August 2010

In-service Road Safety Review

Bovaird Drive (Regional Road 107)
Lake Louise Drive/Worthington Avenue to the Peel/Halton Boundary
City of Brampton, Ontario

Peel Project No. 09-4360

Client: **Regional Municipality of Peel**
Public Works Department

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1. Introduction

1.1 This report documents an In-service Road Safety Review of Bovaird Drive (Regional Road 107) from Louise Drive/Worthington Avenue to the Peel/Halton Boundary (about 1.45 km west of Heritage Road). The review was conducted for the Public Works Department of the Regional Municipality of Peel. The study location is shown in Figure 1.1.

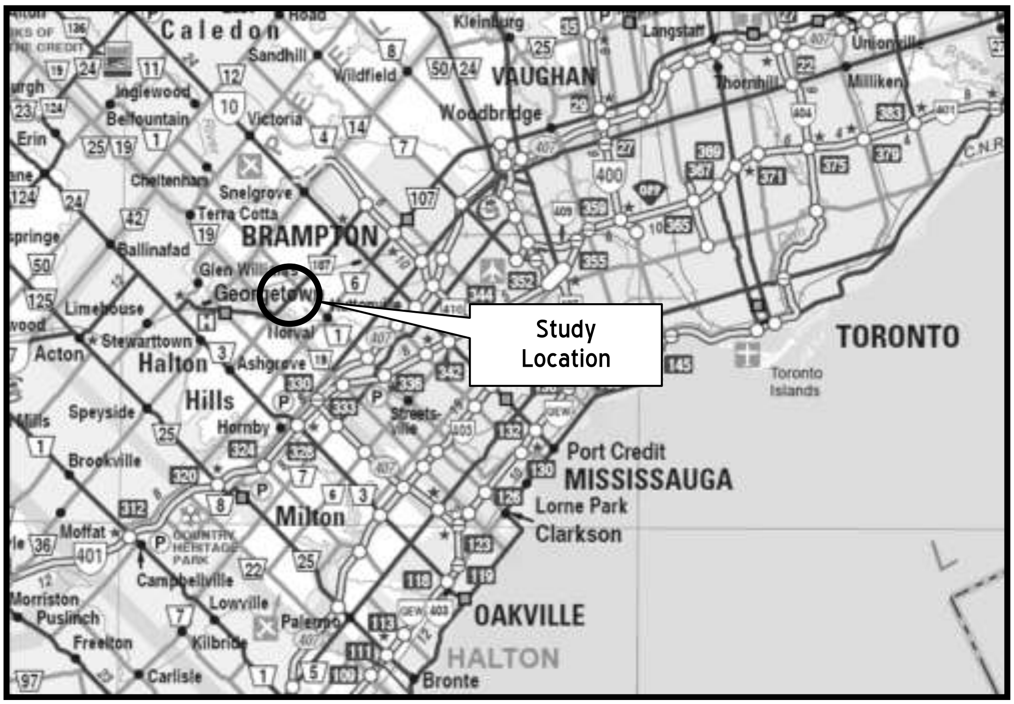


FIGURE 1.1: Study Location

1.2 The safety review was conducted as part of a Class Environmental Assessment (EA) being undertaken by AMEC Earth and Environmental (AMEC) for the Region. The terms of reference for the Class EA process call for a traffic safety review of the corridor to identify deficiencies and possible solutions, including the potential for roundabouts.

1.3 The safety review was carried out by Gerry Forbes, M.Eng, P.Eng, PTOE, at the office of ***Intus Road Safety Engineering Inc.*** in Burlington, Ontario, between December 17, 2009 and March 23, 2010. Site visits were undertaken on November 19, 2009 and March 26, 2010.

1.4 The goal of this safety review was to examine the facility's safety performance, to identify engineering-related factors that may be leading to an increased collision risk, and to recommend solutions to these problems (if any). This goal is supported by the specific objectives of the assignment which are to calculate collision rates for all intersections and road segments in the study area, identify the road-related contributing factors to any high collision risks, recommend collision countermeasures based on identified safety concerns, conduct an evaluation of the recommended countermeasures, and provide advice on the safety impacts of roundabouts for the study area.

1.5 This in-service road safety review has been carried out in general accordance with the ***Canadian Guide to In-service Road Safety Reviews*** (Transportation Association of Canada, 2003).

