Government of Alberta
Transportation

METHODS OF REDUCING COLLISIONS ON ALBERTA ROADS

PHASE 1: DEVELOPMENT OF ENGINEERING STRATEGIES AND MEASURES

FINAL REPORT

JANUARY, 2010

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EXECUTIVE SUMMARY

1. Background and Objectives

Alberta Transportation (TRANS) commissioned Opus International Consultants (Canada) Limited (hereafter referred to as Opus) to investigate and develop engineering strategies to address the collision patterns on all Alberta highways and streets. These roadways are operated by different road authorities including urban municipalities, rural municipalities, Counties and the Province.

This study, entitled "*Methods of Reducing Collisions on Alberta Roads*" (abbreviated as *MORCOAR*), is intended to help achieve the goals of Alberta Traffic Safety Plan, which includes reducing fatal and serious injury collisions by 30% between the years of 2008-2010 compared to the baseline years of 1996-2001.

The primary objective of this project is to develop cost-effective and innovative engineering strategies to cover the range of land use, roadway and speed environments in Alberta. Seven "objective areas" have been clearly identified:

- Speed Related Collisions;
- Signalized Intersection Related Collisions;
- Unsignalized Intersection Related Collisions;
- Vehicle-Wildlife Collisions;
- Collisions Along Roadways (Links);
- Run-Off-Road Collisions; and
- Collisions Involving Vulnerable Road Users.

For each objective area, collision reduction strategies are to be developed for both rural and urban situations, for each of the following posted speed categories:

- 50 km/h or lower;
- 60 km/h to 70 km/h;
- 80 km/h to 90 km/h; and
- 100 km/h or higher.

2. Alberta Collision Trends

An overview of collision trends in Alberta was conducted as a starting point for the identification of strategies and measures. The objective of this exercise was not to identify detailed trends or to screen the road network, but rather to obtain an overall picture of the collision types, trends and concerns over the past several years in both urban and rural areas, to assist in the selection of countermeasures.

The time trend of collisions between 1997 and 2007 in Alberta reveals some trends, including a significant rise in injury and fatal collisions (although this has since decreased in 2008). As well, there has been a migration of injury and fatal collisions to urban areas, with urban areas now being the site of one-third of the fatal collisions and nearly two-thirds of major injury collisions in the Province. This emphasizes the need to include in this study a focus on strategies and measures for urbanized areas, such as signalized intersections and vulnerable road users.

To obtain a more diverse picture, high-level trends were analyzed for the province as a whole and for representative larger, medium-sized and smaller municipalities. Trends are summarized in TABLE ES.1.

TABLE ES.1 MAJOR INJURY / FATAL COLLISION TRENDS

LOCATION OF TREND	INJURY/FATALITY TREND
Province (General Trends)	Run-off-road Intersections Unsafe speed
Larger Municipalities	Intersections Vulnerable road users
Medium-sized Municipalities	Intersections
Smaller Municipalities	Intersections

A number of other issues and underlying collision causes were identified by Opus based on its experience conducting hundreds of safety reviews throughout Alberta. Examples include inappropriate speed zoning, inadequate gap acceptance at unsignalized intersections, design inconsistency and driver workload.

3. Review of Current Practices and Literature

Opus conducted extensive research of strategies and measures for collision reduction, both within and outside Alberta. This included an extensive literature review, a workshop of Alberta stakeholders, supplementary consultation with road agencies in Alberta and the neighbouring provinces, and consultation with traffic safety researchers and authorities in the United States, New Zealand, Australia and the United Kingdom.

Alberta Transportation's current Engineering Strategic Plan was reviewed, which indicated several successful programs that are already in place which should be continued and expanded. These include rumble strips, enhanced warning signs and roadway lighting.

Opus held a workshop, attended by 16 members representing the province and large and small municipalities around Alberta. The primary purpose of the workshop was to identify collision reduction measures in each of the seven objective areas that have been implemented successfully or unsuccessfully in their jurisdictions. While the majority of implementations were not formally monitored, several of them received positive feedback, based on anecdotal evidence. Measures that have been implemented only on highways or in municipalities that may be considered for more widespread use were also identified.

The Canadian and International research was conducted using a four-pronged approach:

1. Consultation with Neighbouring Provinces
2. Consultation with International Experts
3. Consultation with Industry
4. Review of Literature

1) The consultation with neighbouring provinces consisted of interviews with senior representatives of British Columbia and Saskatchewan highway agencies, to identify successful collision reduction measures in their jurisdictions. The interviews highlighted some measures that have traditionally not been used in Alberta, or only to a limited extent:

- *Saskatchewan*: median acceleration lanes, advance intersection warning beacons, overhead stop signs.
- *British Columbia*: "dumbbell" intersections, uninterruptable power supply for traffic signals, transverse pavement markings.

2) The consultation with international experts included the following sources:

- Opus' Practice Interest Networks ("PIN" mailing lists)
- Dr. Darren Walton, Opus Central Labs, New Zealand
- Jeff Bagdade, Opus International, United States
- Dr. Pat McGowen, Western Transportation Institute, Montana
- Dr. Tarek Sayed, University of British Columbia

The consultations revealed a handful of innovative measures that the study team reviewed, including:

- PUFFIN pedestrian crossings
- Directionalized median openings
- Offset right-turn lanes
- Bypass lanes at T-intersections

3) The consultation with industry was focused on innovative products developed by traffic safety suppliers. This led to identification of two particular measures that were eventually included among the recommended measures:

- Highly reflective sign sheeting
- Linear delineation systems

4) The literature review was extensive and included the most recent publications. The four primary sources were:

- Transport Canada, "International Road Engineering Safety Countermeasures and their Applications in the Canadian Context" (2009);
- Federal Highway Administration, "Desktop Reference for Crash Reduction Factors", FHWA-SA-07-015 (2008);
- Alberta Motor Association, "Traffic Safety Engineering Toolbox for Aging Road Users" (2009); and,
- National Cooperative Highway Research Program (NCHRP) "Report 500, Guidance for the Implementation of the AASHTO Strategic Highway Safety Plan." (2004-09).

While the objective of reviewing the primary sources was to compile as much information as possible, our research was biased towards more recent, evidence-based research that referred to specific measures (as opposed to general strategies). Over 50 secondary sources were reviewed, most of which were focused on the specific objective areas identified for this study.

4. Preliminary List of Collision Reduction Measures

Based on the research conducted by Opus, collision reduction measures were identified for each of the seven objective areas. A “master spreadsheet” listing all of the identified countermeasures was developed, containing a total of 1,096 references of over 200 specific measures covering the seven objective areas. For each reference, the following was provided:

- Objective area (one or more of the seven defined areas)
- Setting (land use the measure was evaluated in)
- Speed (speed range the measure was measured in)
- Cost (estimated as high, medium, low)
- Collision reduction factor and collision type/severity
- Proven (whether the measure is “proven”, “tried” or “experimental”)

The spreadsheets are searchable and linkable, such that practitioners can quickly search for e.g. all “proven” measures or “rural” measures or “speed management” measures, and click on the source of the collision reduction factor to find the supporting studies. The spreadsheet is MS Excel based and provided electronically as one of the study deliverables.

5. Collision Reduction Measure Selection Methodology

To extract the collision reduction measures from the master spreadsheet with the highest potential to be effective, the spreadsheet was filtered to include measures that were *proven*, focused on preventing *high-severity* collisions, *recently* studied and *specifically* identified. Approximately 90 measures were selected and placed into the seven objective areas and specific strategy areas within each (e.g. surface treatments, warning devices, conspicuity measures) for a more detailed analysis.

The more detailed analysis included rating each of the measures as “high”, “moderate” or “low” in terms of its documented reduction in injury/fatal collisions, a human factors analysis, and an analysis of its applicability in Alberta. The documented reduction was an interpretation of the published reduction factors. The human factors review was based on a customization of modern approaches, which included an assessment of the expectancy, simplicity, conspicuity and sensory influence. The Alberta applicability review assessed each measure's ability to address the identified collision trends, its previous experience in Alberta, cultural considerations, jurisdictional issues and climatic considerations. Each measure was then given a resultant "overall effectiveness", and "cost effectiveness" (based on order-of-magnitude costs).

6. "Toolbox" of Collision Reduction Measures

As a result of this exercise, 13 measures were rated as having a low overall effectiveness and the majority were removed from the list. A detailed table for each objective area, or "toolbox", is provided in Section 6.0 of this report, including a photograph, basic application considerations, and the ratings for each of the 77 remaining measures. The measures rated as being "highly effective" were then extracted (33 in total), and as a first step towards context-sensitive application, these were further prioritized into land use and speed categories, as shown in TABLE ES.3.

7. "Highly Effective" Collision Reduction Measures

The following key recommendations are made in Phase 1 of this study:

- It is recommended that the 33 "highly effective" measures be considered for adoption as part of Alberta Transportation's 20 year implementation strategy.
- Of the 33 measures, 12 were rated as being high in terms of both effectiveness and cost-effectiveness (referred to as "Priority 1" measures). These are recommended as candidates for immediate development of application guidelines, during Phase 2 of this study, and are listed in TABLE ES.2, by objective area:

TABLE ES.2 "PRIORITY 1" COLLISION REDUCTION MEASURES FOR ALBERTA

OBJECTIVE AREA	COLLISION REDUCTION MEASURE
Speed Management	• Gateway treatments
Unsignalized Intersections	• Conversion to roundabout • Advance warning on major road
Signalized Intersections	• Removal of unwarranted signals • Protected only left-turn phases • Advance warning flashers • Positive offset left-turn lanes
Off-Road Movements	• Rumble strips • Cable barrier systems • Impact attenuators • Removal of fixed objects
Vulnerable Road Users	• Pedestrian countdown signals

TABLE ES.3 "HIGLY EFFECTIVE" MEASURES BY LAND USE AND SPEED CONTEXT

SAFETY MEASURE	URBAN SPEED LIMIT (km/h)				RURAL SPEED LIMIT (km/h)			
	<60	60-70	80-90	>90	<60	60-70	80-90	>90
Speed Management								
1. Gateway treatments							✓	✓
2. Transverse pavement markings	✓	✓	✓					
3. Consistent speed limits	✓	✓	✓	✓	✓	✓	✓	✓
4. Variable speed limits		✓	✓	✓				
Unsignalized Intersections								
5. Conversion to roundabout	✓	✓	✓	✓	✓	✓	✓	✓
6. Advance warning on major road							✓	✓
7. Transverse rumble strips							✓	✓
8. Flashing beacon on stop sign							✓	✓
9. Removal of obstructions	✓	✓	✓	✓	✓	✓	✓	✓
10.Left-turn lanes on major road	✓	✓	✓	✓		✓	✓	✓
Signalized Intersections								
11.Removal of unwarranted signals	✓	✓				✓	✓	
12.Protected only left-turn phases	✓	✓						
13.Advance warning flashers		✓					✓	
14.Positive offset left-turn lanes	✓	✓						
15. Conversion to roundabout	✓	✓			✓	✓	✓	
16. Dedicated left-turn lane / phasing	✓	✓			✓	✓	✓	
17. Signal back plates	✓	✓			✓	✓	✓	
18. Smart Right-Turn Channel	✓	✓						
Roadways (Links)								
19.Delineator posts							✓	✓
20.Edgelines and centrelines	✓	✓	✓	✓	✓	✓	✓	✓
21.Increased sign retroreflectivity	✓	✓	✓	✓	✓	✓	✓	✓
22.Linear delineation systems			✓	✓			✓	✓
23.High-visibility pavement markings	✓	✓	✓	✓	✓	✓	✓	✓
24.Wider pavement markings			✓	✓			✓	✓
Off-Road Movements								
25.Advance curve warning signs	✓	✓	✓	✓	✓	✓	✓	✓
26.Rumble strips							✓	✓
27.Cable barrier systems							✓	✓
28.Impact attenuators							✓	✓
29.Removal of fixed objects	✓	✓	✓	✓	✓	✓	✓	✓
30.Horizontal and vertical realignments	✓	✓	✓	✓	✓	✓	✓	✓
Vulnerable Road Users								
31.Pedestrian countdown signals	✓	✓	✓					
32.New/upgraded intersection lighting	✓	✓	✓	✓	✓	✓	✓	✓
33.Wider sidewalk / paved shoulder	✓	✓	✓	✓	✓	✓	✓	✓
TOTAL NUMBER OF MEASURES	19	23	17	15	14	16	27	22

Bolded items = Priority 1 Measures: High cost-effectiveness and high overall effectiveness.

