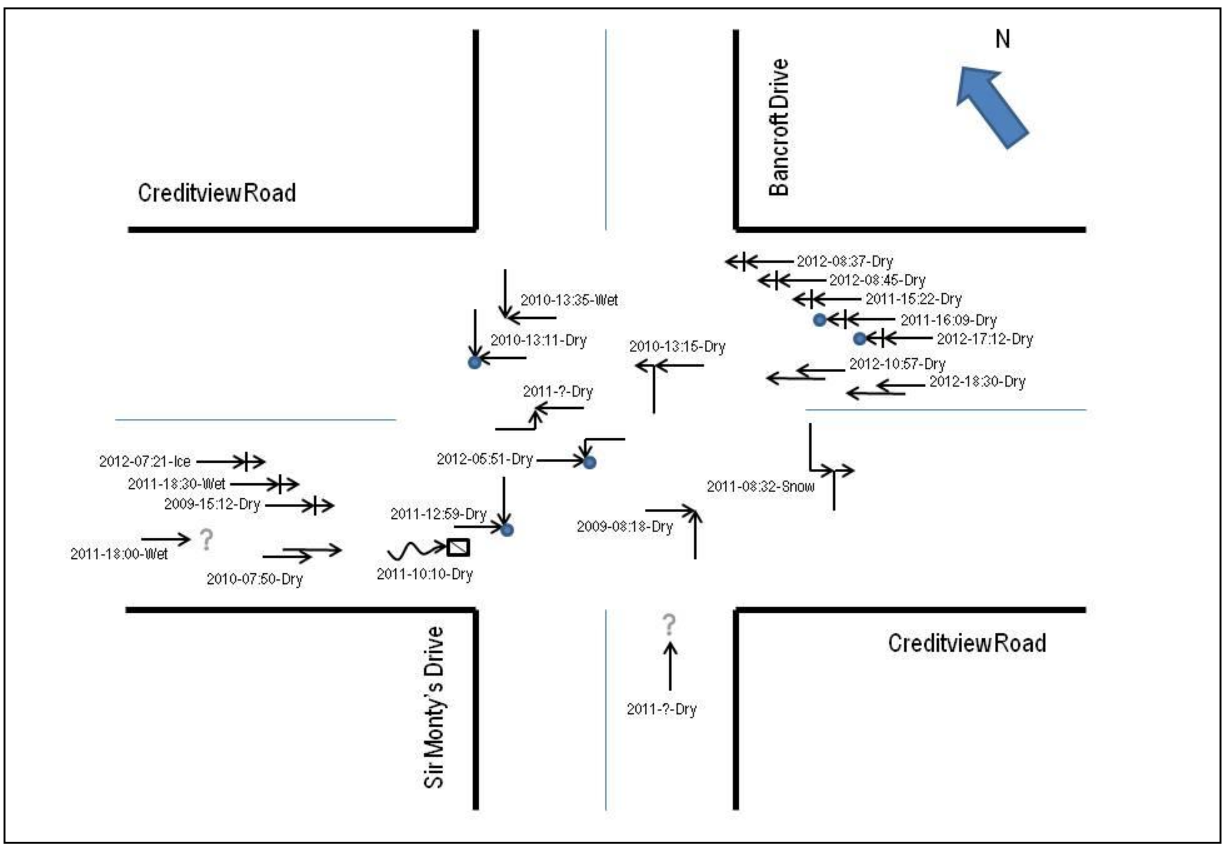

Figure A1: Collision Diagram for Intersection of Creditview Road and Bancroft Drive (2009 – 2012)

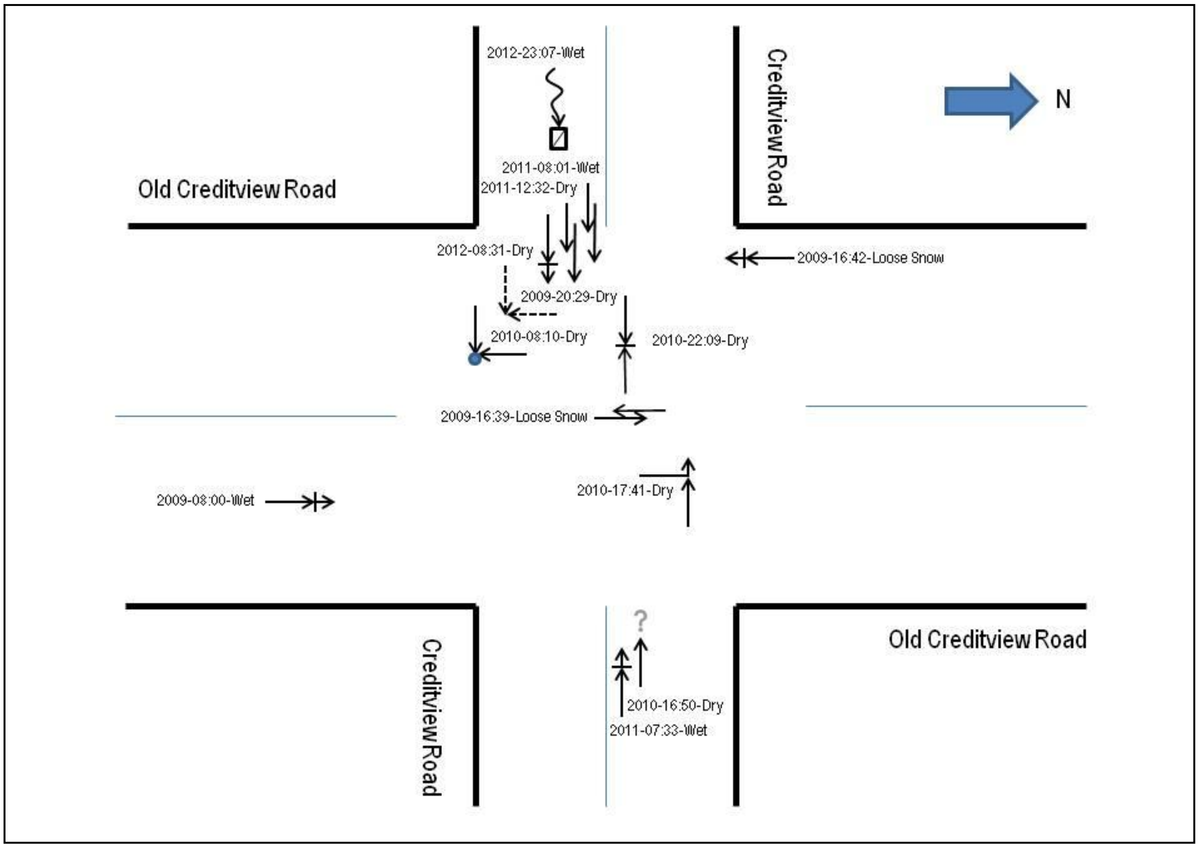

Figure A2: Collision Diagram for Intersection of Creditview Road and Old Creditview Road (2009 – 2012)