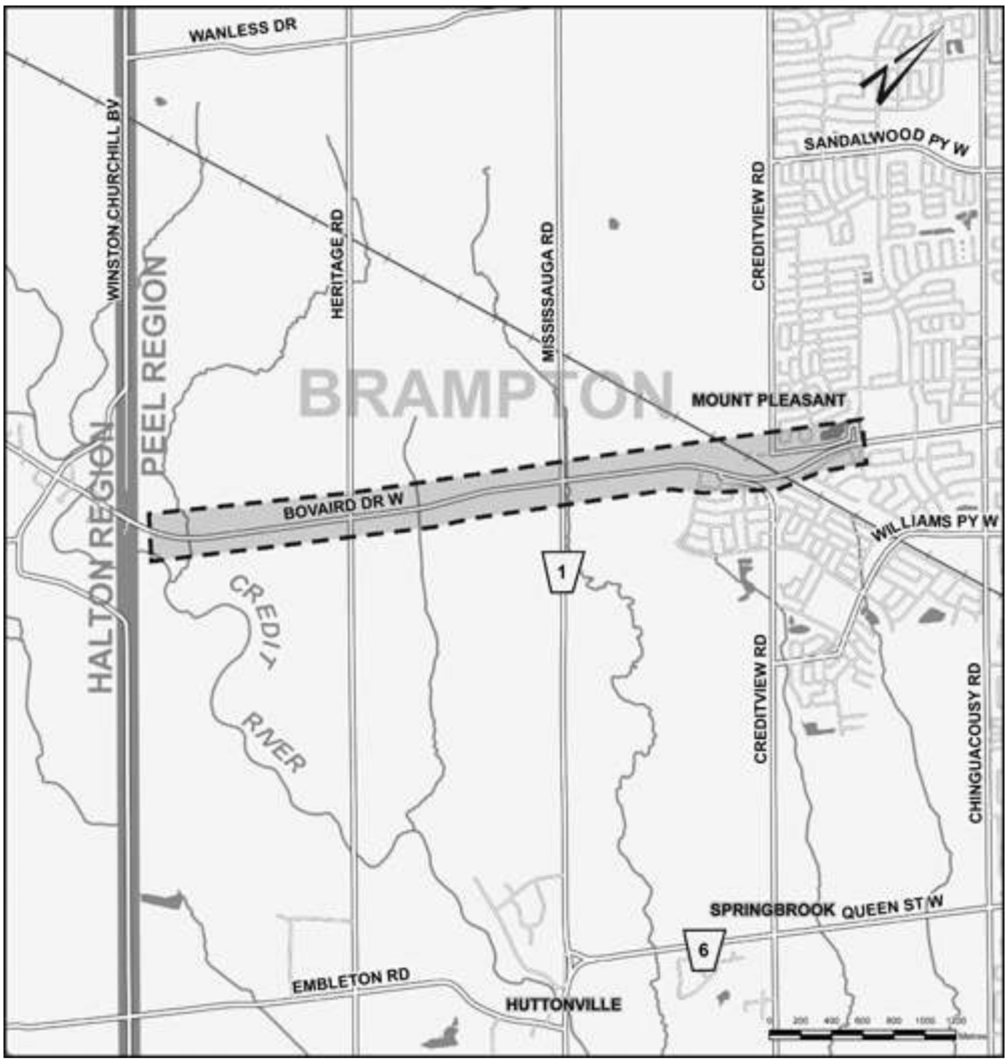
1.6 The material provided to Intus to conduct the safety review is listed in Appendix A.

1.7 It is acknowledged that safety is one of many considerations that AMEC and the Region of Peel need to balance in undertaking the Class EA, including, but not necessarily limited to, cost, environmental protection, congestion management, and community impacts. This report is focused on safety, with the anticipation that in general, the issues identified will be considered in the planning and design process.

2. Description of the Existing Facility

2.1 The section of Bovaird Drive under study is shown in Figure 2.1. For the purposes of this report, Bovaird Drive will be described as running in an east-west direction.

FIGURE 2.1: The Study Area



2.2 Bovaird Drive is an arterial road with a posted speed limit of 70 km/h from Lake Louise Drive/Worthington Drive to west of Heritage Road, and a speed limit of 60 km/h to the west study limit.

2.3 Bovaird Drive at Lake Louise Drive/Worthington Avenue has a six-lane cross-section. However, immediately west of this intersection the cross-section is reduced to four lanes until west side of Ashby Field Road where it becomes a two-lane cross-section. The two-lane cross-section of Bovaird Drive continues through to the west study limit.

2.4 The study area has four signalized intersections: Lake Louise Drive/Worthington Avenue, Ashby Field Road, Mississauga Road, and Heritage Road. Ashby Field Road is opposite the entrance to the Mount Pleasant GO Station.

2.5 Bovaird Drive has a curvilinear alignment and is relatively flat except for vicinal to the rail tracks and the western study limits. An eastbound truck climbing lane is provided in the west end of the study area.

2.6 The land use contiguous to Bovaird Drive in the study area is mostly rural, except at the east and west ends of the study area. The east end is a fully urbanized area with residential and commercial land uses. The west end of the study is the entrance to the Hamlet of Norval – a rural settlement/community.

2.7 The levels of service (LoS) for the intersections in the Bovaird Drive study area were determined by Entra Consultants[1]. The intersections operate at LoS C or better except for the Mississauga Road intersection which operates at LoS D during the AM and PM peak periods. Furthermore, the westbound left-turn movement at the intersection of Bovaird Drive and Mississauga Road experiences LoS F during the AM peak period.

[1] Entra Consultants, Bovaird Drive Class EA, Traffic Study, Draft Report, February 2010.

3. Collision Record

3.1 Collision data from January 1, 2005 to December 31, 2007 were supplied by the Region of Peel as a summary report in an MS-Excel™ spreadsheet.

3.2 According to Regional records, there were 74 reported collisions in the Bovaird Drive study area during this period (see Figure 3.1). This is an average of 24.7 collisions/year [14.4:34.9][2]. The available data shows the collision frequency is increasing at a rate of 39.4% per annum (see Figure 3.1). At least some of the increase in the collision frequency is simply due to the increasing traffic volumes on Bovaird Drive.

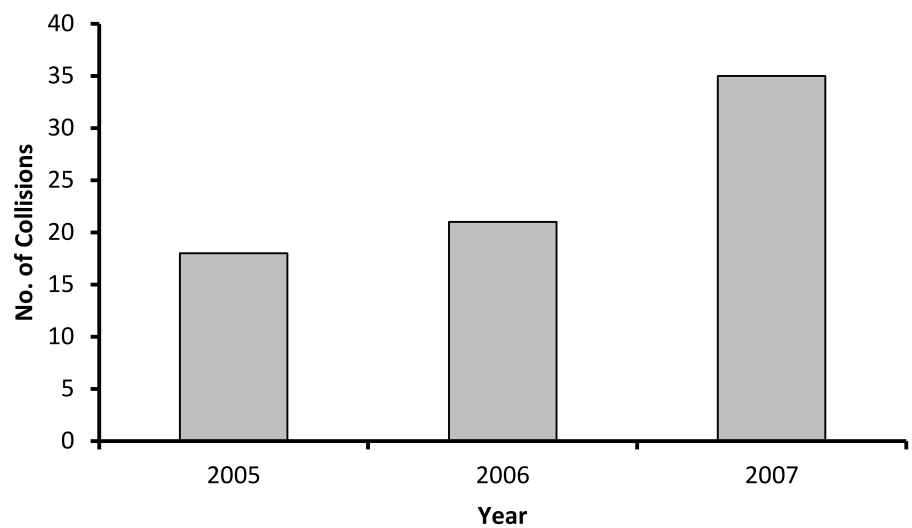


FIGURE 3.1: Annual Collision Frequency

3.3 None of the reported collisions in the study area resulted in a fatality.

3.4 To determine if 24.7 collisions per year is a safety concern, it must be tempered by the exposure (i.e., the length of the facility and/or the volume of traffic using the facility), since roads and intersections accommodating higher volumes experience higher collision frequencies. The method of calculating the safety performance of a facility employed by the Region of Peel is to separate the facility into intersections and road segments, and to calculate the collision rate.