8. Summary and Next Steps

This report provides a summary of the methodology and findings of Phase 1 of the Methods of Reducing Collisions on Alberta Roads project. It identifies the key provincial and municipal collision trends in Alberta, describes our review of current practices in Alberta and research of the most recent literature on the topic. It presents a comprehensive list of measures, a "toolbox" for each of the seven objective areas, systematic criteria for the selection of the more favourable ones (including an explicit human factors review), the application of these criteria to over 90 measures (resulting in the retention of 77 measures shown in TABLES 6.1 through 6.7); and culminating with the selection of 33 highly effective measures anticipated to be the most effective (presented in TABLES 6.8 and 6.10 and) and the 12 "Priority 1" measures (listed in Section 6.8) for further development and implementation.

The 12 measures cover the objective areas with the most severe collision in rural areas (off-road and unsignalized intersections) and in urban areas (signalized intersections and vulnerable road users), and reduce speeds, which can prevent severe collisions in all areas. They include programs at TRANS that should be continued or expanded (such as rumble strips and cable barriers), areas where warrants can better reflect safety benefits (such as protected left-turn phasing), and where formal policies and guidelines can further promote their use (such as roundabouts and gateway treatments).

At the outset of Phase 2, a survey will be conducted of road agencies in order to confirm their experience with each of the 33 measures and the presence and status of any application guidelines that currently dictate their use. Based on this information, the list of Priority 1 measures can be refined. The list of 12 measures should also be reviewed from a strategic perspective to maximize overall potential benefits by minimizing overlapping benefits. The scope of Phase 2 will likely proceed as follows:

- **75 "Toolbox" Measures**: *Summarize their status* of their use in Alberta *and prepare a recommendation* on whether each measure should be newly incorporated, expanded or refined. Also, *identify the appropriate land-use and speed environment for each*.
- **33 "Highly Effective" Measures:** *Identify existing application guidelines* in Alberta, Canada or elsewhere that should be followed, or *identify the need to develop guidelines*. Also, *identify the specific land-use and speed limit combinations* that are appropriate for each measure. The costs and benefits and an implementation strategy will be prepared for these measures (see Tasks 2.5 and 2.6 below).
- **12 "Priority 1" Measures:** *Prepare high-level application guidelines for some of these measures* (further discussed in Section 8.2 of this report).

1.0 INTRODUCTION

1.1 Study Background

The Alberta Traffic Safety Plan (2006) outlines 2010 collision reduction targets for the Government of Alberta and identifies a wide range of traffic safety strategies and sub-targets to meet these targets. The Traffic Safety Action Plan (2007) identifies short-term activities and strategic objectives, focused on the improvement of Albertan's quality of life and the safety and security of communities. Since its inception in 2007, the Engineering Committee has been focused on developing and implementing Alberta Transportation's Engineering Strategic Plan (ESP) in support of the Traffic Safety Plan.

Alberta Transportation (TRANS) commissioned Opus International Consultants (Canada) Limited (hereafter referred to as Opus) to investigate and develop engineering strategies to address the collision patterns on all Alberta highways and streets. These roadways are operated by different road authorities including urban municipalities, rural municipalities, Counties and the Province.

This study, entitled "*Methods of Reducing Collisions on Alberta Roads*" (abbreviated as *MORCOAR*), is intended to help achieve the goals of Alberta Traffic Safety Plan, which includes reducing fatal and serious injury collisions by 30% between the years of 2008-2010 compared to the baseline years of 1996-2001. The time frame for the current plan is nearing completion; however the collision reduction strategy will continue and a new plan is currently under development.

It is emphasized that the subject of this assignment is to investigate and develop engineering strategies only. Education, enforcement, data and other strategies are being developed and evaluated by other committees under the Alberta Traffic Safety Plan. The purpose of this project is to address some of the primary themes identified in the ESP.

1.2 Study Objectives

The primary objective of this project is to develop cost-effective and innovative engineering strategies to cover the range of land use, roadway and speed environments in Alberta. Six "objective areas" have been clearly identified. Due to the availability of specific strategies and measures for signalized and unsignalized intersections, these have been separated into two, for a total of seven objective areas. "Roadways" refer to segments between intersections, commonly referred to as "links".

- Speed Related Collisions;
- Collisions at Unsignalized Intersections;
- Collisions at Signalized Intersections;
- Vehicle-Wildlife Collisions;
- Collisions Along Roadways (Links);
- Run-Off-Road Collisions; and
- Collisions Involving Vulnerable Road Users.

For each objective area, collision reduction strategies are to be developed for both rural and urban situations, for each of the following posted speed categories:

- 50 km/h or lower;
- 60 km/h to 70 km/h;
- 80 km/h to 90 km/h; and
- 100 km/h or higher.

1.3 Study Phases and Tasks

The study phases and tasks of *MORCOAR* are summarized in FIGURE 1.1. The study is divided into two phases. This document represents the Phase 1 final report. In short, this report recommends the collision reduction measures future programming within Alberta, further to the implementation plan and application guidelines to be developed in Phase 2 of this study.

Section 2.0 of this report reviews the collision trends in Alberta. Section 3.0 reviews the research and consultation methods and sources used, and Section 4.0 presents a comprehensive database of collision reduction measures. Section 5.0 describes the methodology for the selection of priority measures (including a human factors review) and Section 5.0 presents a "toolbox" of more effective measures and Section 7.0 summarizes the ones considered to be "highly effective" for the range of land use and speed environments.

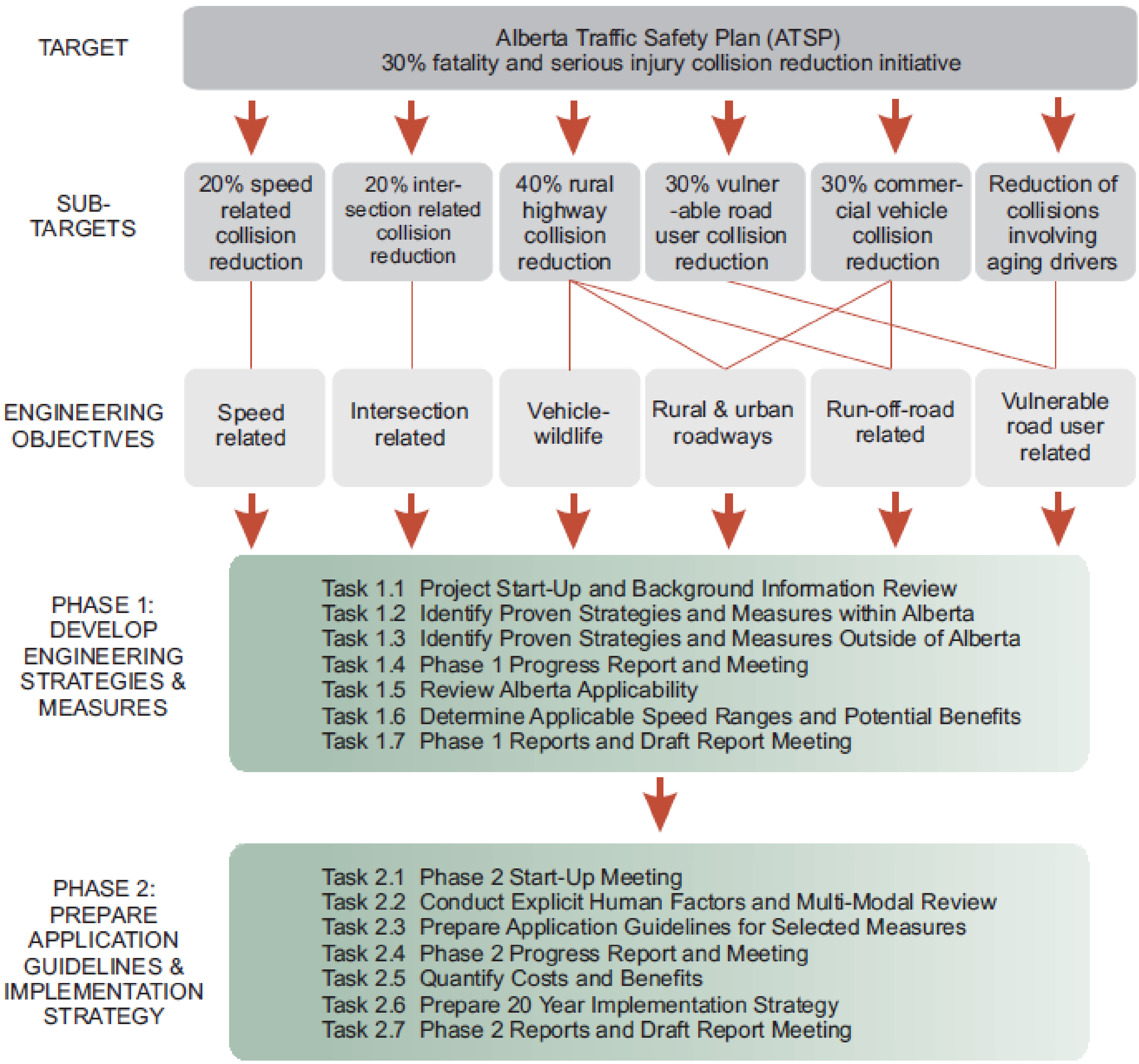


FIGURE 1.1 STUDY PHASES OVERVIEW

2.0 ALBERTA COLLISION TRENDS

An overview of collision trends in Alberta was conducted as a starting point for the identification of strategies and measures. The objective of this exercise was not to identify detailed trends or to screen the road network, but rather to obtain an overall picture of the collision types, trends and causal factors in both urban and rural areas (to assist in the selection of measures). The focus was on fatal and major injury collisions, referred to in this section of the report as "casualty" collisions. The trend analysis is presented in Section 2.1 for all collisions in Alberta, and in Section 2.2 for three differently-sized municipalities.

2.1 Provincial Collision Trends

Alberta Transportation provided collision trends for 1997, 2002, 2007 and 2008. Opus reviewed both the trends over time, and further detail from the 2007 data. FIGURE 2.1 illustrates the change in the Alberta collision trend between 1997 and 2007.

The trends in FIGURE 2.1 indicate that there was a 32% increase in total collisions from 2002 to 2007. While there has been a decrease in minor injury collisions, of particular concern is the rise in fatal (25%) and major injury (5%) collisions. This may be attributed in part to traffic growth, but may also indicate an increase in travel speeds (although this is not documented). Regardless, it reinforces the need to *address the issue of collision severity*. Additionally, there has been a growth in the proportion of fatal (5%) and major injury (9%) collisions in urban areas from 2002 to 2007. This may indicate some resident and traffic migration to urban areas; however, it also emphasizes the need to *consider strategies and measures for urbanized areas* in this study.

TABLE 2.1 shows the annual trend in fatalities and injuries (including major and minor), both in terms of frequency and rate. It indicates that since 2005, the rate and frequency of fatal and injury collisions have remained relatively constant, but declined in 2008. The reasons for this drop are unknown; however, it is likely influenced by the change in the nature of motorized travel during the period of lower economic activity, as well as the successful implementation of the Alberta Traffic Safety Plan.

A closer review of the 2007 collisions was conducted to highlight patterns in severity, urban/rural distribution and collision type.

FIGURE 2.2 indicates the total collision frequency and proportion of each of the four severity categories.