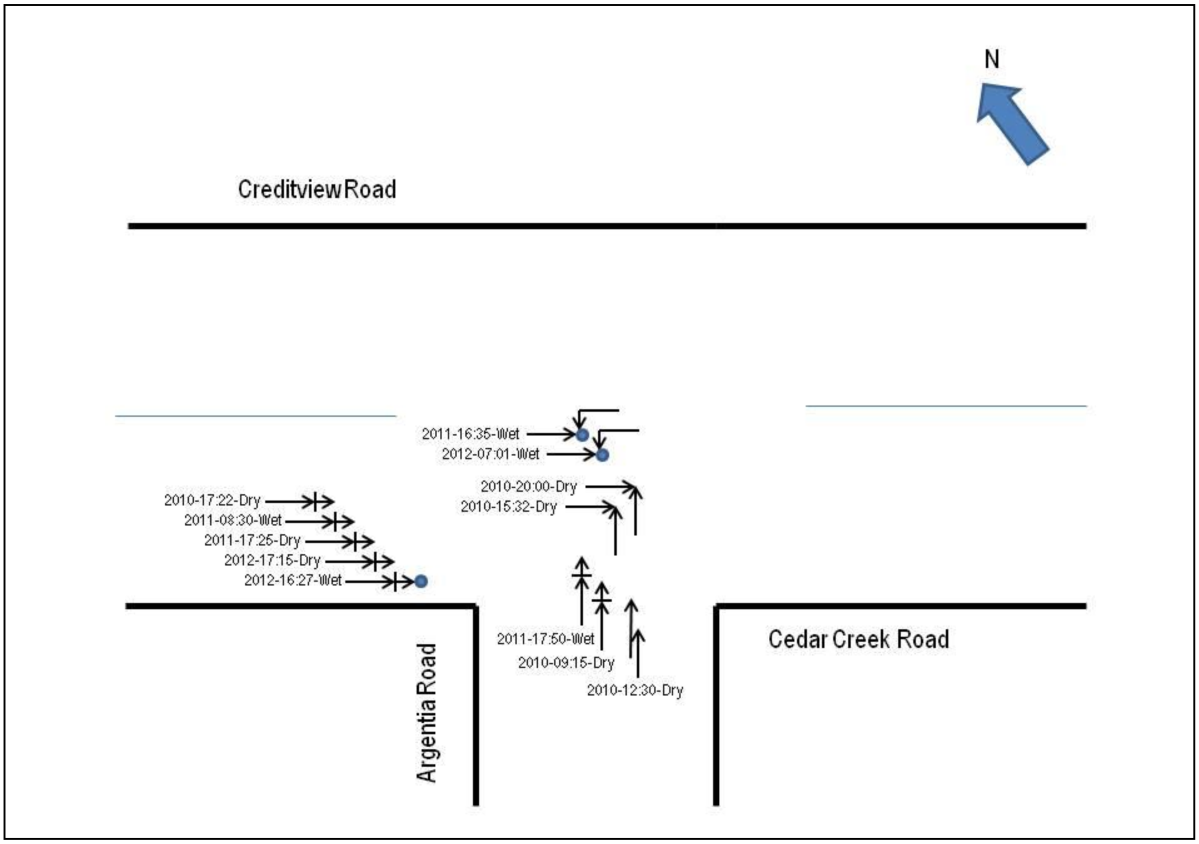

Figure A3: Collision Diagram for Intersection of Creditview Road and Argentia Road (2009 – 2012)

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APPENDIX “B” – DESCRIPTIVE ANALYSIS OF COLLISION DATA

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Table B1: Observed Number of Collisions Classified by Initial Impact Type that Occurred at Intersections along Creditview Road from 2009 to 2012

Creditview Road Intersection at:	Angle	Approaching	Turning Movement	Rear-End	Side-Swipe	SMV / Other	Total
Bancroft Drive (Sir Monty's Drive)	4	0	4	8	3	3	22
Kenninghall Boulevard	0	2	1	4	0	1	8
River Gate Place	0	0	0	1	0	0	1
Falconer Drive	0	1	0	4	0	0	5
Argentia Road	2	0	2	7	1	0	12
Old Creditview Road	2	1	1	4	3	2	13
Total	**8**	**4**	**8**	**28**	**7**	**6**	**61**

Table B2: Observed Number of Collisions Classified by Initial Impact Type Occurred on Mid-Block Road Sections along Creditview Road from 2009 to 2012

Creditview Road Mid-Block Road Section between:	Rear-End	Other	Total
Bancroft Drive (Sir Monty's Drive) and Velebit Court	2	0	2
Velebit Court and Kenninghall Boulevard	2	0	2
River Gate Place and Falconer Drive	1	0	1
Falconer Drive and Argentia Road	1	1	2
Argentia Road and Old Creditview Road	1	0	1
Total	**7**	**1**	**8**

Table B3: Observed Number of Collisions Classified by Lighting Conditions that Occurred at Intersections along Creditview Road from 2009 to 2012

Creditview Road Intersection at:	Daylight	Dark	Dusk	Unknown	Total
Bancroft Drive (Sir Monty's Drive)	17	3	0	2	22
Kenninghall Boulevard	5	2	1	0	8
River Gate Place	0	0	1	0	1
Falconer Drive	3	2	0	0	5
Argentia Road	10	0	2	0	12
Old Creditview Road	8	3	2	0	13
Total	**43**	**10**	**6**	**2**	**61**

Table B4: Observed Number of Collisions Classified by Lighting Conditions that Occurred on Mid-Block Road Sections along Creditview Road from 2009 to 2012

Creditview Road Mid-Block Road Section between:	Daylight	Dark	Total
Bancroft Drive (Sir Monty's Drive) and Velebit Court	0	2	2
Velebit Court and Kenninghall Boulevard	2	0	2
River Gate Place and Falconer Drive	1	0	1
Falconer Drive and Argentia Road	1	1	2
Argentia Road and Old Creditview Road	1	0	1
Total	**5**	**3**	**8**

Table B5: Observed Number of Collisions Classified by Road Surface Conditions that Occurred at Intersections along Creditview Road from 2009 to 2012