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[2] [14.4:34.9] - These are the 95% Confidence Limits associated with the average collision frequency using all of the available collision data.

The volume adjusted collision rate is determined as follows:

Road Sections:

$$CR = \frac{N * 10^6}{365n * ADT * L}$$

Intersections:

$$CR = \frac{N * 10^6}{365n * (ADT_m + ADT_s)}$$

Where: *CR = Collision rate*
N = Number of reported collisions
n = Number of years of collision data available
ADT = Average daily traffic
ADT_m = Average daily traffic entering the intersection from the main street
ADT_s = Average daily traffic entering the intersection from the minor street
L = Length of the road section (kms)

The collision rates yielded by the above equations are then compared to a statistically adjusted average collision rate to yield a likely or *as expected* critical collision rate which is used to determine the facility's safety performance. The critical collision rate is calculated as follows:

$$R_c = \lambda + k\sqrt{\frac{\lambda}{m}} + \frac{1}{2m}$$

Where: *R_c = Critical collision rate*
λ = Average collision rate for the facility type
m = number of vehicles traversing particular road section (millions of vehicle-km) or number of vehicles entering particular intersection (millions of vehicles) during the analysis period
k = Probability factor determined by the level of statistical significance desired for R_c (1.96 for a 95% level of confidence)

The Region of Peel does not currently produce average collision rates for their facilities. Therefore, the following rates reported by the City of Hamilton (1995-1999 data) are used in determining safety performance[3]:

[3] City of Hamilton (1999) "1999 Hamilton-Wentworth Collision Report", Volume 1: Trends and Locations, Transportation, Operations and Environment Division, Traffic Engineering Section, 36 pp.

- *Signalized intersections: 0.44 collisions per million-vehicles entering (MVE)*
- *Arterial roads (signalized intersections excluded): 1.49 collisions per million-vehicle kilometres (MVK)*

The above rates are from a southern Ontario municipality that conforms to similar geometric design and traffic operations standard as the Region of Peel. Therefore, these average rates are acceptable for comparison purposes.

The collision rates for the study intersections and road segments are shown in Table 3.1.

TABLE 3.1: Collision Rates for the Bovaird Drive Study Area

Signalized Intersection	No. Collisions (3 years)	ADT Bovaird*	ADT Side*	Collision Rate	Critical Collision Rate
Lake Louise/Worthington	8	25,184	7,276	0.23	0.86
Ashby Field/GO Station Entrance	N/A	---	---	---	---
Mississauga Road	***36***	***20,504***	***12,112***	***1.01***	***0.86***
Heritage Road	12	18,906	1,806	0.53	0.98
Road Segment	**No. Collisions (3 years)**	**ADT Bovaird***	**Length⁺ (km)**	**Collision Rate**	**Critical Collision Rate**
Lake Louise/Worthington to Ashby Field/GO Station Entrance	7	26,086	1.08	0.23	2.28
Ashby Field/GO Station Entrance to Mississauga Road	2	22,162	0.90	0.09	2.45
Mississauga Road to Heritage Road	5	18,948	1.38	0.17	2.32
Heritage Road to Peel/Halton Boundary	4	18,774	1.49	0.13	2.29

*ADTs were estimated as twice the number of vehicles entering the intersection during the eight hour turning movement count period.
⁺Segment lengths were measured from Google Earth™, accessed on March 22, 2010

The collision rates for all intersections and segments are below the critical collision rate, except for the intersection of Bovaird Drive and Mississauga Road. This indicates that Bovaird Drive is performing well from a safety perspective, except at the intersection with Mississauga Road. There is no reliable collision data for the intersection of Bovaird Drive with Ashby Field Road, since this intersection was constructed during the 2005 to 2007 period.

3.5 Because the collision rates used in this analysis were borrowed from the City of Hamilton, the results can be verified using criteria included in the ITE guidelines on traffic impact studies[4] which indicate that collision rates "vary, but any intersection with more than one accident per million entering vehicles is worthy of additional analysis." The ITE guideline is more subjective, and more stringent than the Hamilton averages, but they verify the safety performance of the study area.

3.6 The collisions at the intersection of Bovaird Drive and Mississauga Road are punctuated with a spike in collision occurrence in 2007. Specifically, the annual intersection collision frequency is 9, 5, and 22 for 2005, 2006, and 2007, respectively. The spike in 2007 collisions may be spurious or may be indicative of a change in conditions that has degraded safety.

3.7 Despite the macro-level analysis indicating that only the intersection of Bovaird Drive and Mississauga Road is potentially problematic, further analysis of the collision data for trends or patterns that may be representative of a infrastructure deficiencies was conducted. In that regard an analysis of collision characteristics in the entire study area, and for the intersection of Bovaird Drive and Mississauga Road was undertaken.

3.8 A collision characteristic is considered to be *aberrant* if the site collision characteristic is statistically significantly different from the collision characteristics for a group of similar sites. In the instance of this study the comparison group includes all collisions in the province of Ontario in 2006. This comparison dataset is appropriate and acceptable to identify aberrant collision patterns at the study location.

3.9 The following collision characteristics were compared to the provincial averages to assess whether certain collision characteristics were occurring more often than expected:

- Collision severity;
- Temporal distributions (i.e., time-of-day, and day-of-week);
- Environmental conditions;
- Lighting conditions; and
- Road surface conditions.