2007	Fatal Collisions		Major Injury Collisions		Minor Injury Collisions		Total Collisions	
	n	%	n	%	n	%	n	%
Urban	136	33.8	1620	60.7	12207	80.4	124063	80.6
Rural	266	66.2	1050	39.3	2980	19.6	29838	19.4
Total Reportable Collisions	**402**	**100.0**	**2670**	**100.0**	**15187**	**100.0**	**153901**	**100.0**

2002	Fatal Collisions		Major Injury Collisions		Minor Injury Collisions		Total Collisions	
	n	%	n	%	n	%	n	%
Urban	93	28.9	1328	52.0	14949	84.9	93333	80.2
Rural	229	71.1	1226	48.0	2649	15.1	22975	19.8
Total Reportable Collisions	**322**	**100.0**	**2554**	**100.0**	**17598**	**100.0**	**116308**	**100.0**

1997	Fatal Collisions		Major Injury Collisions		Minor Injury Collisions		Total Collisions	
	n	%	n	%	n	%	n	%
Urban	86	24.1	953	47.9	11892	83.5	74066	80.2
Rural	271	75.9	1037	52.1	2349	16.5	18299	19.8
Total Reportable Collisions	**357**	**100.0**	**1990**	**100.0**	**14241**	**100.0**	**92365**	**100.0**

FIGURE 2.1 ALBERTA CASUALTY COLLISIONS BY LAND USE (2007)

TABLE 2.1 ALBERTA COLLISION RATES (2004-2008)

Year	Fatality Rate	Injury Rate	Total Fatalities	Total Injuries	Total Kilometres Travelled (in millions)
2004	10	628	387	24,249	38,614
2005	10.6	555.1	466	24,504	44,146
2006	10	570.7	453	25,964	45,496
2007	9.6	513.2	458	24,530	47,798
2008	8.6	464.2	410	22,015	47,425

Rates expressed as casualties per billion vehicle-kilometres travelled

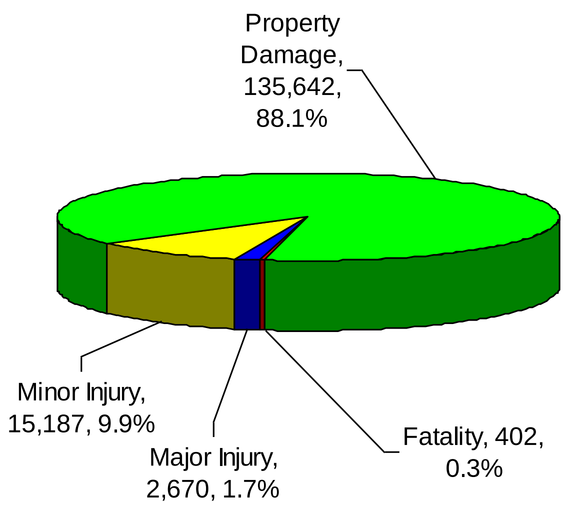


FIGURE 2.2 ALBERTA COLLISIONS BY SEVERITY (2007)

While this study focuses on reducing the fatal and major injury collisions (3,072 collisions, accounting for a combined 2 percent), it is expected that the strategies will also have an impact on minor injury and property damage only collisions.

FIGURE 2.3 shows the split between rural and urban collisions for both fatal and major injury collisions. There were approximately twice as many fatal collisions in rural areas compared to urban areas in 2007, but substantially more major injury collisions in urban areas than rural areas. The results are consistent with expectations, given the typically higher speeds in rural areas that increase the risk of fatal collisions, and the high traffic volumes in urban areas that contribute to more frequent, but lower severity collisions.

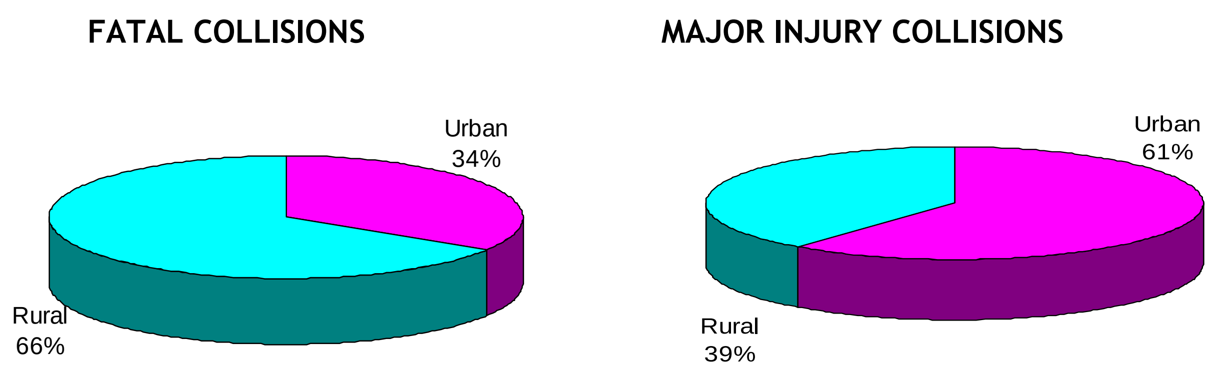


FIGURE 2.3 ALBERTA FATAL/MAJOR INJURY COLLISIONS BY LAND USE (2007)

The collision types associated with fatal and major injury collisions in Alberta are summarized in
FIGURE 2.4.

FATAL COLLISIONS **MAJOR INJURY COLLISIONS**

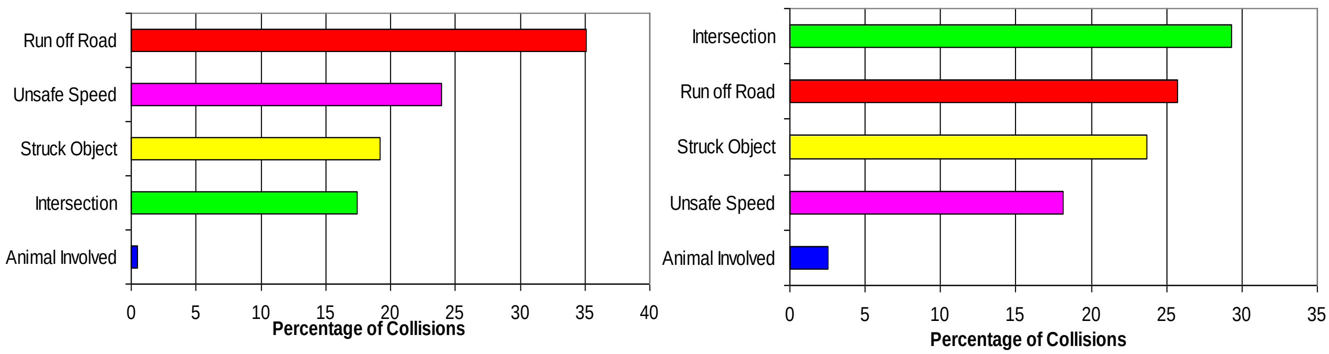


FIGURE 2.4 ALBERTA CASUALTY COLLISIONS BY TYPE (2007)

The distributions indicate that approximately half of the fatal and major injury collisions are likely the result of off-road movements (the combination of run-off-road collisions and a proportion of the other collision types - particularly unsafe speed and struck object, which frequently involve off-road movements). A significant proportion of collisions are also related to speed and intersections, with unsafe speed being a greater contributor to fatal collisions and intersections to major injury collisions. These patterns support the key objective areas identified for this study.

FIGURE 2.5 and 2.6 indicate the type of road users involved in fatal and major injury collisions in urban and rural areas. In urban areas, the more “vulnerable” road user modes (motorcyclists, bicyclists, and pedestrians) are casualties in approximately 30 percent of fatal and 20 percent of major injury collisions. Pedestrians are the most susceptible, followed by motorcyclists. In rural areas, these more vulnerable users account for only about 8 percent of the total collisions, with pedestrians accounting for most deaths and motorcyclists accounting for most injuries. These trends clearly emphasize the need to focus on pedestrian measures in order to address casualty collisions in urban areas.

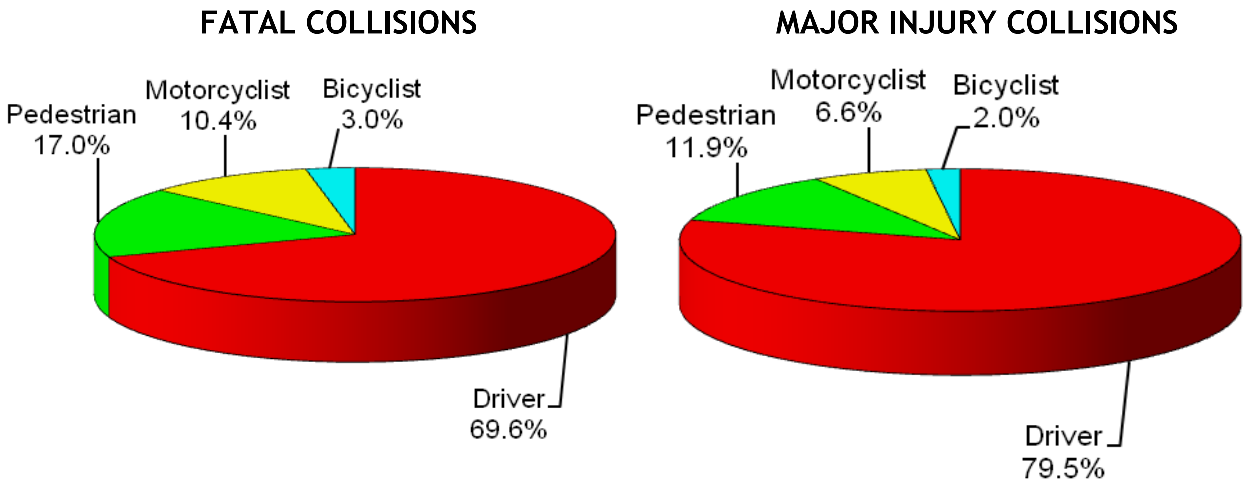


FIGURE 2.5 ALBERTA URBAN ROAD USERS INVOLVED IN CASUALTY COLLISIONS (2007)

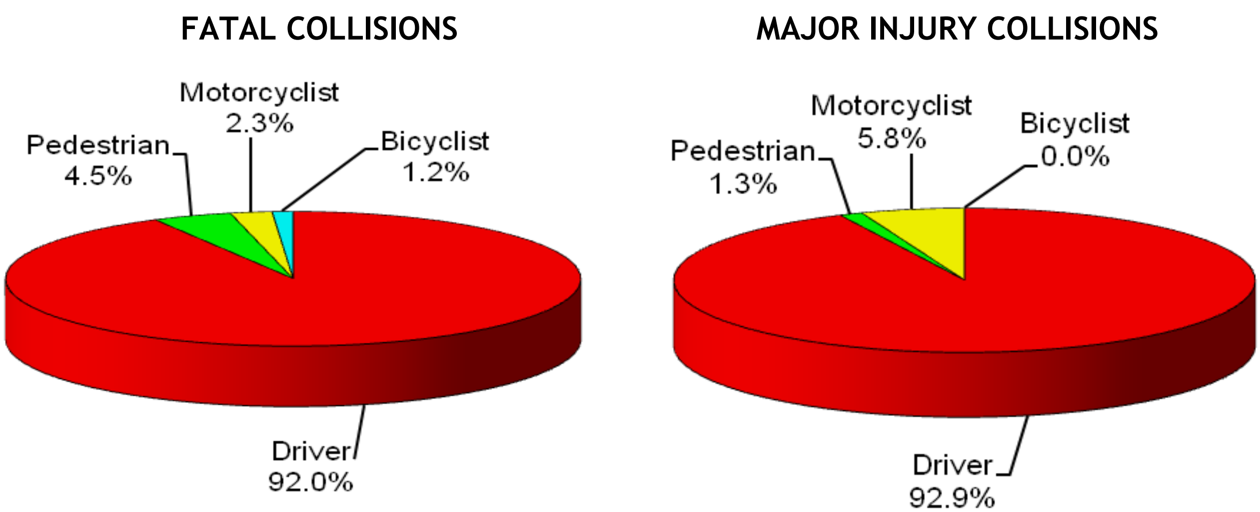


FIGURE 2.6 ALBERTA RURAL ROAD USERS INVOLVED IN CASUALTY COLLISIONS (2007)

2.2 Municipal Collision Trends

To obtain a more specific profile of collisions in the more urbanized areas, the collision trends of five selected municipalities were reviewed. This included two "large" municipalities (Calgary and Edmonton), one "medium-sized" municipality (Strathcona County), and two "smaller" municipalities (Camrose and Airdrie). 2008 collision data was reviewed for the large municipalities. Three years of data (2006-08) were reviewed for the medium-sized and smaller municipalities in order to obtain significant trends.