Creditview Road Intersection at:	Dry	Wet	Ice	Loose Snow	Total
Bancroft Drive (Sir Monty's Drive)	17	3	1	1	22
Kenninghall Boulevard	8	0	0	0	8
River Gate Place	1	0	0	0	1
Falconer Drive	4	1	0	0	5
Argentia Road	7	5	0	0	12
Old Creditview Road	7	4	0	2	13
Total	**44**	**13**	**1**	**3**	**61**

Table B6: Observed Number of Collisions Classified by Road Surface Conditions that Occurred on Mid-Block Road Sections along Creditview Road from 2009 to 2012

Creditview Road Mid-Block Road Section between:	Dry	Wet	Ice	Total
Bancroft Drive (Sir Monty's Drive) and Velebit Court	2	0	0	2
Velebit Court and Kenninghall Boulevard	1	1	0	2
River Gate Place and Falconer Drive	1	0	0	1
Falconer Drive and Argentia Road	1	1	0	2
Argentia Road and Old Creditview Road	0	0	1	1
Total	**5**	**2**	**1**	**8**

Table B7: Observed Number of Collisions Classified by Environment Conditions that Occurred at Intersections along Creditview Road from 2009 to 2012

Creditview Road Intersection at:	Clear	Rain	Snow	Other*	Total
Bancroft Drive (Sir Monty's Drive)	17	1	2	2	22
Kenninghall Boulevard	8	0	0	0	8
River Gate Place	1	0	0	0	1
Falconer Drive	5	0	0	0	5
Argentia Road	8	3	0	1	12
Old Creditview Road	9	2	1	1	13
Total	**48**	**6**	**3**	**4**	**61**

*"Other" category includes fog, strong wind, and other environment conditions

Table B8: Observed Number of Collisions Classified by Environment Conditions that Occurred on Mid-Block Road Sections along Creditview Road from 2009 to 2012

Creditview Road Mid-Block Road Section between:	Clear	Rain	Total
Bancroft Drive (Sir Monty's Drive) and Velebit Court	2	0	2
Velebit Court and Kenninghall Boulevard	2	0	2
River Gate Place and Falconer Drive	1	0	1
Falconer Drive and Argentia Road	1	1	2
Argentia Road and Old Creditview Road	1	0	1
Total	**7**	**1**	**8**

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Memorandum

APPENDIX "C" – THE EMPIRICAL BAYES FRAMEWORK TO CALCULATE POTENTIAL FOR SAFETY IMPROVEMENT

The EB Framework to Calculate Potential for Safety Improvement (PSI)

The objective of the Empirical Bayes (EB) framework is to estimate the long-term safety performance of a site. Specifically, it aims to smooth out the random fluctuations in the collision data by specifying the actual safety of a segment as an estimate of its long-term mean (m) instead of its short-term counts (x). The estimate of ‘m’ is obtained by combining the ‘x’ of a specific section in the most recent ‘n’ years with an estimate of the predicted annual number of collisions based on history of similar segments, E{m}.

According to the EB technique, for a specific collision severity level (i.e. fatal, injury, or property-damage-only),

$$m = w_1 \times x + w_2 \times E\{m\} \tag{C1}$$

where w_1 and w_2 are the weighting factors that can be estimated by,

$$w_1 = \frac{E\{m\}}{\left(1/k\right) + \left(n \times E\{m\}\right)} \tag{C2}$$

$$w_2 = \frac{\left\lfloor 1/k \right\rfloor}{\left(1/k\right) + \left(n \times E\{m\}\right)} \tag{C3}$$

where,

m = the long-term number of collisions expected to occur at the location, per year;
E{m} = the number of collisions predicted to occur as an “average” per year;
x = observed number of collisions at a specific location over n years;
n = number of years for which the collision counts are available;
k = the over-dispersion parameter that describes the relationship between E{m} and VAR{m}, as previously described.

The “sites with potential for safety improvement” can be identified from a list of many locations by the PSI values. Because the PSI of a location is the difference between its long-term expected safety performance and its predicted safety performance, taking into account the societal cost of collisions, in this study the $PSI_{(All)}$ of a location is comprised of both the PSI for severe (fatal and injury) collisions , and also PSI for PDO collisions.

As mentioned above, a PSI for a location is estimated by:

$$PSI_{(Total)} = PSI_{(Severe)} + PSI_{(PDO)} \tag{C4}$$

where,

$$PSI_{(Severe)} = \lfloor m_{(Severe)} - E\{m\}_{(Severe)} \rfloor \times (Societal\ Cost\ of\ Fatal\ and\ Injury\ Collisions)$$
$$PSI_{(PDO)} = \lfloor m_{(PDO)} - E\{m\}_{(PDO)} \rfloor \times (Societal\ Cost\ of\ PDO\ Collisions)$$

For the purpose of this study, for intersections, an approximate economic weighted ratio of 135.5:3.3:1 was considered for fatal, injury, and PDO collisions. In other words, it was assumed that the collision costs associated with fatal collisions are 135.5 times higher as compared to those of PDO collisions and collision costs for injury collisions are 3.3 times higher (as compared to PDO collisions).

To simplify the calculation process, some weighting factors could be used to substitute for the societal costs of collisions in estimating the PSI. If assuming that the weighting factor of PDO collisions = 1, then:

$$PSI_{(F+I)} = \lfloor m_{(Severe)} - E\{m\}_{(Severe)} \rfloor \times (Weighted\ Factor\ of\ Fatal\ and\ Injury\ Collisions)$$
$$PSI_{(PDO)} = \lfloor m_{(PDO)} - E\{m\}_{(PDO)} \rfloor$$

Because the $SPF_{(Severe)}$ is used in this study, the economic weighted factor, or relative safety index (RSI), must be derived for severe collisions. The RSI for intersections is estimated by,

$$RSI = \frac{135.5 \times Number\ of\ Fatal\ Collisions + 3.3 \times Number\ of\ Injury\ Collisions}{Total\ Number\ of\ Fatal\ and\ Injury\ Collisions} \quad \text{(C5)}$$

For this study, RSI value for intersections are obtained based on the respective number of recorded fatal and injury collisions for intersections in the Region of Halton. Table C1 shows the RSI values and the pertaining number of injury and fatal collisions for intersections using Equation C5.