3.10 Non-parametric tests of significance were used to assess whether differences between the characteristics of site collisions and those of the provincial averages were statistically significant at a 95% level of confidence[5].

3.11 The statistics are shown in Tables 3.4 to 3.10. The collision characteristics in the study area that are statistically different from the provincial averages are:

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[4] Institute of Traffic Engineers (1991) "Traffic Access and Impact Studies for Site Development: A Recommended Practice", ITE Publication No. RP-020B, Institute of Transportation Engineers, Washington, DC.

[5] The statistical tests of significance are explained in Appendix B.

- There were more collisions occurring in the study area during midday (0900h to 1459h) than expected (at a 99.5% level of confidence); and
- There were more collisions occurring at the intersection of Bovaird Drive and Mississauga Road during daylight than expected (at a 97.4% level of confidence).

TABLE 3.4: Severity Distribution of Collisions

Collision Severity	Ontario Roads in 2006		2005-2007 Study Area		2005-2007 Mississauga Road Intersection	
	Number	Percentage	Number	Percentage	Number	Percentage
Fatal + Injury	48,103	22%	7	10%	3	9%
PDO	168,144	78%	66	90%	33	91%
All	216,247	100%	73	100%	36	100%

TABLE 3.5: Seasonal Distribution of Collisions

Season	Ontario Roads in 2006		2005-2007 Study Area		2005-2007 Mississauga Road Intersection	
	Number	Percentage	Number	Percentage	Number	Percentage
Spring (Mar, Apr, May)	46,788	22%	18	24%	9	25%
Summer (Jun, Jul, Aug)	52,160	24%	23	31%	12	33%
Autumn (Sep, Oct, Nov)	59,167	27%	15	20%	5	14%
Winter (Dec, Jan, Feb)	58,132	27%	18	24%	10	28%
Total	216,247	100%	74	100%	36	100%

TABLE 3.6: Weekly Distribution of Collisions

Day of the Week	Ontario Roads in 2006		2005-2007 Study Area		2005-2007 Mississauga Road Intersection	
	Number	Percentage	Number	Percentage	Number	Percentage
Weekdays	163,229	75%	55	74%	30	83%
Weekends	53,018	25%	19	26%	6	17%
All	216,247	100%	74	100%	36	100%

TABLE 3.7: Daily Distribution of Collisions

Time of day	Ontario Roads in 2006		2005-2007			
			Study Area		Mississauga Road Intersection	
	Number	Percentage	Number	Percentage	Number	Percentage
AM Peak (0600 to 0859)	28,710	13%	9	12%	8	22%
Midday (0900 to 1459)	68,958	32%	***35***	***47%***	15	42%
PM Peak (1500 to 1759)	50,439	24%	16	22%	7	19%
Other (1800 to 0559)	66,270	31%	14	19%	6	17%
All	214,377	100%	74	100%	36	100%

TABLE 3.8: Lighting Conditions During Collisions

Lighting	Ontario Roads in 2006		2005-2007			
			Study Area		Mississauga Road Intersection	
	Number	Percentage	Number	Percentage	Number	Percentage
Day	148,967	69%	54	73%	***31***	***86%***
Dawn	3,767	2%	2	3%	1	3%
Dusk	7,109	3%	2	3%	0	0%
Dark	56,056	26%	16	22%	4	11%
Other	348	0%	0	0%	0	0%
All	216,247	100%	74	100%	36	100%

TABLE 3.9: Environmental Conditions During Collisions

Environment	Ontario Roads in 2006		2005-2007			
			Study Area		Mississauga Road Intersection	
	Number	Percentage	Number	Percentage	Number	Percentage
Clear	167,658	78%	59	80%	31	86%
Rain	30,132	14%	10	14%	5	14%
Snow/Freezing Rain	15,279	7%	4	5%	0	0%
Other	3,178	1%	1	1%	0	0%
All	216,247	100%	74	100%	36	100%

TABLE 3.10: Road Surface Condition During Collisions

Surface Condition	Ontario Roads in 2006		2005-2007			
			Study Area		Mississauga Road Intersection	
	Number	Percentage	Number	Percentage	Number	Percentage
Dry	148,121	68%	55	74%	27	75%
Wet	46,092	21%	14	19%	8	22%
Snow/Ice	20,305	9%	5	7%	1	3%
Other	1,729	1%	0	0%	0	0%
All	216,247	100%	74	100%	36	100%

3.12 An important characteristic in assessing safety performance is initial impact type. The initial impact type is not compared to the provincial averages, because comparing signalized intersections or a rural road segment to a dataset that is an amalgam of signalized intersections, unsignalized intersections, and urban and rural road segments is not a meaningful comparison. Instead, the impact types for the study area and the intersection of Bovaird Drive and Mississauga Road are presented and subjectively reviewed (see Figures 3.2 and 3.3).

Rear-end, angle, and single motor vehicle[6] collisions are the three dominant collision types in the study area. These three types make up about 75% of the collisions occurring. Given the relatively sparse development, and the low access density the relatively high incidence of angle collisions is surprising.

Rear-end and angle collisions are the dominant collision types at the intersection of Bovaird Drive and Mississauga Road. Since this intersection is signalized, the relatively high incidence of angle collisions is somewhat surprising at this location.

3.13 An examination of the collision locations reveals that 81% of the collisions in the study area occur at the intersections within the study area. Intersection and intersection-related collisions typically comprise only about 44% of all collisions. Even if the potentially spurious data from 2007 is removed from the analysis, 71% of the collisions in the study area occur at intersections.

3.14 Because of the relatively high incidence of collisions at the Mississauga Road intersection, a collision diagram was prepared (see Figure 3.4). Seven of the angle collisions are north-west configuration, four collisions are a south-west configuration, and one is a south-east configuration[7]. In any event, all but one of the angle collisions involved westbound vehicles.