A. Large Municipalities

The City of Calgary and the City of Edmonton are the two largest cities in Alberta, with populations of approximately 1,000,000 and 750,000, respectively. The City of Calgary reported a total of 46,684 collisions in 2008, while the City of Edmonton reported 41,482 collisions. The difference in the definition of "major injury" between the two municipalities makes it difficult to directly compare major injuries.

FIGURE **2.7** shows a combined overall distribution of collision severity for the two cities.

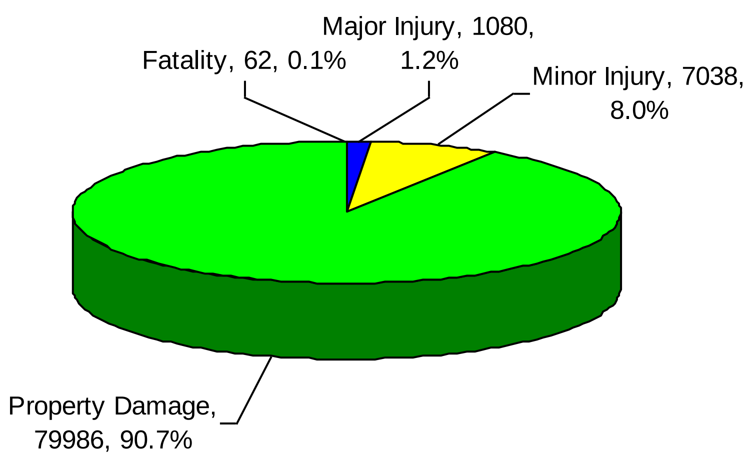


FIGURE 2.7 LARGE MUNICIPALITY COLLISIONS BY SEVERITY (2008)

The distribution indicates that the proportion of fatal collisions is lower than the Alberta average, which is expected in a more urbanized area due to the lower-speed environment. The proportion of major injury collisions is comparable to Alberta average. FIGURE 2.8 illustrates some of the contributing factors to fatal collisions in Calgary and Edmonton.

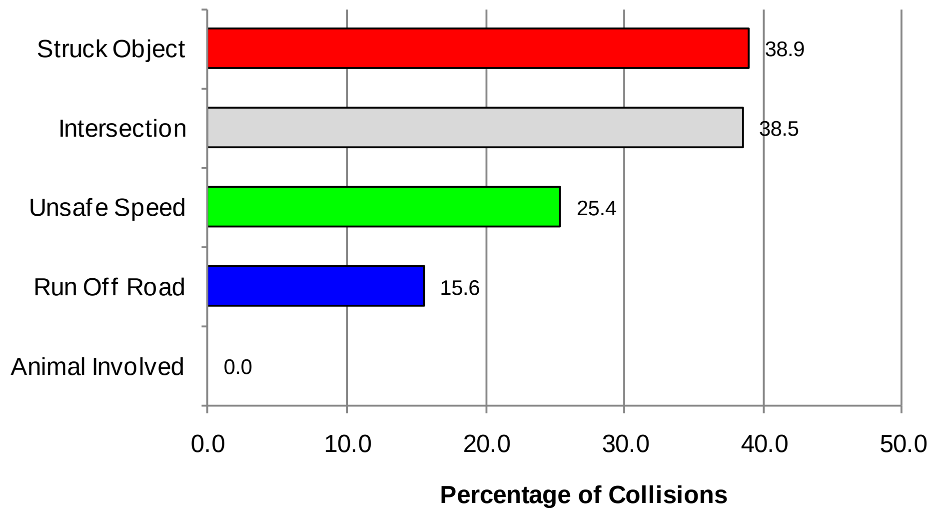


FIGURE 2.8 LARGE MUNICIPALITY FATAL COLLISIONS BY CONTRIBUTING FACTOR (2008)

The two most common contributing factors to fatal collisions in Calgary and Edmonton were "struck-object" and "intersection". Speed-related collisions were also significant.

FIGURE **2.9** illustrates the type of road user involved in fatal and major injury collisions in Calgary and Edmonton.

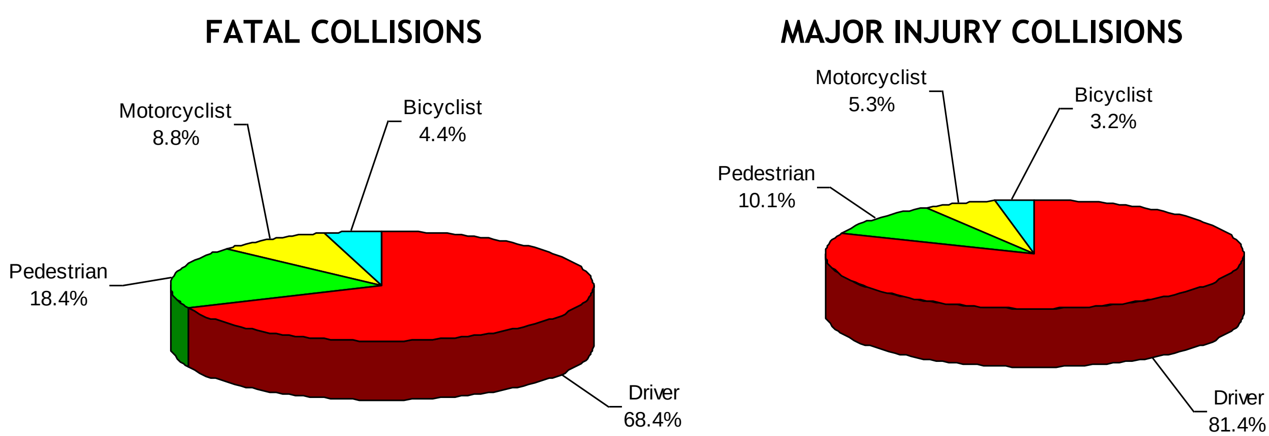


FIGURE 2.9 LARGE MUNICIPALITY ROAD USERS INVOLVED IN CASUALTY COLLISIONS (2008)

Over 30% of fatal collisions in Calgary and Edmonton involved a vulnerable road user mode (pedestrians, motorcyclists and bicyclists). In comparison, vulnerable road users accounted for a combined 19% of major injury collisions.

B. Medium Sized Municipalities

Strathcona County was selected to analyze trends of a medium-sized municipality, including the differences between the urban and rural parts. Strathcona County has a population of approximately 82,500 and was the site of 3,391 total collisions in 2008. The TRANS Office of Traffic Safety indicated that 80% of fatal crashes in the County are in the rural areas and about 63% of the major injury crashes are rural. FIGURE 2.10 indicates the percentage of collisions by severity for 2006 to 2008.

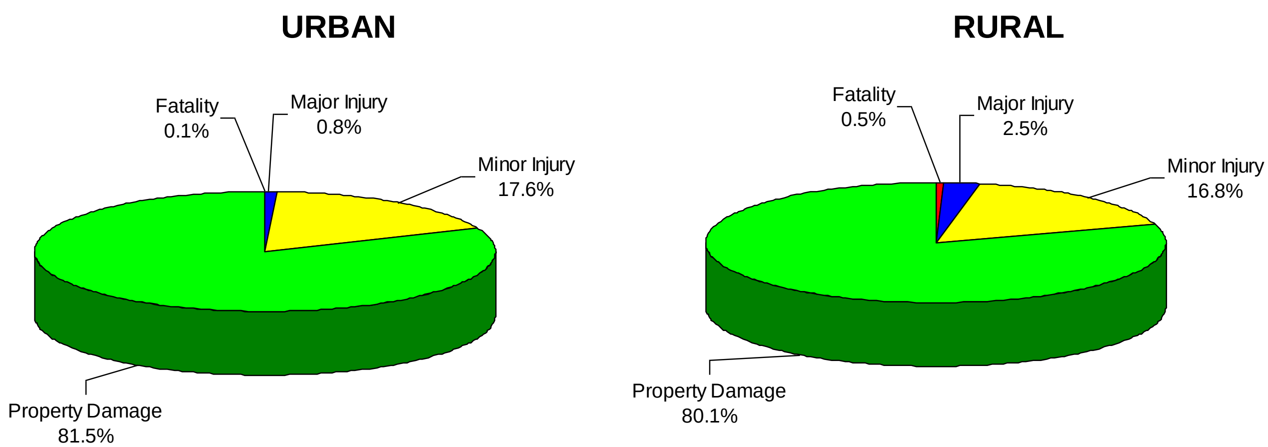
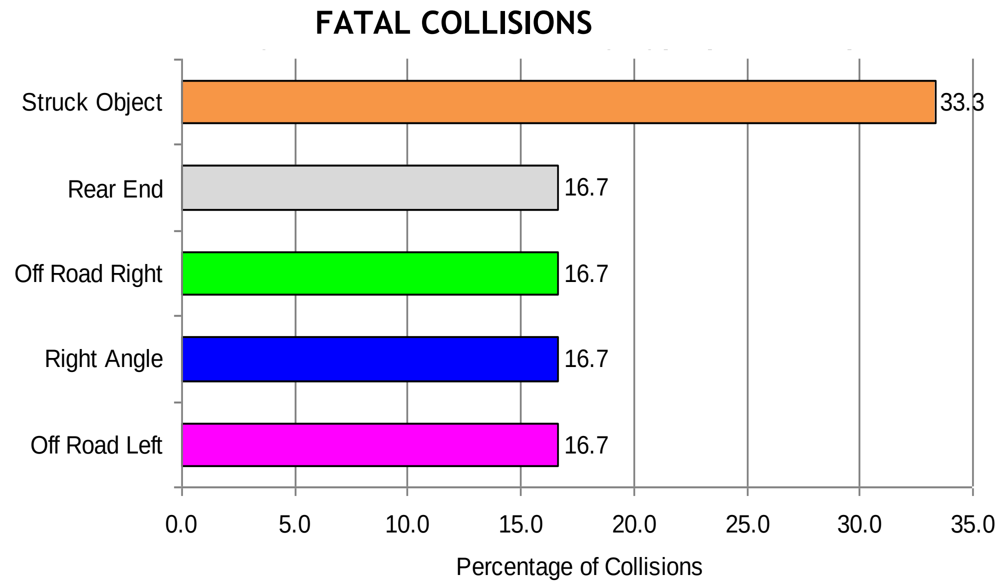


FIGURE 2.10 MEDIUM-SIZED MUNICIPALITY COLLISIONS BY SEVERITY (2006-2008)

The Strathcona County collision severity distribution is generally comparable to Calgary and Edmonton and to the overall Alberta distribution; however there is a higher proportion of minor injury collisions. The urban and rural collision type distribution is provided in FIGURE 2.11 and FIGURE 2.12.