Table C1: RSI Values for Intersections

Intersection Traffic Control Type and Number of Legs	Fatal	Injury	PDO	RSI
Signalized – 4 Legged	12	1874	8011	4.14
Signalized – 3 Legged	6	308	757	5.83
Stop-Controlled – 3 Legged	7	320	1045	6.13

Taken together, the following equations are used in this study to estimate the PSIs for the intersections:

$$PSI_{(F+I)} = \lfloor m_{(Severe)} - E\{m\}_{(Severe)} \rfloor \times (RSI) \quad \text{(C6)}$$

$$PSI_{(PDO)} = \lfloor m_{(PDO)} - E\{m\}_{(PDO)} \rfloor \quad \text{(C7)}$$

$$PSI_{(All)} = PSI_{(Severe)} + PSI_{(PDO)} \quad \text{(C8)}$$

It should be noted that only positive PSI values are used for consideration. Generally, if the PSI is negative for a roadway element, it should be assigned a value of zero since the negative sign means that the intersection experiences fewer collisions than is expected.

Sample Calculations

To illustrate the presented methodology in this report, a case study is presented in this section. The following example serves as a step-by-step analysis to identify "intersections with potential for safety improvement". Let's consider the intersection with the characteristics given below, whose collisions are observed between 2009 and 2012. The intersection that is analyzed is a three-legged stop-controlled intersection at Creditview Road and Falconer Drive. The relevant information for this intersection is shown in Table C2.

Table C2: Information for Intersection of Creditview Road and Falconer Drive

Collision Information					**Intersection Characteristics**	
Fatal = 0					Number of Approaches = 3	
Injury = 1					Traffic Control Type = Stop Sign	
PDO = 4						
Entering AADT					**Input Variables**	
Year	**NB**	**SB**	**EB**	**WB**	**Major AADT (F_1)**	**Minor AADT (F_2)**
2013	6,051	6,444	541	-	12,495	541

Step 1: Collision Prediction Model Form Identification

Identify the SPFs pertaining to this intersection for prediction of number FI and PDO collisions. Since the intersection in this example is a 3-legged stop-controlled intersection, the following models for severe and PDO collisions were used.

a) Severe Collisions

$$E(m_{PDO}) = 1.539 \times 10^{-6} \times (F_1)^{1.3362} \times \left(\frac{F_2}{F_1 + F_2} \right)^{0.6523}$$

b) PDO Collisions

$$E(m_{PDO}) = 1.478 \times 10^{-5} \times (F_1)^{1.3123} \times \left(\frac{F_2}{F_1 + F_2} \right)^{0.7337}$$

Step 2: Estimate the Predicted Number of Collisions

In this step, the predicted number of collisions (as “average” per year) was calculated using the models reported in the Step 1. These values are shown in Table C3.

Table C3: Predicted Annual Collisions Using Collision Prediction Model

$E(m_{Severe})$	$E(m_{PDO})$
0.0575	0.3402

Step 3: Estimate the Long-Term Number of Collisions

Estimate the long-term number of collisions expected to occur at this intersection combining the short-term collisions observed at the intersections over 4-year period (2009 through 2012) with its SPF.

Detailed calculations, using Equations C1, C2, and C3, to obtain the long-term number of PDO and severe collisions expected to occur at this intersection are shown below in Table C4. Note that in this example, n=4 (period from 2009 through 2012). From Table C2, the number of PDO collisions observed is 4, and the number of severe collisions observed is 0 + 1 = 1.

Step 4: Computing the RSIs

Table C1 contains the RSI value for stop-controlled three-legged intersection which is 6.13.

Step 5: PSI Calculation

Calculate the $PSI_{(All)}$ for the location. Using Equations C6 to C9, and the RSI values for intersections, the $PSI_{(All)}$ for this intersection is calculated and shown in Table C5.

Table C4: Estimate the Long-Term Number of Collisions

Data readily available				
Data available		**Severe Collisions**	**PDO Collisions**	**Data source**
E{m}		0.0575	0.3402	From Step 2
k		1.0087	1.0404	Table 5
n		4	4	Study period
x		1	4	Table C2
Terms to be estimated				
Term		**Severe Collisions**	**PDO collisions**	**Equation**
w_1	**Expression**	0.0575/((1/1.0087)+4×0.0575)	0.3402/((1/1.0404)+4×0.3402)	C2
	Value	0.0471	0.1465	
w_2	**Expression**	(1/1.0087)/((1/1.0087)+ 4×0.0575)	(1/1.0404)/((1/1.0404)+ 4×0.3402)	C3
	Value	0.8117	0.4139	
m	**Expression**	0.0471×1+0.8117×0.0575	0.1465×4+0.4139×0.3402	C1
	Value	0.0938	0.7269	

Table C5: PSI Calculation

Model parameters	Severe Collisions	PDO Collisions
E{m}	0.0575	0.3402
m	0.0938	0.7269
m-E{m}	0.0363	0.3867
RSI	6.13	1
PSI	0.2223	0.3867
$PSI_{(All)}$	0.6090	

APPENDIX “D” – PHOTOS OF IDENTIFIED ROAD SAFETY ISSUES

Figure D1 – Incorrect Connection of W-Beam Steel Guiderail to Credit River Bridge Parapet Wall (East Side)

Figure D2 – Incorrect Installation of W-Beam Steel Guiderail - Credit River Bridge Parapet Wall (West Side)

Figure D3 – Improper Repair of Barrier Curb over Credit River Bridge (East Side)

Figure D4 – Improper W-Beam Steel Guiderail End Treatment (Southbound Approach to Credit River Bridge)

Figure D5 – W-Beam Steel Guiderail Not in Good State of Repair (South of Credit River Bridge)

Figure D6 – Steep Grade Adjacent to East Sidewalk – Section between Bancroft Drive and Credit River Bridge