[6] Single motor vehicle collisions include collisions with animals.
[7] Based on the vehicle movements, two of the “angle” collisions are actually “turning” collisions and are not included in this summary.

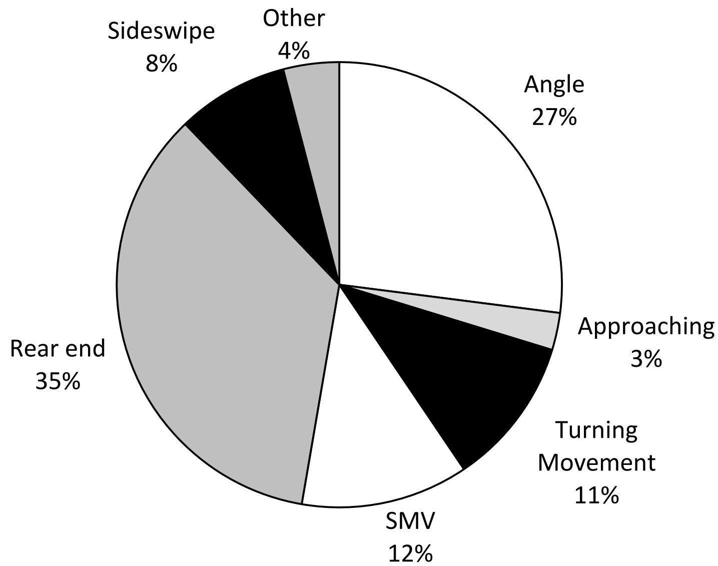

Figure 3.2: Initial Impact Type for Collisions in the Study Area

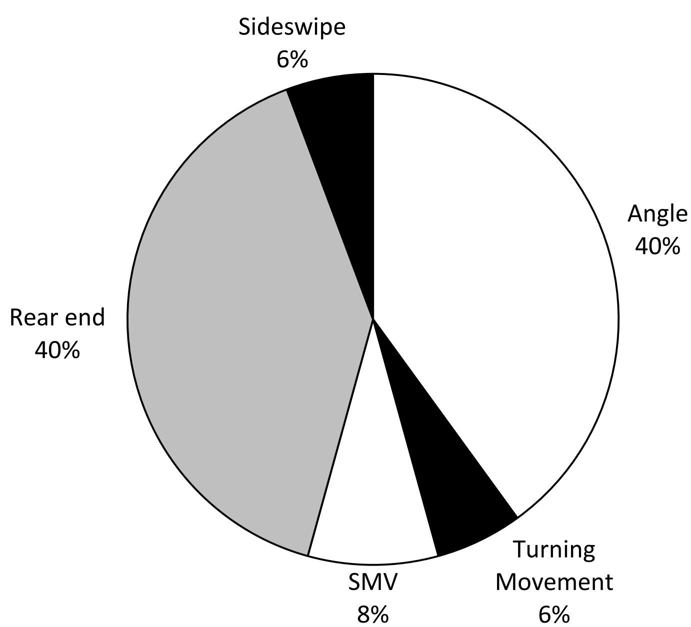

Figure 3.3: Initial Impact Type for Collisions at Bovaird Drive and Mississauga Road