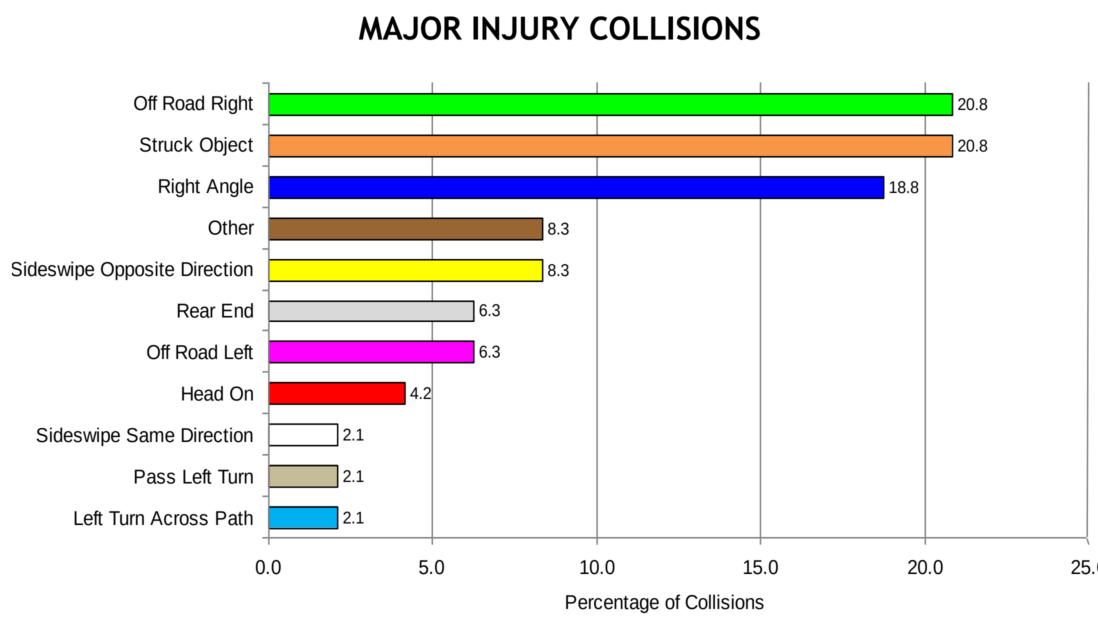
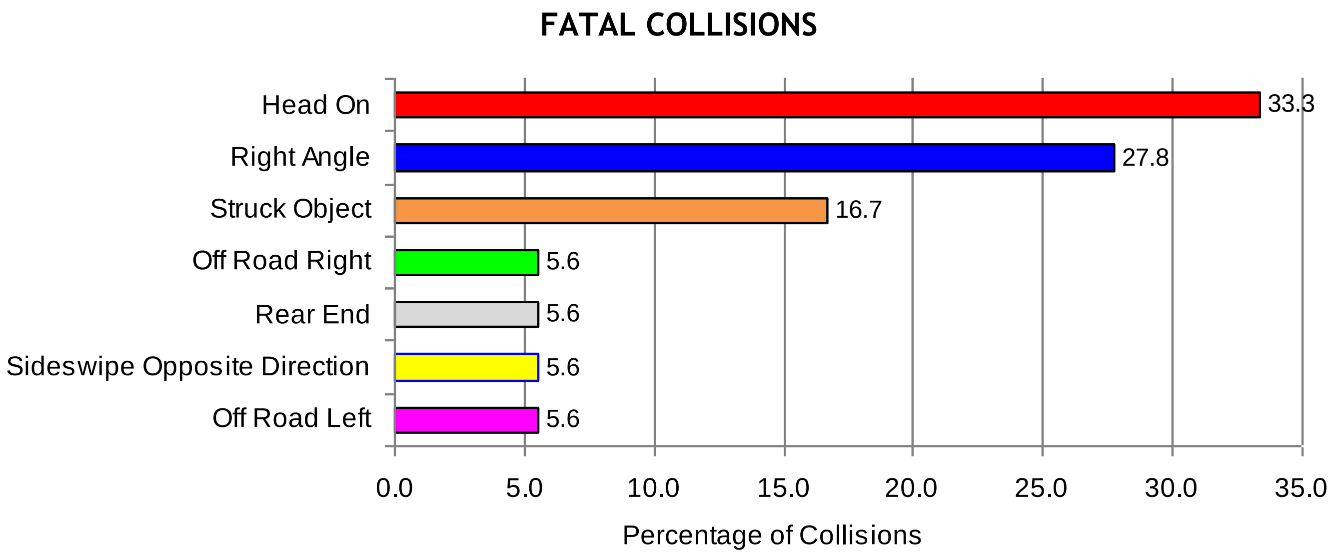


FIGURE 2.11 MEDIUM MUNICIPALITY URBAN CASUALTY COLLISIONS BY TYPE (2006-2008)



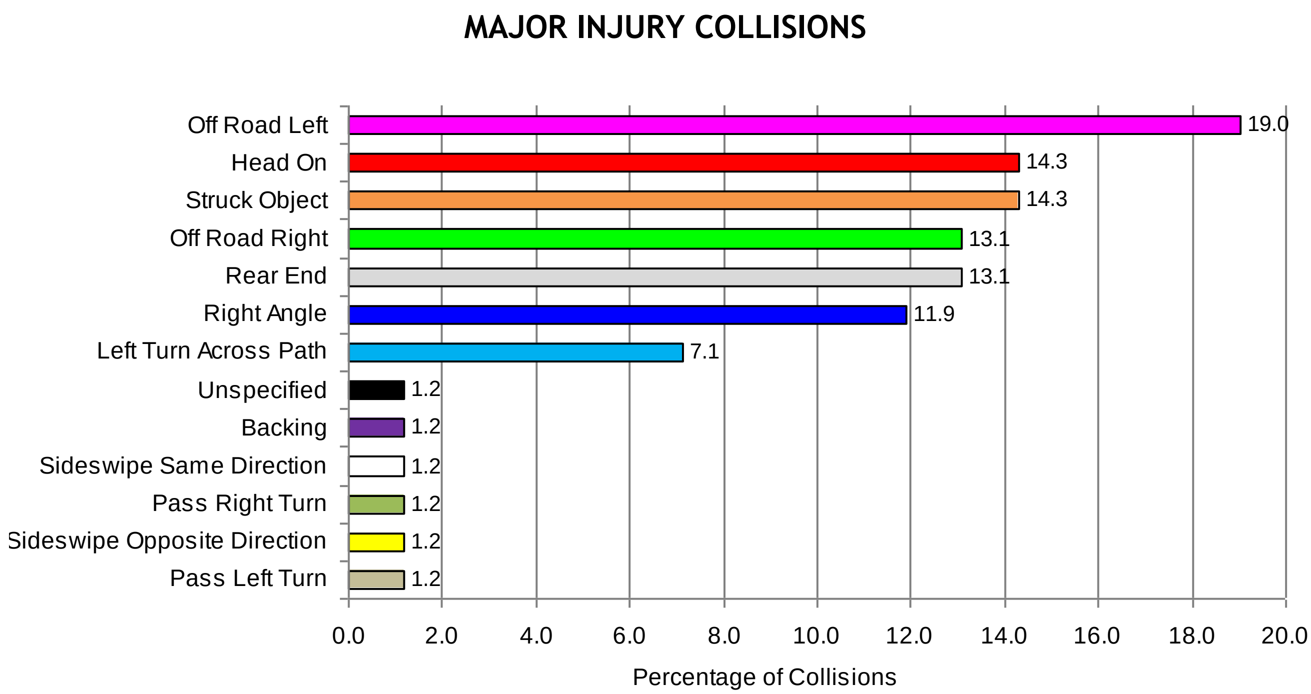


FIGURE 2.12 MEDIUM MUNICIPALITY RURAL CASUALTY COLLISIONS BY TYPE (2006-2008)

The distributions indicate that in the urban areas, the most common types of casualty collisions are struck object. The majority of these are likely at intersections and/or involving vulnerable road users. In contrast, in the rural areas the patterns are less distinct, but more of the casualties are the result of head-on and right-angle collisions. Although Strathcona County contains a larger rural area than most medium-sized municipalities, these patterns suggest that in the urban areas, a more targeted approach can be taken, particularly focused at intersections. FIGURE 2.13 illustrates the type of road users involved in fatal and major injury collisions in Strathcona County.

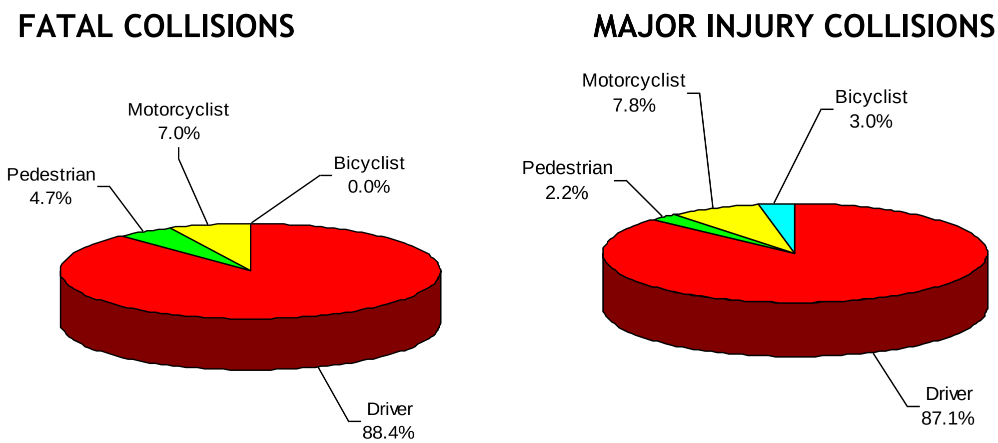


FIGURE 2.13 MEDIUM-SIZED MUNICIPALITY ROAD USERS IN CASUALTY COLLISIONS (2006-2008)

The distribution reveals that the proportion of vulnerable road users involved in major injury collisions and fatalities is lower than in the large municipalities. This implies that in medium-sized municipalities there are fewer vulnerable users facing fewer issues than in the larger municipalities. Although motorcyclists are more susceptible than pedestrians and cyclists, the total numbers are relatively low.

C. Smaller Municipalities

The City of Camrose and the City of Airdrie were used to obtain an indication of collision trends in smaller municipalities in Alberta. Camrose has a population of approximately 15,500 and encountered a total of 733 collisions in 2008, while Airdrie has a population of approximately 35,000 and encountered a total of 1,811 collisions in 2008. FIGURE 2.14 indicates the percentage of collisions by severity for 2006 to 2008.

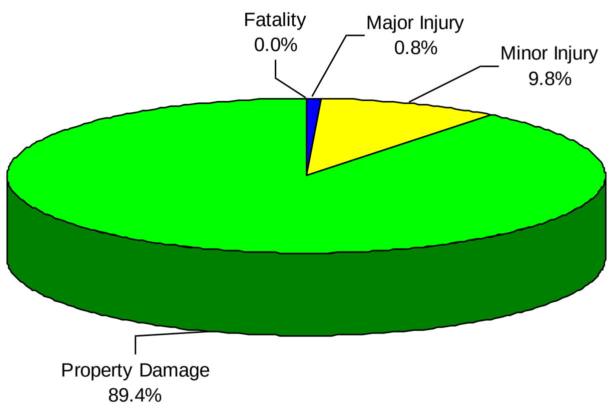


FIGURE 2.14 SMALLER MUNICIPALITY COLLISIONS BY SEVERITY (2006-2008)

The distribution indicated that there was one fatal collision and 51 (0.8%) major injury collisions. The severity of collisions in the smaller municipalities is significantly lower than the medium-sized and larger municipalities. Due to the low number of fatal and major injury collisions, trends in the collision type and road user distribution are insignificant.