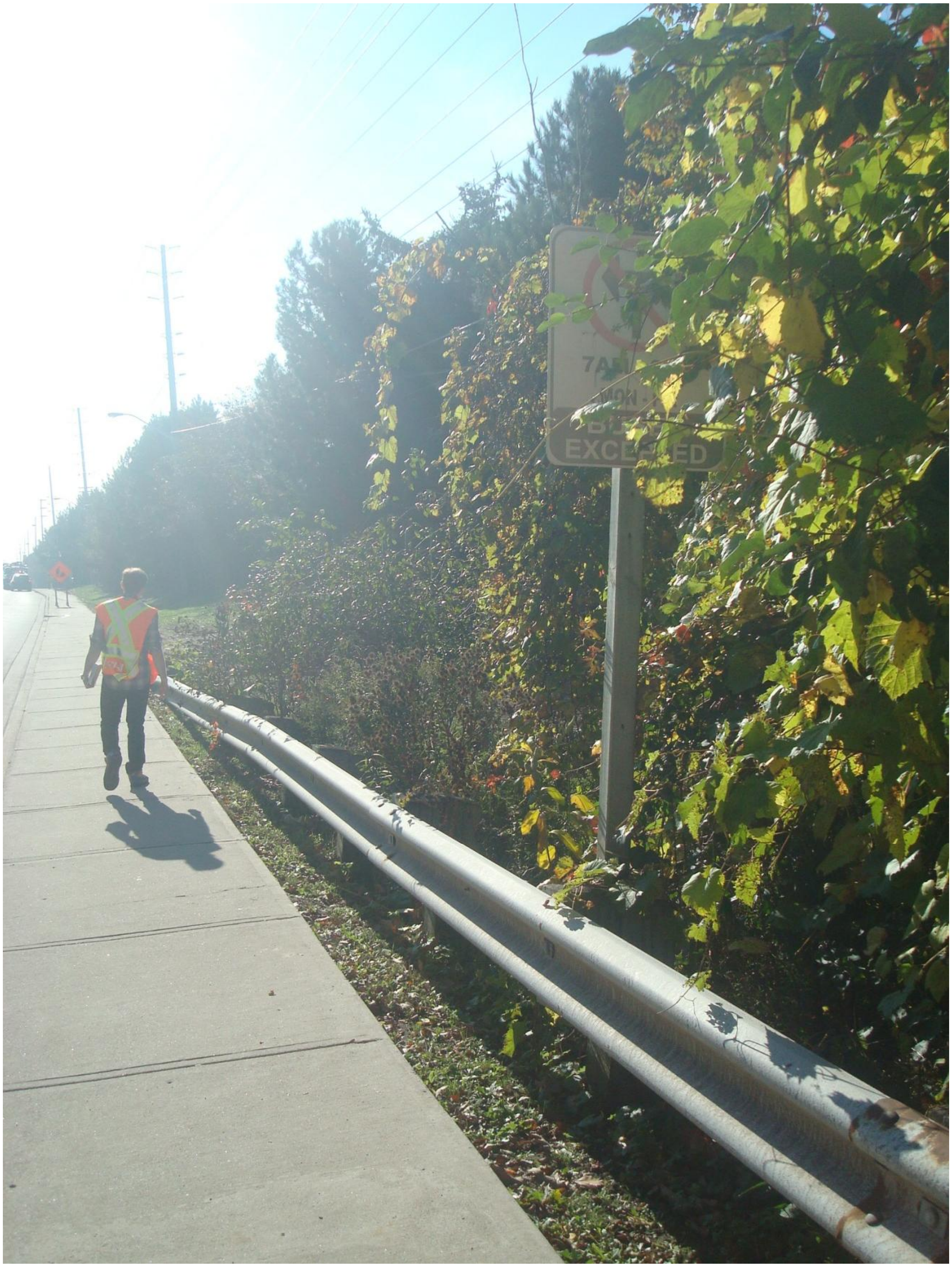

Figure D7 – Hidden “NO TURNS” Sign – North Approach to Intersection of Creditview Road and Bancroft Drive

Figure D8 – Insufficient Clear Sight Distances due to Vertical Alignment – Looking North at Intersection of Creditview Road and Bancroft Drive

Figure D9 – Improperly Located "HIDDEN DRIVEWAY" Sign – North Approach to Uncontrolled Intersection of Creditview Road and River Gate Place

Figure D10 – Insufficient Clear Sight Distances due to Vertical Alignment – Looking North at Intersection of Creditview Road and Falconer Drive

Figure D11 – Hidden "HIDDEN DRIVEWAY" Sign - South Approach to Intersection of Creditview Road and Argentia Road

Figure D12 – Worn-out “BICYCLE ROUTE” Sign – Intersection of Creditview Road and Old Creditview Road

Figure D13 – Worn-out Pavement Marking for "RIGHT TURN ONLY" Arrow on North Approach to Highway 401 Bridge

Figure D14 – With "NO HEAVY TRUCKS" Signs Installed on Both Ends of Study Corridor Trucks were Seen Travelling along Study Corridor

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Memorandum

To	Tammy Dow	Page	1
CC	Pranav Dave, Owen McGaughey, Diana Addley, Mirjana Osojnicki, Shahid Mahmood		
Subject	City of Mississauga – Creditview Road EA Study – Road Safety Assessment of Preferred Alternative Design		
From	Hossein Zarei		
Date	October 16, 2015	Project No.	60304588

As part of the Class Environmental Assessment (EA) Study, Schedule “C”, this memorandum is intended to assess the safety performance of the “preferred” alternative design in comparison to the existing design in a quantitative way.

In order to evaluate the safety performance of the “preferred” design, an estimate of the safety performance of the existing design was required as well. Site-specific Empirical Bayes (EB) estimates of the expected collision frequency were previously obtained for each mid-block road section and intersection in the study corridor for the existing condition. For detailed methodology of obtaining these estimates and the results, refer to the Safety Assessment of Existing Conditions Technical Memorandum (i.e., M-2014-03-04-Creditview Road EA - Safety Assessment of Existing Conditions – 60304588.PDF).

The expected collision frequency pertaining to the existing design was also estimated for horizon year 2031, which was selected as the planning horizon year for the proposed design. These estimates were obtained in order to determine what the safety performance of the study corridor will be in 2031 if the existing design continues to be in place as it is now without making any improvements to it.

The following are the proposed changes to the geometry and traffic control devices in the “preferred” alternative design from what currently exist in the field:

- Increase in number of lanes from two lanes to four lanes along Creditview Road between east of Argentia Road and Old Creditview Road;

- Introduction of single-lane roundabouts at the Creditview Road / Kenninghall Boulevard and Creditview Road / Falconer Drive intersections;
- Introduction of a two-lane roundabout at the intersection of Creditview Road / Argentia Road;
- Provision of 4.5-m wide paved shoulder between the outside edge of travel lane and the edge of sidewalk on both sides of Creditview Road over the Credit River Bridge;
- Accommodating a left-turn lane along Creditview Road for southbound motorists at the intersection of Creditview Road / River Gate Place; and
- Provision of a separate right-turn lane on the south leg (for the northbound traffic) of the intersection of Creditview Road / Old Creditview Road.

Collision Modification Factors (CMFs)

To conduct a quantitative safety assessment, collision modification factors (CMFs) are required in order to more accurately obtain the change in expected number of collisions as a result of the implementation of the proposed changes to the existing design in terms of geometry and traffic control devices.

CMFs provide estimates of the reduction / increase in the frequency of collisions that occur due to deviation from standard geometric design practice in terms of roadway geometric design, roadside design, type of traffic control devices, etc. CMFs are developed in such a way as to yield a value of 1.0 when the associated design component or element represents a standard condition. For instance, a CMF related to lane width assumes a value of 1.0 when the lane width of the road under consideration is 3.65 m; a deviation from this typical condition to a more generous or desirable design condition may result in CMF value of less than 1.0, and deviation to a more restricted condition results in a CMF value of more than 1.0.