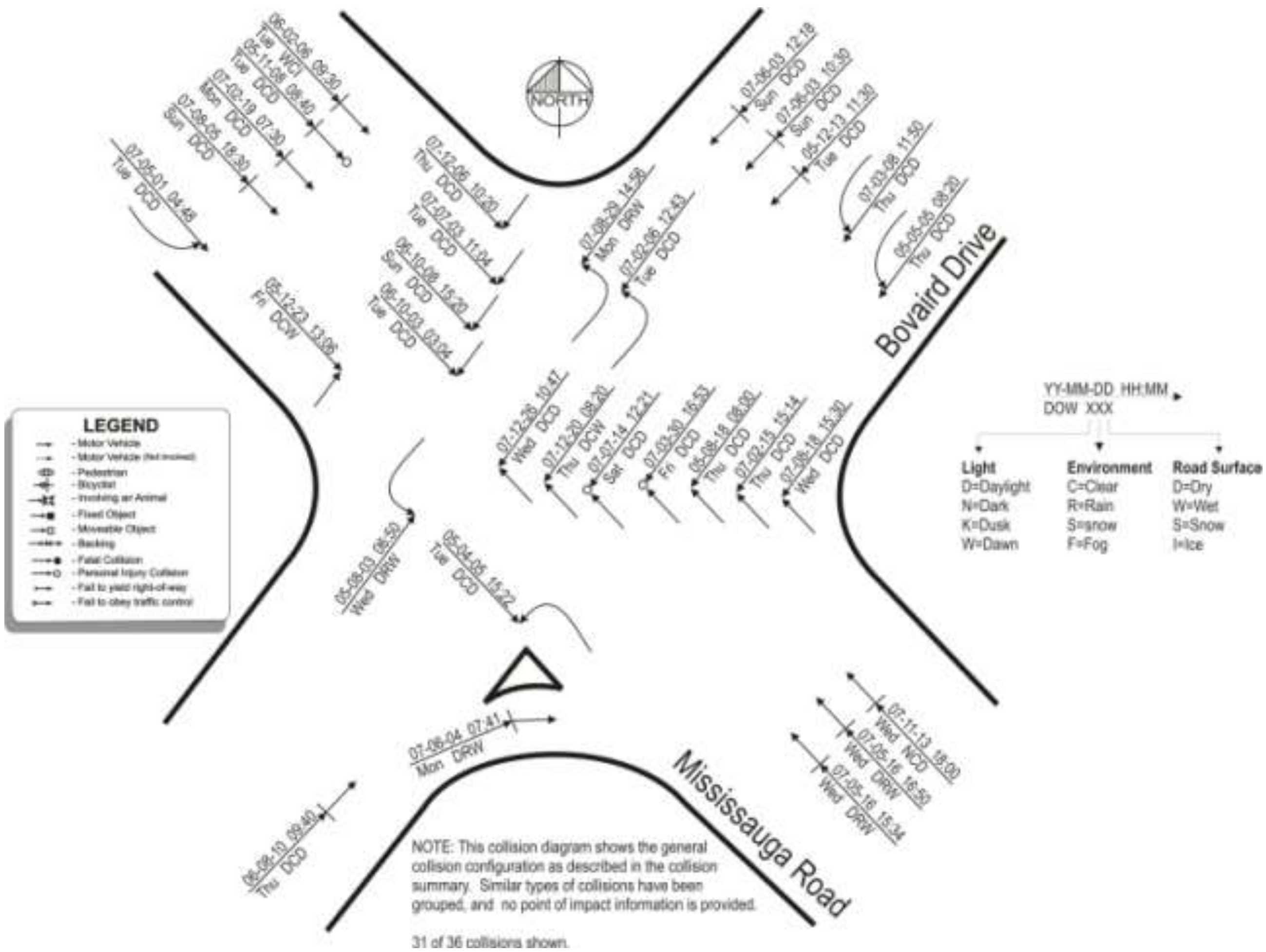

FIGURE 3.4: Collision Diagram for Bovaird Drive at Mississauga Road

3.15 Conclusions

3.15.1 The safety performance of Bovaird Drive from Lake Louise Drive/Worthington Avenue to the Peel/Halton Boundary is better than average, except for the intersection of Bovaird Drive with Mississauga Road.

3.15.2 Despite the relative good safety performance of the study area, midday collisions in the entire study area are overrepresented. Also, the majority of the collisions occur at the intersections in the study area, so opportunities to improve safety should be focused on improving intersection safety.

3.15.3 At the intersection of Bovaird Drive and Mississauga Road daytime collisions are overrepresented. This location has a higher than expected proportion of angle collisions for a signalized intersection. All but one of the angle collisions involve a westbound vehicle.

4. Site Visit

4.1 Site visits were conducted on November 19, 2009 and March 26, 2010 with a purpose of reviewing road user operations and interactions, and identifying site-specific deficiencies that may be leading to any increased collision risk in the study area.

4.2 A positive guidance review was undertaken on Bovaird Drive from a passenger vehicle and was initiated a minimum of one kilometre upstream on both approaches to the study area. This methodology assists in understanding the motorists' mindset and workload issues upon arriving at the study area.

4.3 The following items were noted during the site visit:

- The roadway's vertical alignment is relatively flat except as Bovaird Drive passes over the rail tracks at the east end of the study area, and at the west end of the study area where the road descends into Norval (moving from east to west). An eastbound truck climbing is present at the grade change in the west.

- The horizontal alignment of Bovaird Drive is curvilinear, and none of the curves are posted or require advisory speeds that are lower than the posted speed limit. The curves in the east end of the study area are proximate to signalized intersections. However, signal head placement appears to be adequate and additional signal heads have been added as required.

- Westbound on Bovaird Drive immediately west of the rail bridge, there is an intersection warning sign that is not required (see Figure 4.1). Similarly, there is an eastbound intersection warning sign vicinal to the truck climbing lane that appears unnecessary (see Figure 4.1).

- The "signal ahead" signs at the intersection of Bovaird Drive and Mississauga Road are too close to the intersection. The same is true of the eastbound intersection warning sign for Caseley Drive.

- At the intersection of Bovaird Drive and Mississauga Road the eastbound to southbound right turn channelization is posted with a 30 km/h advisory speed. This is a fairly typical channelization for a signalized intersection and the posted warning suggests that there ***may*** have been some difficulties with this movement in the past.

- The downstream end of the taper for the eastbound truck climbing lane ends where the upstream end of the right turn taper for Hertiage Road starts. The proximity of these two physical features to each other creates overlapping "information handling zones" for motorists.

FIGURE 4.1: Unnecessary Intersection Warning Signs

- The signal heads for the northbound, southbound, and westbound directions at the intersection of Bovaird Drive and Mississauga Road are on span wires, while the signal heads for the eastbound approach (and all other signals in the study area) are on mast arms.

- Incandescent lamps are used in the signal heads at the intersection of Bovaird Drive and Mississauga Road, while the signal heads at the Ashby Field and Lake Louise Drive intersections use LEDs.

- The separation between the signal head for the southbound approach to the intersection of Bovaird Drive and Mississauga Road were not measured but appear to be very close together.

- During the site visit (midday during a weekday) the westbound advance left-turn phase was activated even when there was no traffic in the westbound left-turn lane[8].

- Overall, the placement of the signal heads in the study area requires review. In many instances the lenses of some heads are temporarily blocked from view by the mast arms or signal heads for the opposing direction (see Figure 4.2).

FIGURE 4.2: Signal Head Obstructed by Mast Arm at Heritage Road

[8] It is understood from Regional staff that this is a temporary measure.

5. Problem Statement

5.1 The study area experienced 74 collisions in the 2005 to 2007 period; an average of 24.7 collisions per year. Given the volume of traffic and the size of the study area, the safety performance of the road segments and intersections in the study area (i.e., the expected annual average collision frequency) is better than expected except for the intersection of Bovaird Drive and Mississauga Road.

5.2 However, the three-year collision record for the Bovaird Drive and Mississauga Road intersection shows a marked spike in collisions in 2007 – 22 collisions compared to an average of 7 collisions per year in 2005 and 2006. This may be random noise in the data, or it may be attributed to a change in conditions. To be confident in making a determination, the record of work completed at the intersection and/or additional collision data from 2008 and 2009 is required.

5.3 A higher than expected number of collisions are occurring at the study intersections, hence efforts to improve road safety should be focused on improving intersection safety in general.

5.4 At the intersection of Bovaird Drive and Mississauga Road the collisions are overrepresented in daylight. This may be attributed to heavier commuter traffic volumes and potentially signal timing/congestion issues during this time period.