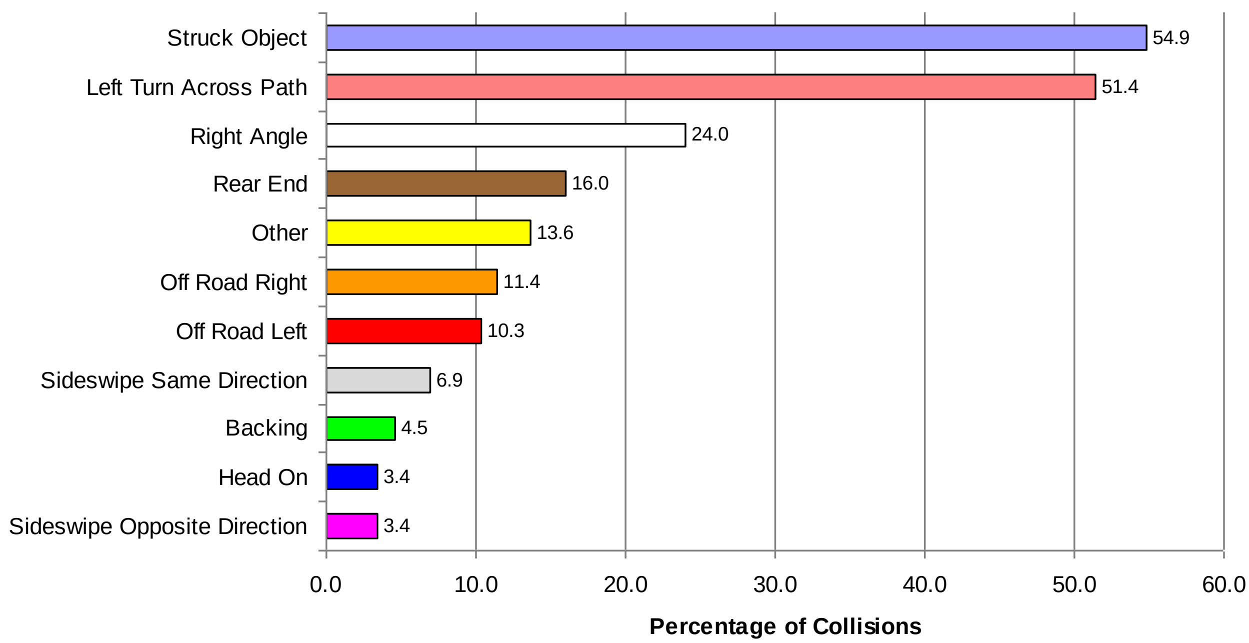


FIGURE 2.15 SMALLER MUNICIPALITY MAJOR INJURY COLLISIONS BY TYPE (2006-2008)

The high proportion of left-turn across path and right-angle collisions occur at intersections, and may imply inadequate gap acceptance, which is common in smaller cities where there is a lower tolerance for gaps. The struck object collisions may include some pedestrians. In general, the results indicate that there are much fewer severe collisions in the smaller municipalities, both in terms of frequency and proportion, but that the majority occur at intersections.

2.3 Overall Collision Trends

The purpose of this analysis was to identify the high-level trends affecting jurisdictions of different sizes and land use types, such that these trends can be addressed among the countermeasures generated in this study.

TABLE 2.2 MAJOR INJURY/FATALITY TRENDS

LOCATION OF TREND	INJURY/FATALITY TREND
Province (General Trends)	Off-road Intersections Unsafe speed
Larger Municipalities	Intersections Vulnerable road users
Medium-sized Municipalities	Intersections
Smaller Municipalities	Intersections

2.4 Common Safety Issues Identified by Opus

Opus has conducted numerous traffic safety studies in Alberta, both at a network level and for individual collision-prone locations. Based on both the analysis of collision data and professional observation, the project team has identified key common safety issues so that they can be addressed as much as possible among the countermeasures. These include:

- Limited intersection sight distances;
- Inconspicuous or deteriorated pavement markings and signs;
- Inappropriate speed zoning;
- Inadequate adjustment of speed when entering urban areas;
- Inconsistent/over-application of stop control enhancements;
- Inadequate gap acceptance at unsignalized intersections;
- Inadequate visibility of traffic signal displays;
- Glare from sunlight;
- Loss of pavement friction;
- Inadequate clearance time at traffic signals for vehicles or pedestrians;

- Steep side slopes and narrow shoulders;
- Overly wide cross-sections;
- Unclear turning paths and right-of-way through intersections;
- Design inconsistency between successive curves;
- Sign clutter/workload at intersections and interchanges;
- Simultaneous changes in cross-section and alignment;
- Ineffective delineation for lower visibility conditions; and,
- Fixed objects or non-crashworthy structures within the clear zone.

3.0 REVIEW OF CURRENT PRACTICES AND LITERATURE

Opus conducted extensive research of strategies and measures for collision reduction, both within and outside Alberta. This included an extensive literature review, a workshop of Alberta stakeholders, supplementary consultation with road agencies in Alberta and the neighbouring provinces, and consultation with international traffic safety researchers and authorities.

3.1 Review of Current Practices in Alberta

Prior to investigating road safety engineering literature and practices outside of Alberta, the study team researched the measures that have already been implemented or evaluated within Alberta. The purpose of this exercise was to identify measures that have been successful or are currently being tested. Proven "Made-in-Alberta" solutions have the potential to be among most effective solutions, and their use can be more easily expanded than newer measures.

Alberta Transportation's traffic safety activities have been underway for several years. The Engineering Strategic Plan (ESP) is the engineering component of the Alberta Traffic Safety Plan (TSP). The ESP outlines the engineering strategies that have been implemented, the applications and costs, and some cursory evaluation. A summary of the measures that have shown to be effective is provided in FIGURE 3.1. The circles provide a cursory indication of the extent to which each is implemented. For example, there is some evaluation and monitoring being conducted of the first five measures, including rumble strips. More details on the specific measures that are summarized in these areas are available in APPENDIX B.

Depending on their stage of implementation and degree of success, measures may be identified for:

- More widespread implementation, provided they meet the objectives of this study;
- Modification of their application, based on performance and recent research; and
- Reduction in implementation, based on limited success.

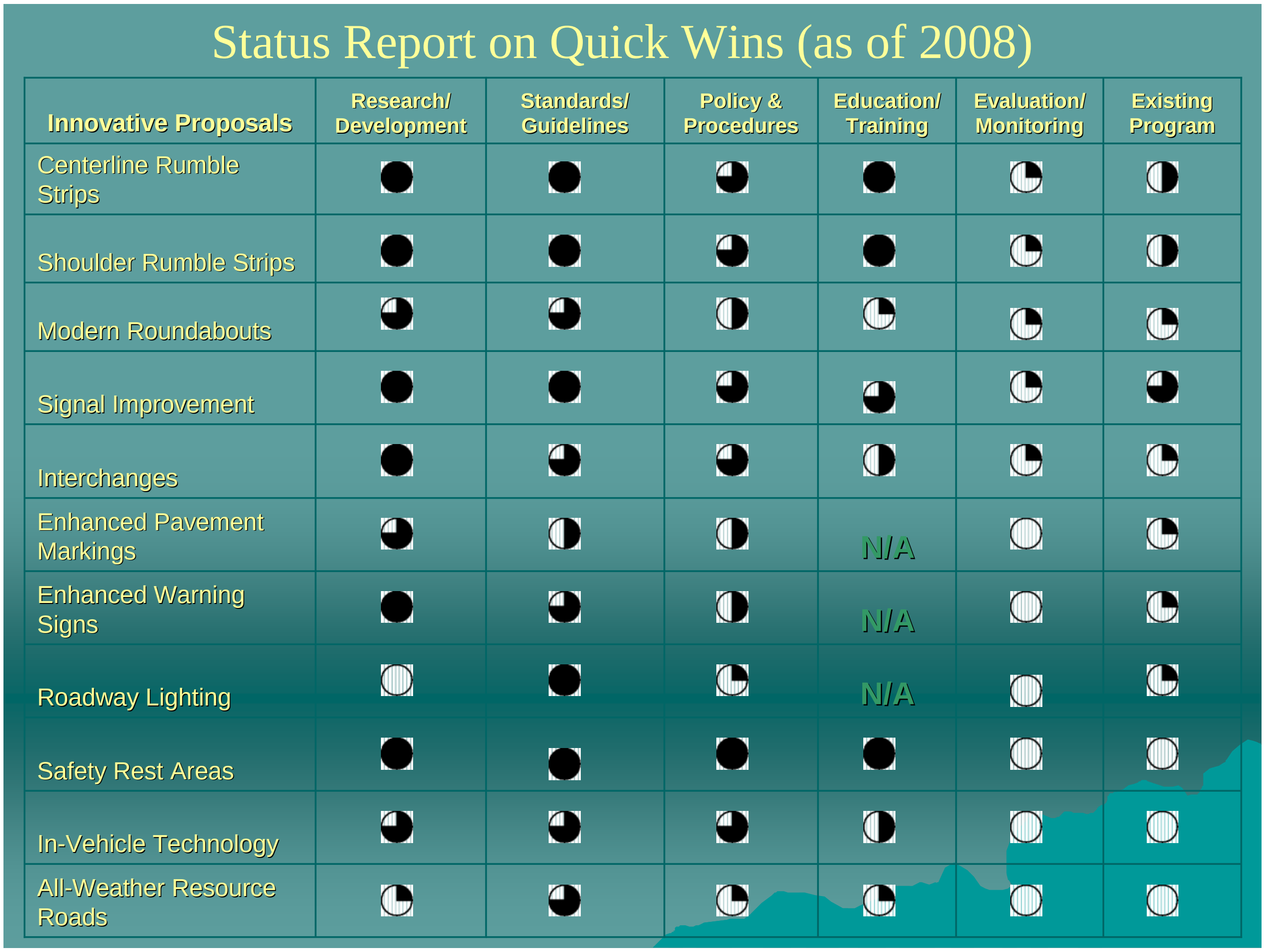


FIGURE 3.1 EFFECTIVE ENGINEERING COMPONENTS OF TRAFFIC SAFETY ACTION PLAN

Source: Alberta Transportation's Engineering Strategic Plan (2009)

To obtain additional anecdotal Alberta experience for both highways and urban centres, Opus conducted a workshop in Edmonton on August 19, 2009. The workshop involved 16 representatives from various departments within Alberta Transportation, the City of Edmonton, the City of Calgary, the City of Red Deer and a representative of the smaller municipalities of Alberta. The purpose of the workshop was to identify collision reduction measures that have been implemented, either successfully or unsuccessfully, in their jurisdictions. The workshop team also brainstormed various measures they have considered, tried or observed for each of the key engineering objective areas. Lists of the measures identified are included in APPENDIX A.

To expand on the information gathered during the workshop, various road agencies throughout Alberta were individually contacted to collect information and specific studies regarding the effectiveness of any countermeasures they have tested. The measures for which the benefits have been formally tested in Alberta include:

- Snowplowable pavement markings (Alberta Transportation);
- Simple radius design (right-turn), Edmonton;
- Free flow design (right-turn), Edmonton; and
- Aussie right design (right-turn), Edmonton.

All four of these have been considered successful based on public feedback and other measures, but not in terms of reduced collisions. The majority of the road agencies contacted did not formally evaluate their safety measures (for example through before-after studies), but provided anecdotal evidence of their effectiveness based on observation and public feedback. Other measures that have not been tested but have received positive feedback include:

TABLE 3.1 ALBERTA-TESTED SAFETY MEASURES

SAFETY MEASURE	CURRENT USAGE
Enhanced pavement markings (wet night)	Widespread
Protected left-turn phases	Widespread
Rumble strips (shoulder and centre line)	Widespread (highways)
Modern roundabouts	Limited (municipalities)
Speed limit observation and warning	Limited (large municipalities)
Clear-view fencing	Limited (large municipalities)
Quadrant intersections	Limited
Accessible pedestrian signals	Widespread (large municipalities)
Extended walk phases at signalized intersections around homes for the elderly	Limited (municipalities)
Increased visibility signals (LED)	Widespread
Yellow signal head backboard	Widespread
Chicanes for urban traffic management	Limited (municipalities)
Solar-powered red flashing beacon on stop signs	Widespread
Clearview font on signs	Limited
Pedestrian countdown signals	Limited (municipalities)

Alberta Transportation currently has a program in place for selecting locations for the installation of shoulder and centreline rumble strips based on *expected* benefit-cost from reduced off-road and head-on collisions. It is suggested that this be formally reviewed.

In 2007, there were 2441.7 km of highway throughout Alberta that were designated as high priority for *shoulder* rumble strips. Approximately 60 percent of this was on undivided roads. There was an additional 1265 km of highway designated as high priority for *centreline* rumble strips. The benefit cost ratio (BCR) range for each type of rumble strip is indicated in TABLE 3.2.