The ratio of the CMF after the improvement to the CMF before the improvement represents the CMF for the improvement itself. Therefore, in this study a CMF for the “preferred” alternative is calculated by dividing the CMFs for the changes proposed in the alternative design by the corresponding values for the existing conditions.

A literature review of available CMFs was conducted in order to select the best applicable CMFs for the road segments and intersections within the study corridor.

CMFs used for his analysis were extracted from the following references:

- AASHTO Highway Safety Manual;

- Application and Evaluation of Collision Modification Factors for Ontario Highway Applications – Geometric Design and Safety Design[1];
- Federal Highway Administration (FHWA) CMF Clearinghouse[2]; and
- Road Safety Design Synthesis[3].

CMFs for Intersections

CMF (1) - CMF for Increase in Number of Through Lanes at Intersection Approaches

In the "preferred" design, Creditview Road is proposed to be widened from two lanes to four lanes between east of Argentia Road and Old Creditview Road.

According to "Road Safety Design Synthesis" and "AASHTO Highway Safety Manual", an increase in lanes at a signalized intersection is associated with an increase in severe collision frequency with all other factors remaining unchanged. The "Road Safety Design Synthesis" provides the CMFs for number of through lanes at urban signalized intersections. As per this document, the CMF values reflect a base condition of four through lanes on the Major Street and two through lanes on the Minor Street.

Table 1 presents the CMF values for the change in number of through lanes at urban signalized intersections.

Table 1: CMF for Change in Number of Through Lanes on Approaches to Urban Signalized Intersections

Approach Type	CMF for Severe Collisions	
	Number of Through Lanes	CMF (1)
Major	3 or fewer	0.99
	4 or 5	1.00
	6 or more	1.01

As such the CMF value for the proposed improvement at the intersection of Creditview Road / Old Creditview Road, as a result of increasing the number of through lanes from two lanes in existing condition to four lanes in the "preferred" alternative design along the Major Street is obtained by dividing the CMF of the preferred design (i.e., Major Street with four lanes) by the CMF of the existing design (Major Street with two lanes) at 1.01 (= 1.00 / 0.99).

[1] *Application and Evaluation of Collision Modification Factors for Ontario Highway Applications – Geometric Design and Safety Design, Prepared by AECOM (then operating as SYNECTICS Transportation Consultants Inc.), February 2003.*
[2] *www.CMFclearinghouse.org (accessed in October 2015).*
[3] *Bonneson J., Zimmerman, K., and K. Fitzpatrick, Roadway Safety Design Synthesis, Publication no. FHWA/TX-05/0-4703-P1, November 2005.*

CMF (2) - CMF for Conversion of Two-Way Stop-Controlled Intersection to Roundabout

In the “preferred” design, a single-lane roundabout is proposed to be introduced at the currently unsignalized intersection of Creditview Road / Falconer Drive. In its current form, this intersection operates under free flow of traffic along Creditview Road and STOP sign for traffic on the Falconer Drive approach.

As per the FHWA “CMF Clearinghouse”, the CMF related to conversion of a two-way stop-controlled intersection into a roundabout is 0.75 overall and 0.65 for fatal and injury collisions (Qin *et al.*, 2013).

CMF (3) - CMF for Conversion of Signalized Intersection to Roundabout

In the “preferred” design, roundabouts are proposed to be introduced at the currently signalized intersections of Creditview Road / Kenninghall Boulevard and Creditview Road / Argentia Road.

As per the FHWA “CMF Clearinghouse”, the CMF related to conversion of a signalized intersection into a roundabout is 0.96 overall (Qin *et al.*, 2013).

CMF (4) - CMF for Adding Right Turn Lane on Intersection Approaches

In the “preferred” design, an exclusive right-turn lane is proposed to be added on the northbound approach of the Creditview Road / Old Creditview Road intersection.

Table 2 presents the CMF values related to the addition of right-turn lane to urban four-leg intersections which are excerpted from the MTO’s “Application and Evaluation of CMFs for Ontario Highway Applications – Geometric Design and Safety Design”.

Table 2: CMF for Adding Right-Turn Lane to Urban Four-Leg Signalized Intersections

No. of Approaches to which Right-Turn Lanes are to be Added	CMF for All Collisions
	CMF (4)
One	0.96
Two	0.92

As per information provided in Table 2, CMF of 0.96 is used where a right-turn lane is to be added to one intersection approach only. As a shared through / right-turn lane currently exists on the Creditview Road’s northbound approach to the Old Creditview Road intersection, the CMF for the existing condition is considered to be 1.00. The CMF for the safety improvement following provision of a separate right-turn lane is derived by dividing the CMF of the preferred design (i.e., with adding right turn lane on one approach) by the CMF of the existing design (i.e., no separate right-turn lane) at 0.96 (= 0.96 / 1.00).

CMFs for Mid-Block Road Sections

CMF (5) - CMF for Increase in Shoulder Width

In the “preferred” design, for the section of Creditview Road over the Credit River Bridge, 4.5-m wide paved shoulders are proposed to be provided on both sides.

According to “Road Safety Design Synthesis”, with a base combination of area type, number of lanes and median type (i.e., urban four-lane roadway with a raised-curb median) and a base condition shoulder width of 0.5 m (equivalent to 1.5 feet), the CMF values accounting for the deviation from these base conditions is calculated by the following formula[4]:

$$\text{CMF (5)} = 1.0 + (e^{-0.014\,(W - 1.5)} - 1.0)\, P / 0.088$$

“P” denotes the proportion of collisions such as single-motor-vehicle (SMV) collisions which are expected to be impacted by changes in shoulder widths. **Table 3** shows the values of “P” for various median type and number of lanes scenarios.

Table 3: Collision Distribution for Urban Street Shoulder Width CMF

Median Type	Number of Through Lanes (Bi-Directional)	Proportion of SMV Collisions (P)
Undivided or Two-Way Left-Turn Lane	2	0.17
	4	0.10
Raised Curb	2	0.054
	4	0.088
	6	0.087

With the existing minimum shoulder width of 0.5 m (i.e., 1.5 feet), the CMF for the existing condition is calculated to be 1.00. The CMF for the proposed improvement (i.e., shoulder widening over the Credit River Bridge) within the mid-block section between Velebit Court and Bancroft Drive/Sir Monty’s Drive is derived by dividing the CMF of the preferred design (i.e., with 4.5 m wide paved shoulders), obtained using the above formula, by the CMF of the existing design (i.e., with 0.5 m wide paved shoulders), resulting at 0.67.