5.5 The percentage of angle collisions at the intersection of Bovaird Drive and Mississauga Road is higher than expected, and may present opportunities for safety improvement. The angle collisions mostly involve westbound vehicles perhaps suggesting that signal visibility for westbound traffic is an issue. The roadway geometry presents good visibility to the westbound signal heads, and as such the solutions for the angle collisions at Mississauga Road should focus on larger signal lenses, converting the LED lenses, and or better advance warning signs. Signal timing may also be contributing the angle collisions, and should be reviewed.

6. Opportunities for Safety Improvement

6.1 General

6.1.1 The safety performance of the majority of the existing infrastructure is as expected for a Regional facility.

6.1.2 As a result of the relative good safety record of Bovaird Drive in the study area, the remainder of this report will focus on opportunities for safety improvements as identified by the detailed collision analysis. In other words, the intersection of Bovaird Drive and Mississauga Road.

6.1.3 In discussing opportunities for safety improvement, the report will focus on geometric design options and other roadway features that are associated with larger capital expenditures and longer time frames that are consistent with the Class Environmental Assessment process. Short-term solutions are mentioned and are roughly evaluated for the sake of assessing whether short-term solutions may be desirable until reconstruction. Education and enforcement options are not discussed as these measures are typically the responsibility of other agencies or departments, and are not generally consistent with the infrastructure focus of this study.

6.2 Angle Collisions at the Intersection of Bovaird Drive and Mississauga Road

6.2.1 The preponderance of angle collisions at this intersection is likely being caused by the poor level of service during the morning commute, and the signal design. This intersection uses signal heads that are mounted on span wires, and incandescent lamps.

6.2.2 The reconstruction of the Bovaird Drive and Mississuaga Road intersection to better accommodate the growing traffic demand is expected to lower the collision risk at this location to a level that is more acceptable. The exact magnitude of the change in the collision risk is uncertain.

6.2.3 A potential long-term, infrastructure-based solution for the angle collisions is a roundabout. Roundabouts have been demonstrated to provide dramatic reductions in injury crashes by controlling speeds through the intersection. At single and multilane urban/suburban roundabouts that were previously controlled by traffic signals, collisions have been reduced by 48%, and injury collisions by 78%. A similar finding for rural locations is not available.

6.2.4 The general approach to countermeasure selection is that it be economically attractive, and fit within the project budget. The industry-accepted criterion for determining if a countermeasure is economically attractive is a benefit-cost ratio of 2:1. However, during a reconstruction effort and when the safety record indicates the need for intervention, a 1:1 or even a 0.8:1 benefit-cost ratio has been used.

6.2.5 Using the estimated reduction in all collisions of 48% a roundabout at the intersection of Bovaird Drive and Mississauga Road yields a net present value in collision savings of $754k (see Appendix C for the benefit-cost parameters and calculation sheet). Therefore, in order to achieve a favourable benefit-cost ratio (2:1), the incremental cost of constructing a roundabout needs to be less than about $377k.

6.2.6 If the roundabout option is to be pursued, it would be required for the designers to assess the appropriate sight distances to determine feasibility.

6.2.7 The roundabout has been identified as an opportunity to improve safety but is not a *required* measure. As such it is prudent for the Region to consider whether the application of this measure is consistent with their current operating practices in order to achieve consistency and uniformity in design and operation of their facilities. This is important because consistency is a cornerstone in traffic engineering practice that allows roadway designs to meet driver expectations and reduce overall collision risk.

6.2.8 The benefits achieved from any operational efficiencies in traffic have not been accounted for in this analysis.

6.2.9 With respect to short-term measures, the available options for addressing the angle collisions are to revise the signal timing to improve the level of service, or to improve conspicuity of the signal heads through larger lenses, converting from span wire to mast arms, reflective tape on the backboards, conversion from incandescent to LED lamps, and/or additional signal heads.

6.2.10 Before employing any of the above short-term options it is prudent to obtain and assess the 2008 collision data to determine if the collision risk at the intersection of Bovaird Drive and Mississauga Road is higher than expected or if the 2005 to 2007 collision rate is an outlier.

6.2.11 The option of revised signal timing is, in essence, already being done. The Region continually monitors and updates the signal timing for all signalized locations under their jurisdiction. However, it was noted during the site visit that while detectors are present at this intersection, the signal was not operating in traffic actuated mode. Reactivating the traffic actuation may reduce overall delay, and hence collision risk.

6.2.12 The effectiveness of the above countermeasures is based on the best available evidence at the time of writing this report. It is important to note that the reduction factors are estimates and the actual effectiveness of the countermeasures are likely to vary from site-to-site depending on the specifics of the situation.

7. Conclusions

7.1 The Region of Peel is undertaking a Class EA for Bovaird Drive from Lake Louise Drive/Worthington Avenue Road to the Peel/Halton boundary, which includes this road safety review.

7.2 The study area experienced 74 collisions from January 1, 2005 to December 31, 2007, for an average of 24.7 collisions per year.

7.3 Taking into account the volume and distribution of traffic in the study area the overall safety performance of the intersections and road segments in the study area are acceptable except for the intersection of Bovaird Drive with Mississauga Road.

7.4 The following collision trends and patterns are noticeable:

- A higher than expected number of collisions are occurring at the study intersections, hence efforts to improve road safety should be focused on improving intersection safety in general.

- The three-year collision record for the Bovaird Drive and Mississauga Road intersection shows a marked spike in collisions in 2007 – 22 collisions compared to an average of 7 collisions per year in 2005 and 2006. This may be random noise in the data, or it may be attributed to a change in conditions. To be confident in making a determination, the record of work completed at the intersection and/or additional collision data from 2008 and 2009 is required.

- At the intersection of Bovaird Drive and Mississauga Road the collisions are overrepresented in daylight. This may be attributed to heavier commuter traffic volumes and potentially signal timing/congestion issues during this time period.