TABLE 3.2 ALBERTA TRANSPORTATION'S RUMBLE STRIPS EFFECTIVENESS CRITERIA

RUMBLE STRIP TYPE	TOTAL KM	NUMBER OF SITES	BCR RANGE
Shoulder	2441.7	101	13.4 - 447
Centreline	1265.0	54	2.3 - 12.3

Source: Alberta Transportation Technical Standards Branch

Although the highest BCR for shoulder rumble strips is 447, a handful (seven) of the 101 sites predicted a BCR greater than 100. However, the large majority expected significant benefits.

Alberta Transportation also has a program in place for selecting locations for truck driver Safety Rest Areas based on expert opinion from both the trucking industry and TRANS. In 2008, there were 13 locations selected as Safety Rest Area Priority Locations. Three of these are located northwest of Edmonton, while the rest are east and/or south. However, specific information on the projected or proven benefits was unavailable.

A more detailed summary of Alberta-tested measures is provided in APPENDIX B.

The Canadian and International research was conducted using a four-pronged approach:

1. Consultation with Neighbouring Provinces
2. Consultation with International Experts
3. Consultation with Industry
4. Review of Literature

The process and findings of these tasks are described in Sections 3.2 to 3.5, respectively.

3.2 Consultation with Neighbouring Provinces

The provinces of British Columbia and Saskatchewan were also consulted for this study. The importance of leveraging the successes of neighbours as well as seeking consistency between adjacent provinces was recognized. The highlights of these consultations are as follows.

3.2.1 Saskatchewan

Through discussion with a representative of Saskatchewan Highways and Transportation, some countermeasures in place in Saskatchewan were identified that are not in place in Alberta. These measures are thought to be effective; however no studies were available that have proven this through collision reduction.

- *Median Acceleration Lanes*: These are primarily implemented on divided highways. Their purpose is to provide storage for turning vehicles as well as a safer two-stage crossing.
- *Advance Intersection Warning Beacon*: These are used to warn drivers on the uncontrolled highway approaching a STOP controlled intersection.
- *Wide Median Openings with Traffic Controls*: It is more common in Saskatchewan to have openings in the wide medians provided on divided highways. The median openings typically store multiple vehicles. They provide a yield sign and a centreline in the median for the crossing traffic, but the implementation of these devices is inconsistent.
- *Overhead STOP Sign*: In some jurisdictions, particularly lower-class roads in the municipalities, STOP signs are provided on cantilever arms. This is considered effective in emphasizing the STOP control by placing the sign directly within the driver's field of vision.

Saskatchewan has implemented shoulder rumble strips after noting their effectiveness in Alberta, and may also consider implementing centre line rumble strips now that they have been tested in Alberta. Some of the other safety measures/programs mentioned as being effective in Saskatchewan are also in use in Alberta:

- Roadside guardrail on bridge approaches;
- Sideslope flattening;
- Channelized turning lanes; and
- Flashing beacons above STOP signs.

The bridge approach guardrails and the flashing beacons have been evaluated. The results are unavailable for this study, but are reportedly positive.

3.2.2 British Columbia

Through discussion with a representative of the British Columbia Ministry of Transportation, a handful of measures were identified that are not as widespread in Alberta. Several specific studies have been conducted by the Insurance Corporation of British Columbia on nearly every type of engineering countermeasure; some of these have been sourced in the generation of the highly effective measures lists and reduction factors presented in Section 6.0. From the BC highways perspective, the most effective collision reduction measures implemented are:

- Rumble strips;
- Roundabouts;
- Upgraded traffic signal displays;
- Use of Uninterruptable Power Supply at traffic signals; and
- Highly reflective warning and constructions signs (ASTM Type 9).

In particular, British Columbia has installed several roundabouts, especially with the "dumbbell" design at interchanges, and developed specific guidelines and processes to ensure consistency. This may assist in the development of a roundabouts policy for Alberta. Also, the formal use of context sensitive design may provide some hints for us in the identification of land use and speed categories.

Collision reduction measures found to be *ineffective* include transverse pavement markings.

3.3 Consultation with International Experts

Consultation was undertaken with international experts, both within Opus and externally, in Canada, the United States, the United Kingdom, Australia and New Zealand. Numerous innovative collision reduction measures were identified based on conversations with these experts. Although promising, most measures lack studies to prove their effectiveness. A summary of the findings from discussions with international experts is provided here:

- Opus' own Practice Interest Networks (PINs) were used to gather information on collision reduction measures that are used elsewhere in the world, including Australia, New

Zealand and the United Kingdom. The PINs feedback recommended the review of relevant resources such as Austroads guides and various other research reports.

- Dr. Darren Walton from Opus' Central Labs in New Zealand provided the research team with additional resources from Australia and New Zealand, particularly perceptual roadway measures and those related to bicycle safety.
    - Near-side PUFFIN pedestrian display (a modification of our "special crosswalk");
    - Flush medians (painted; may have slight profile);
    - De-icing/anti-icing;
    - Scramble pedestrian crossing (dedicated pedestrian phase in all directions); and
    - C-roundabout (low-speed modern roundabout to allow cyclists to proceed with vehicular traffic)

Anti-icing is already practiced in Alberta. The other measures were reviewed and dropped due to lack of evidence of collision reduction or applicability. Scramble pedestrian crossings were identified during the initial research conducted by Opus and have been identified by numerous other experts. Scramble pedestrian crossings are not considered highly effective as there are few locations within Alberta where pedestrian volumes would be high enough for these crossings to be effective. TAC is soon embarking on the development of guidelines to determine when pedestrian crossings, including scramble crossings, are warranted.

- Jeff Bagdade of Opus' Detroit office, who is active on several U.S. National committees, provided input regarding the latest research from the Federal Highway Administration and other US agencies. This included an abundance of recent literature on innovative intersection improvements. Jeff provided the following measures that met the criteria for inclusion on the shortlists for intersections:
    - Directionalized median openings ("Michigan left" – downstream u-turn); and,
    - Offset right-turn lanes at signalized intersections (combined in this study with the dedicated right-turn lanes on major approach measure).

Other new collision reduction measures identified by Jeff but excluded on the basis of lack of evidence or Alberta applicability were:

- J-Turns at intersections on rural high speed expressways (jughandle concept);
- Continuous flow intersections (left-turns on major street separated upstream o f intersection to the left side of the approach);
- Superstreet intersections (left-turns from the minor road separated);
- 30-60-90 pork chops at channelized rights (Smart right-turn channel concept);
- Offset right-turn lanes at unsignalized intersections (to eliminate shadowing);

- Rectangular Rapid Flash Beacon (at activated pedestrian crossings);
- Flashing yellow arrows (newly approved display for permissive left-turns);
- U-turn signal indications; and,
- HAWK signals (signals at pedestrian crossings that display amber and red).

Several of these measures have to do with separating left-turns from intersections and with traffic signal displays. While these are new concepts for Alberta, incompatible with current standards and are therefore not considered "early winners" for this project, the Province is strongly encouraged to investigate them further and discuss future feasibility.

- Dr. Pat McGowen of the Western Transportation Institute in Montana (and the co-manager of the FHWA's National Wildlife Vehicle Collision Study) was consulted regarding vehicle-wildlife collision reduction measures. The most recent measures were identified and discussed. Dr. McGowen also pointed us to other research currently taking place in Alberta:
  - Dr. Tony Clevenger, a wildlife biologist with the Western Transportation Institute at Montana State University, has spent the past 12 years assessing measures to reduce habitat fragmentation on the Trans-Canada Highway in Banff National Park, which contains 24 wildlife crossings. The fencing and crossing structures in Banff saw a greater than 80 percent reduction in collisions for all large mammals. Specifically for ungulates (deer, elk, and moose), there was a 94-96 percent reduction. The analysis was based on carcass data and not reported crashes which is believed to be more reliable as smaller mammals cause little damage to the vehicle and are typically not reported. It should be noted that Banff National Park is a somewhat unique setting with very little development alongside the roadway and thus very few accesses. Accesses (or approach roads) are a challenge when fencing highways as they create a gap in the fence; however, cattle guards may be incorporated to maintain the barrier.

- Dr. Tarek Sayed of the University of British Columbia reviewed ITS and technology applications for the study team. Besides the measures already mentioned, Dr. Sayed suggested the following measures:
  - Adaptive speed limiters;
  - Offset left-turn lanes at unsignalized intersections; and,
  - Bypass Lanes at T-intersections.

Although adaptive speed limiters could have a significant impact on operating speeds, as they physically govern vehicle speeds, they require vehicle modifications and are therefore not a road engineering measure. Offset left-turn lanes were included among the recommendations. The collision reduction factor associated with bypass lanes was too low to justify its use.

3.4 Consultation with Industry

As part of the search for new and innovative traffic safety measures, Opus consulted with a supplier of traffic control and traffic safety products. The 3M Canada Company provided information on collision reduction measures corresponding to the seven objective areas. Measures that were deemed by the study team to be proven effective are:

- Increased Sign Retroreflectivity; and
- Linear Delineation Systems.

Some of the measures that were reviewed and excluded from the recommendations based on the lack of evidence are:

- Reflective license plates (increase conspicuity of disabled vehicles during dark conditions);
- Fluorescent warning signs; and
- Dynamic driver feedback signs.

All of the measures provided by suppliers have a potential to reduce collisions. However, no specific evidence based research was available to justify their extensive use at this time.

3.5 Literature Review

Opus conducted an extensive literature review to uncover the latest studies on road safety engineering measures and their effectiveness. Our approach to the literature review was to start with the most recent and comprehensive sources published, and then proceed to a number of secondary sources for further information on specific objectives areas or to find the specific studies referred to by the recent synthesis documents. The search was restricted to:

- *Road safety engineering measures*. This included anything within the right-of-way that would be considered part of the road infrastructure. This excluded enforcement-focused measures (such as red-light cameras), education-focus measures (such as billboards with road safety messages); and vehicle-based engineering measures (such as occupant restraints and vehicle speed limiters). In some cases, these other measures can have a significant impact on traffic safety, so the Province is strongly encouraged to pursue or continue these in parallel.

- *Measures focused on the 7 objective areas*. This excluded measures specific to road network components that were not identified among the seven objective areas: most notably *interchanges* and *at-grade railway crossings*. It is acknowledged that the range of measures explored will still impact safety in other areas (e.g. speed reductions will reduce collision severity throughout the network; some intersection measures are applicable at interchange intersections; improvements along links may reduce collisions at railway crossings).

The four primary literature sources Opus started with were:

- Transport Canada, "International Road Engineering Safety Countermeasures and their Applications in the Canadian Context" (2009);
- Federal Highway Administration, "Desktop Reference for Crash Reduction Factors", FHWA-SA-07-015 (2008);
- The Traffic Safety Engineering Toolbox for Aging Road Users (2009); and,
- National Cooperative Highway Research Program (NCHRP) "Report 500, Guidance for the Implementation of the AASHTO Strategic Highway Safety Plan." (2004-09).

These sources provided a comprehensive list of collision reduction measures for all seven objective areas. The "International Road Safety Engineering Countermeasures and their Applications in the Canadian Context" report by Transport Canada evaluates the appropriateness of measures within Canada based on a number of factors such as compatibility with current legislation, design manuals, construction practices, climate and public acceptance. The document also indicates the anticipated performance towards achieving targets of Canada Road Safety Vision 2010 and the relative cost of each measure.

The "Desktop Reference for Crash Reduction Factors", is a report by FHWA that provides an extensive list of collision reduction measures, including expected collision reduction factors. Where available, the collision reduction factors are broken down based on the collision type, collision severity, land use, geometrics and traffic control.

The "Traffic Safety Engineering Toolbox for Aging Road Users" was prepared under the leadership of the Alberta Motor Association, in consultation with Alberta Transportation and other municipal road agencies in Alberta. It identified over 150 design and traffic control enhancements to the road and sidewalk infrastructure to better accommodate the limitations of the aging population and provide superior safety for all road users.