CMF (6) - CMF for Increase in Number of Through Lanes within Mid-Block Road Sections

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[4] *Note that W should be input to the formula in feet not meters.*

In the “preferred” design, Creditview Road is proposed to be widened from two lanes to four lanes between east of Argentia Road and Old Creditview Road.

We were unable to find a reliable CMF for the increase in number of lanes within the mid-block road sections. Although the “FHWA – CMF Clearinghouse” reports the CMF for the increase in number of lanes at 0.8 (Gan *et al.*, 2005), it is noted that the quality of this CMF cannot be rated.[5] In other words, the FHWA reviewing committee have not been able to assess the validity of this reported CMF. Therefore for the purpose of the safety evaluation of the “preferred” alternative, the CMF for increasing the number of lanes from two to four lanes is conservatively assumed to be 1.00.

Note that the total required CMF was obtained for total collisions, by multiplying all the CMF’s described above, as shown by the equation below:

$CMF_{Total} = CMF\ (1) \times CMF\ (2) \times CMF\ (3) \times \ldots$

Table 4 and **Table 5** summarize the individual CMF values as well as the overall CMF for individual intersections and mid-block road sections of the “preferred” alternative.

Note that the road elements (i.e., the intersection of Creditview Road / Velebit Court and the mid-block road section of Creditview Road between Kenninghall Boulevard and River Gate Place) that had no reported collisions over the collision analysis period (i.e., beginning of January 2009 to end of December 2012) were not included in Table 4 and Table 5. In addition, the City of Mississauga currently does not have any safety performance functions (SPFs; also known as collision prediction models) developed for intersections with no traffic control device. Therefore the uncontrolled three-legged intersection of Creditview Road / River Gate Place was also excluded from any further analysis. As a result, the potential improvements in safety performance of this intersection following the provision of a left-turn lane within the center median (in the “preferred” design) cannot be quantified.

Table 4: CMFs for Study Intersections

Creditview Road Intersection at:	CMF(1)	CMF(2)	CMF(3)	CMF(4)	Overall CMF
Bancroft Drive/Sir Monty’s Drive	1.00	1.00	1.00	1.00	1.00
Kenninghall Boulevard	1.00	1.00	**0.96**	1.00	**0.96**
Falconer Drive	1.00	**0.75**	1.00	1.00	**0.75**
Argentia Road	1.00	1.00	**0.96**	1.00	**0.96**
Old Creditview Road	**1.01 ***	1.00	1.00	**0.96**	**0.97**

*This CMF is for severe collisions only.

[5] *For additional information, refer to http://www.cmfclearinghouse.org/res_zero2.cfm*

Due to the very low number of historical collisions (i.e., average of two collisions per year) along the entire Creditview Road's mid-block road sections over the collision analysis period (i.e., beginning of January 2009 to end of December 2012), the study mid-block road sections along Creditview Road in the existing condition are considered to have better safety performance (i.e., experiencing fewer numbers of collisions) in comparison to similar roadways within the City. As per the information provided in Table 5, the implementation of the "preferred" design is expected to result in the same level of safety performance along the mid-block road sections with the exception of the section between Bancroft Drive and Velebit Court. Hence, for the purpose of quantitative evaluation of change in safety performance of the study corridor following the implementation of the "preferred" design, this technical memorandum focuses on the study intersections only and Table 5 is provided for information only.

Table 5: CMFs for Study Mid-Block Road Sections

Creditview Road Mid-Block Road Section between:	CMF(5)	CMF(6)	Overall CMF
Bancroft Drive (Sir Monty's Drive) and Velebit Court	**0.67**	1.00	**0.67**
Velebit Court and Kenninghall Boulevard	1.00	1.00	1.00
River Gate Place and Falconer Drive	1.00	1.00	1.00
Falconer Drive and Argentia Road	1.00	1.00	1.00
Argentia Road and Old Creditview Road	1.00	1.00	1.00

Estimate of the Expected Number of Collisions per Year

The safety assessment of the proposed "preferred" design was done in the planning horizon year of 2031 by providing an answer to the following question:

> *What will be the expected average collision frequency in planning horizon year (2031) for the "preferred" design and how will it be different from the expected average collision frequency if the modifications to the study corridor are not applied?*

The expected average collision frequencies for the existing design were estimated previously following the EB methodology, combining the observed numbers of collisions and the predicted numbers of collisions. The expected average number of collisions in the planning horizon year (2031), for the existing condition design is obtained using the following equation, assuming that the proportion of the expected and predicted numbers of collisions in the horizon year will be similar to that of existing conditions (base year):

$$E_{ef} = \frac{P_{ef} \times E_e}{P_e} \qquad \text{(Equation 1)}$$

Where:

Eef = Expected average number of PDO equivalent collisions in the study horizon year (2031) if no changes are applied to the existing design

Ee = Expected average number of collisions in the base year (2013) for the existing design (already known from the Safety Assessment of Existing Conditions Technical Memorandum)

Pef = Predicted number of PDO-equivalent collisions in the study horizon year (2031) if the changes are not applied to the existing design (obtained from **Equation 2** below by using the AADT values pertaining to the horizon year, and proper SPF formula with inclusion of applicable weighting factors)

Pe = Predicted number of collisions in the base year (2013) for the existing design (already known from the Safety Assessment of Existing Conditions Technical Memorandum)

Based on the engineering judgement, it is assumed that given the much lower costs and higher frequency of PDO collisions in comparison to those of severe collisions (fatal and injury), assigning appropriate weighting factors (to account for different societal costs of severe versus PDO collisions), multiplying those factors to predict the number of severe collisions for each location, and adding up the product to a corresponding number of predicted PDO collision frequencies would result in a more tangible measure of safety performance of that specific location. Therefore, before calculation of E_{ef} (using **Equation 1**), P_{ef} is calculated as shown below:

$$p_{ef} = SPF_{Severe} \times RSI + SPF_{PDO} \qquad \text{(Equation 2)}$$

In the above formula, the relative safety index (RSI) is a weighting factor used to convert severe collision frequencies to PDO-equivalent collision frequencies. Refer to the Safety Assessment of Existing Conditions Technical Memorandum for more information on calculating RSI values.