- The percentage of angle collisions at the intersection of Bovaird Drive and Mississauga Road is higher than expected, and may present opportunities for safety improvement. The angle collisions mostly involve westbound vehicles perhaps suggesting that signal visibility for westbound traffic is an issue. The roadway geometry presents good visibility to the westbound signal heads, and as such the solutions for the angle collisions at Mississauga Road should focus on larger signal lenses, converting the LED lenses, and or better advance warning signs. Signal timing may also be contributing the angle collisions, and should be reviewed.

- In the long-term, angle collisions can be successfully mitigated through conversion of intersections to roundabouts. The study team may want to explore this option. From a safety perspective a roundabout at the intersection of Bovaird Drive and

Mississauga Road may be expected to produce net present collision savings of $754k.

- The roundabout requires verification of sight distance requirements, and might be considered if the incremental cost of construction is $377k or less (to yield a favourable benefit-cost ratio). Furthermore, the design team will have to consider the operational performance and capacity of a roundabout, property requirements, and other non-safety related factors before making an informed decision on roundabout use at this location.

Appendix A: Material Available for the In-service Road Safety Review

The following material was supplied by the Region of Peel for the conduct of this in-service road safety review:

- TES Summary of Collisions on Bovaird Drive from Lake Louise Drive to the Peel/Halton Boundary for 2005 to 2007, inclusive.
- Directional Traffic Flow Diagrams for all intersections in the study area conducted in September 2009.
- Entra Consultants, Bovaird Drive Class EA, Traffic Study, Draft Report, February 2010.

Appendix B: Statistical Tests of Significance for the Difference Between Two Proportions

Chi-square Test

The chi-square test is a measure of the differences between measured and expected frequencies. If the number of collisions at a subject location is greater than the expected number of collisions for a particular characteristic (i.e., "wet pavement" collisions), then use of the chi-square test will assist the analyst in determining if the difference is statistically significant or likely a random variation in the data. The expected number of collisions is determined by using collisions statistics from a number of years, or a number of similar locations.

The chi-square test for a 2 x 2 table can be calculated using the following equation:

$$X^2 = \frac{(x - pn)^2}{pn} + \frac{[(n - x) - n(1 - p)]^2}{n(1 - p)}$$

where: X^2 = chi-square test value
p = the average ratio for the collision type being investigated
x = the number of collision types being investigated, and
n = the total number of collisions at the site.

If a 95 percent level of confidence is used the chi-square test value is 3.84 (i.e., this is the value for a 2 x 2 collision table). Therefore, if the calculated X^2 is greater than or equal to 3.84, then the difference between the measured collision frequency is statistically different from the expected collision frequency to a 95 percent level of confidence.

The chi-square test is not reliable when the *expected* frequency is less than five. The expected frequency is determined by multiplying p and n. If p*n is less than five, then the Fisher Exact Test should be used.

Fisher Exact Test

The Fisher exact test calculates an exact probability value for the relationship between two variables, as found in a 2 x 2 table. It works in exactly the same way as the chi-square test for independence; however, the chi-square gives only an *estimate* of the true probability value, an estimate that might not be very accurate if there is a small value (less than five) in one of the cells. In such cases the Fisher exact test is a better choice than the chi-square test.

To explain the Fisher exact test, consider the notation in the following table, and note that the table should be arranged so that "a" is the smallest value in the table.

Collision Characteristic	**GROUP**		**Sum**
	SITE	**COMPARISON**	
X	a	b	a+b
Not X	c	d	c+d
Sum	a+c	b+d	N

The probability of obtaining this set of values is calculated by:

$$p = \frac{(a + b)!\,(c+d)!\,(a+c)!\,(b+d)!}{N!a!b!c!d!}$$

where: p = probability of obtaining the values in the 2 x 2 table
a,b,c,d = the cell values in the 2 x 2 table
N = a+b+c+d
! indicates the factorial, for example if N=5,
then N! = 5*4*3*2*1. (Note: 0!=1)

In order to calculate the probability that the proportions are different between the site and the comparison groups, one must also consider all results that are equal to or "more extreme" than the one observed (i.e., the table provided). Therefore, the probabilities for all tables that have 1) an "a" that is less than or equal to the observed "a", and 2) row and column sums that are the same as in the "observed" table, are calculated and summed.

The summed "p" values provide the probability that the observed values are different than the expected/comparison values.

Appendix C: Benefit-Cost Calculations

Intus Road Safety Engineering Inc.

Benefit/Cost Ratio Worksheet

Location:	***Bovaird Drive Road Safety Review***						
Analysis Period:	*01/01/2005*	*to*	*12/31/2007*	Form Completed by:	*GJF*	Date:	*03/26/2010*

Miscellaneous Data

Rate of Return:	5%
No of years of collision data	3.0

Collision Cost Data

Collision Severity	*Collision Cost*
Property Damage Only:	$8,000
Injury:	$23,440
Fatality:	$973,650

Predicted Change in Collisions due to Improvement(s)

Improvement	Target Collisions	CRF (+ or -)	No. of Target Collisions: PDO	Injury	Fatal
Roundabout at Mississauga Road	All Collisions	-48%	33	3.00	0.00

Benefit/Cost of Improvements (Safety Benefits Only)

Improvement	Cons-trtn Cost (K)	Ann M/O Cost (K)	Life of Impvt (yrs)	Annual Change in Collisions: PDO	Injury	Fatal	Annual Change in Collision Cost	Net Present Value of Collision Savings	Net Present Value of All Costs	Benefit/Cost Ratio (Safety Benefits Only)
Roundabout at Mississauga Road	377.0	0.0	25	-5.3	-0.48	0.0	-$53,491	$753,902	$376,951	2:1

Benefit Cost Formula (Safety Benefits Only)

$$\text{B/C Ratio} = \frac{\text{(Present Value of Annual Reduction in Collision Cost)}}{\text{(Construction cost)+(Present Value of Annual Increase in Maintenance Cost)}}$$