In addition, the predicted number of PDO equivalent collisions for the “preferred” design in the planning horizon year (2031) is obtained using the formula below:

$$p_p = p_{ef} \times CMF \qquad \text{(Equation 3)}$$

To estimate the expected average number of PDO equivalent collisions per year for the “preferred” design the following formula is used.

$$E_p = \frac{P_p \times E_e}{P_e} \qquad \text{(Equation 4)}$$

Where:

E_p = Expected average number of PDO equivalent collisions for the “preferred” design

E_e = Expected average number of collisions for the existing design (already known from the Safety Assessment of Existing Conditions Technical Memorandum) in the base year (2013)

P_p = Predicted number of PDO equivalent collisions for the “preferred” design (obtained from **Equation 3**)

P_e = Predicted number of collisions for the existing design (already known from the Safety Assessment of Existing Conditions Technical Memorandum) in the base year (2013)

Figure 1 illustrates the theoretical relationship between the predicted and expected collision frequencies with the existing and “preferred” designs.

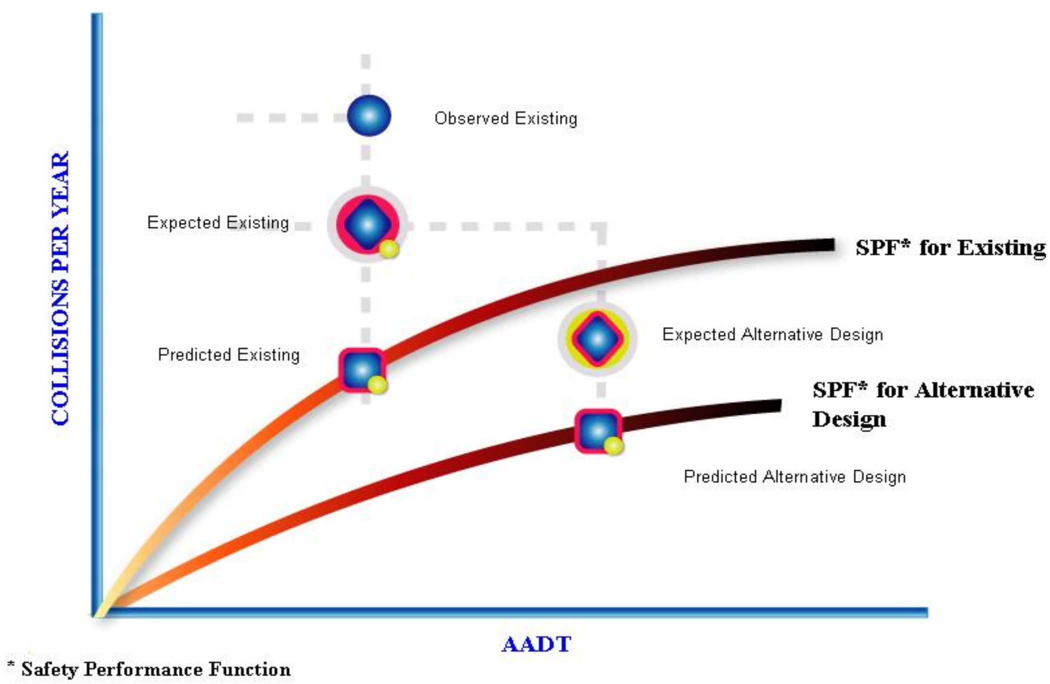

Figure 1: Theoretical Relationship between Predicted and Expected Collision Frequencies with Existing and “Preferred” Designs

Safety Assessment for Planning Horizon Year 2031

The expected numbers of PDO equivalent collisions at the study intersections in the horizon year 2031 with the existing design are obtained by using Equations 1 and 2. The results are shown in **Table 6**.

Note that an annual growth factor of 0.9% is assumed and applied to the actual entering AADT volumes from the Major and Minor Streets that were collected in 2013 to estimate the entering AADT volumes in the planning horizon year (2031). This annual growth factor matches the future growth rates presented in Table 4 of the Creditview Road Traffic Operations Analysis Report, dated September 2015, for the "no-widening" scenario in the horizon year 2031.

Table 6: Total Predicted and Expected Numbers of Collisions at Study Intersections in the Planning Horizon Year (2031) with Existing Design

Creditview Road Intersection at:	Estimated Major Road AADT in 2031	Estimated Minor Road AADT in 2031	Predicted no. of PDO-Equivalent Collisions	Expected no. of PDO-Equivalent Collisions
Bancroft Drive (Sir Monty's Drive)	13,365	1,953	1.94	7.50
Kenninghall Boulevard	16,543	1,071	1.73	3.11
Falconer Drive	14,682	541	0.77	1.59
Argentia Road	13,287	5,052	2.84	4.82
Old Creditview Road	9,671	2,312	1.58	4.39

In addition, the predicted and expected PDO-equivalent collision frequencies in the future year with the "preferred" alternative design were obtained by using Equations 2, 3, and 4. The results are shown in **Table 7**.

Table 7: Total Predicted and Expected Numbers of Collisions of Study Intersections in the Planning Horizon Year (2031) with "Preferred" Design

Creditview Road Intersection at:	Overall CMF	Predicted no. of PDO-Equivalent Collisions ("Preferred" Design)	Expected no. of PDO-Equivalent Collisions ("Preferred" Design)
Bancroft Drive (Sir Monty's Drive)	1.00	1.94	7.50
Kenninghall Boulevard	0.96	1.66	2.98
Falconer Drive	0.75	0.58	1.19
Argentia Road	0.96	2.73	4.62
Old Creditview Road	0.97	1.54	4.26

Table 8 shows the change in safety performance of the individual intersections in the study horizon year (2031) with the “preferred” design from those with the existing design (i.e., if the proposed modifications to the study corridor are not applied). As shown in Table 8, there would be an equivalent reduction of one PDO collision per year (i.e., 4% reduction in number of collisions) with the “preferred” alternative design, compared with the Do-nothing scenario.

Table 8: Change in Safety Performance of Individual Intersections in the Planning Horizon Year (2031) with “Preferred” Alternative Design

Creditview Road Intersection at:	Total Expected no. of PDO-Equivalent Collisions in 2031 with Existing Design	Total Expected no. of PDO-Equivalent Collisions in 2031 with “Preferred” Design	Reduction in no. of PDO-Equivalent Collisions in 2031	Percentage of Reduction in No. of PDO Equivalent Collisions
Bancroft Drive (Sir Monty’s Drive)	7.50	7.50	0.00	0.00%
Kenninghall Boulevard	3.11	2.98	0.13	4.18%
Falconer Drive	1.59	1.19	0.40	25.16%
Argentia Road	4.82	4.62	0.20	4.15%
Old Creditview Road	4.39	4.26	0.13	2.96%
Total	**21.41**	**20.55**	**0.86**	**4.02%**