NCHRP's Report 500 contains 22 volumes of research. Each volume relates to reducing specific collision types. For example, Volume 8 of the series provides a guide to reducing collisions involving utility poles. Detailed information is provided for each measure identified including the expected effectiveness, keys to success, potential difficulties, appropriate measures and data, associated needs, costs involved, training and legislative needs. The volumes that were closely aligned to the objective areas of this study were reviewed.

While the objective of reviewing the primary sources was to compile as much information as possible, the research was biased towards more recent, evidence-based research that referred to specific measures (as opposed to general strategies). The secondary sources that were reviewed for specific information that covered several of the objective areas included:

- Other NCHRP reports in 500 series (2004-2009);
- Transportation Association of Canada, "In-Service Road Safety Review Guide" (2004);
- Alberta Motor Association, "Synthesis of Road Safety Engineering Countermeasures";
- Federal Highway Administration, "FHWA Human Factors Literature Review On Intersections, Speed Management, Pedestrians And Cyclists, And Visibility" (2006);
- Transport Canada, "Synthesis of Safety for Traffic Operations" (2003);
- PIARC Catalogue of Design Safety Problems and Potential Countermeasures (2009); and
- Federal Highway Administration, "Highway Design Handbook for Older Drivers and Pedestrians", (2001).

Additional sources used for specific strategies are listed below.

A. Speed Related Collision Reduction Measures

In addition to the research indicated in Sections 3.1 to 3.5, the following sources were used to gather information for speed related collision reduction measures.

- Federal Highway Administration "Traffic Calming on Main Roads Through Rural Communities" FHWA-HRT-08-067 (2009);
- Research and Innovative Technology Administration (RITA), "Intelligent Transportation System Countermeasures" http://www.rita.dot.gov/;
- Insurance Corporation of British Columbia, "Review of Speed Reduction Devices";

- Research and Innovative Technology Administration ITS Crash Reductions; and
- OECD Report on Speed Management (2006).

The Transport Canada and FHWA primary documents provided the best resources for speed related measures. Reduced speed limits, traffic calming and speed cameras were the most common measures encountered in the research.

B. Intersection Related Collision Reduction Measures

Signalized Intersections

Numerous resources providing collision reduction measures for signalized intersections are available. The FHWA in particular, has prepared numerous documents that identify and evaluate signalized intersection measures, including numerous evidence-based studies. In addition to the research indicated in Sections 3.1 to 3.5, the following sources were used to gather information for collision reduction measures at signalized intersections.

- Land Transport Safety Administration "New Zealand Pedestrian Guide" http://www.ltsa.govt.nz/road-user-safety/walking-and-cycling/pedestrian-planning-design-guide/index.html (2007);
- Federal Highway Administration "Safety Evaluation of Advance Street Name Signs" FHWA-HRT-09-030 (2009);
- Oregon Department of Transportation Research Unit "Update and Enhancement Of ODot's Crash Reduction Factors" http://www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/Crash_Reduction_Factors.pdf (2006);
- Federal Highway Administration "Synthesis of the Median U-Turn Intersection Treatment, Safety, and Operational Benefits" FHWA-HRT-07-033;
- Federal Highway Administration "Drivers' Evaluation of the Diverging Diamond Interchange" FHWA-HRT-07-048;
- Federal Highway Administration "Advantages of the Split Intersection" http://www.tfhrc.gov/pubrds/mayjun00/advantages.htm ;
- Federal Highway Administration "Techbrief: Safety Evaluation of Offset Improvements for Left-Turn Lanes" FHWA-HRT-09-036 (2009);
- Federal Highway Administration "NM 68, Riverside Drive City of Española, New Mexico ITS Project Final Evaluation Report" (2008);

- State of Florida Department of Transportation "Update of Florida Crash Reduction Factors and Countermeasures to improve the Development of District Safety Improvement Projects" http://lctr.eng.fiu.edu/Documents/CRFFinalReport.pdf (2005);
- Institute of Transportation Engineers and Federal Highway Administration, "ITE Report on Red Light Running" (2004); and
- Research and Innovative Technology Administration (RITA), "Intelligent Transportation System Countermeasures" http://www.rita.dot.gov/.

Unsignalized Intersections

In addition to the research indicated in Sections 3.1 to 3.5, the following sources were used to gather information for collision reduction measures at unsignalized intersections:

- Land Transport Safety Administration "New Zealand Pedestrian Guide" http://www.ltsa.govt.nz/road-user-safety/walking-and-cycling/pedestrian-planning-design-guide/index.html (2007);
- Federal Highway Administration "Synthesis of the Median U-Turn Intersection Treatment, Safety, and Operational Benefits" FHWA-HRT-07-033;
- Centre for Transportation Engineering and Planning, "Enhancement of Stop Control at Rural Highway Intersections" (2003);
- Insurance Corporation of British Columbia, "ICBC Intersection Collision Countermeasures"; and
- Federal Highway Administration "Safety Evaluation of STOP AHEAD Pavement Markings" FHWA-HRT-08-043 (2007).

There is noticeably less research available regarding collision reduction measures for unsignalized intersections, compared to signalized intersections. FHWA's "Desktop Reference for Crash Reduction Factors" and NCHRP's "Report 500" provided the best references for unsignalized intersections.

C. Vehicle-Wildlife Collision Countermeasures

In addition to the research indicated in Sections 3.1 to 3.5, the following sources were used to gather information for collision reduction measures for collisions between vehicles and wildlife.

- Federal Highway Administration "Wildlife Vehicle Collision Reduction Study, FHWA" (2008);
- Keith K. Knapp, "Deer-Vehicle Crash Countermeasure Toolbox: A Decision and Choice Resource" (2004); and,
- Research and Innovative Technology Administration (RITA), "Intelligent Transportation System Countermeasures" http://www.rita.dot.gov/.

While there were a lot of resources available for vehicle-wildlife collisions, there was a significant lack of evidence-based research available. The measures identified focused on keeping wildlife separated from the roadway, either through deterrence, or providing alternative facilities for them to cross.

D. Collision Countermeasures for Roadways (Links)

In addition to the research indicated in Sections 3.1 to 3.5, the following sources were used to gather information for collision reduction measures along rural and urban links.

- Insurance Corporation of British Columbia and Opus International Consultants "The Safety Benefits of Road Diets: Phase I Final Report" (2009);
- Land Transport Safety Administration "New Zealand Pedestrian Guide" http://www.ltsa.govt.nz/road-user-safety/walking-and-cycling/pedestrian-planning-design-guide/index.html (2007);
- Federal Highway Administration "Safety Evaluation of Lane and Shoulder Width Combinations on Rural, Two-Lane, Undivided Roads Advantages of the Split Intersection" http://www.tfhrc.gov/safety/pubs/09031/index.htm (2009);
- Federal Highway Administration "FHWA Advance Street Name Signs" FHWA-HRT-09-029 (2009);
- Oregon Department of Transportation Research Unit "Update and Enhancement Of ODot's Crash Reduction Factors" http://www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/Crash_Reduction_Factors.pdf (2006);
- Institute of Transportation MOTC, Chinese Taipei "Compendium of Road Safety Initiatives" http://www.apec-tptwg.org.cn/TPT/tpt-main/Completed-Projects/Project1/Road%20Safety%20Compendium%20(for%20CD).pdf (2004);
- State of Florida Department of Transportation "Update of Florida Crash Reduction Factors and Countermeasures to improve the Development of District Safety

Improvement Projects" http://lctr.eng.fiu.edu/Documents/CRFFinalReport.pdf (2005);

- Research and Innovative Technology Administration (RITA), "Intelligent Transportation System Countermeasures" http://www.rita.dot.gov/ ; and,
- Federal Highway Administration "Tech Brief: Safety Evaluation of Centre Two-way Left-Turn Lanes on Roads" FHWA-HRT-08-046 (2008).

E. Run-Off-Road Collision Countermeasures

In addition to the research indicated in Sections 3.1 to 3.5, the following sources were used to gather information for off-road collision reduction measures.

- Research and Innovative Technology Administration (RITA), "Intelligent Transportation System Countermeasures" http://www.rita.dot.gov/

The Transport Canada, FHWA and NCHRP documents provided numerous collision reduction measures to address both the frequency and severity of off-road collisions. The measures can be divided into measures that reduce the likelihood of a driver running off the road, such as improved delineation, and measures that reduce the severity of off-road movements such as cable barriers.

F. Vulnerable Road User Collision Countermeasures

In addition to the research indicated in Sections 3.1 to 3.5, the following sources were used to gather information to help improve the safety for vulnerable road users.

- Research and Innovative Technology Administration (RITA), "Intelligent Transportation System Countermeasures" http://www.rita.dot.gov/ ;
- Dangerous by Design: Solving the Epidemic of Preventable Pedestrian Deaths, Transportation for America (2009).

Extensive research related to vulnerable road user collision reduction measures was available. However, there was a general lack of *evidence-based* research, with the exception of collision reduction measures for pedestrians. Literature containing collision reduction countermeasures for motorcyclists was particularly scarce. NCHRP 500 A Guide for Addressing Collisions Involving Motorcycles: Contains many measures geared at reducing driver error and changing driver behaviour. There are fewer measures that focus on engineering strategies. The only listed proven measure is about helmet regulations. The only strategy that has been successfully tried (but not proven) is the use of warning signs to alerts motorcyclists of reduced traction and irregular roadway surfaces, for example in work zones.

4.0 DATABASE OF COLLISION REDUCTION MEASURES

From the research conducted by Opus, the collision reduction measures were divided into the seven objective areas. A spreadsheet-based MS Excel database has been prepared, called *"Collision Reduction Measure Database"* or *"CRM Database"*. This contains all the literature references and information pertaining to each. Separate worksheets in the workbook are provided for each of the seven objective areas. The information included for each measure is summarized in TABLE 4.1.

TABLE 4.1 COLLISION REDUCTION MEASURE SPREADSHEET DETAILS

Source	Indicates the document from which the information was obtained.
Objective Area(s)	Identifies which of the seven objective areas, identified in Section 1.2, the countermeasure addresses. The first column indicates the main strategy that the collision reduction measure addresses, the second column indicates the secondary strategy and the final column identifies any additional strategies that may be addressed.
Setting	Indicates the land use condition in which the collision reduction measure was evaluated, including urban only, rural only and urban and rural.
Speed	Indicates the speed zones that the countermeasure was evaluated in (50 km/h or less, 60 km/h - 70 km/h, 80 km/h - 90 km/h, 100 km/h or higher). This was generally not specified in any of the studies.
Collision Information	The collision type, severity (fatal, injury, property damage only) and anticipated collision reduction factor for each collision reduction measure are identified along with any other additional collision information.
Costs	The relative cost of implementing the collision reduction measure is identified as high, medium or low.
Proven Measure?	Based on the system used by FHWA, each collision reduction measure is identified as proven, tried or experimental. 'Proven' indicates the measure was implemented in several locations with positive results; 'Tried' indicates it was implemented, but more information is required regarding results; 'Experimental' indicates it was implemented in too few locations to determine its effectiveness.
Notes	Any additional information relevant to the collision reduction measure.

In total, 1,096 references were found for over 200 unique measures and reviewed by Opus. The breakdown by objective area is as follows:

- Speed related: 62 references
- Unsignalized intersections: 204 references
- Signalized intersections: 307 references
- Wildlife related: 27 references
- Roadways (links): 201 references
- Run-off-road related: 233 references
- Vulnerable road users: 62 references

The database is one of the deliverables Opus is submitting for this study, in addition to the required project report. While it represents a highly comprehensive compilation of references for this study, it can be treated as a living document and updated by TRANS on an ongoing basis as new measures or collision reduction factors are developed.

To support its utility and user-friendliness, the database is searchable and linkable, such that practitioners can quickly search for e.g. all "proven" measures or "rural" measures or "speed management" measures, and click on the source of the collision reduction factor to find the supporting studies that are available on the worldwide web.

The complete list of collision reduction measures identified is provided in Appendix C of this report. An example of the spreadsheet data is provided inFIGURE 4.1.

Note that although not specifically stated in most references, 'All' (in terms of collision type) is assumed to refer to collisions within the affected area only.

Countermeasure	Strategy Type #1	Strategy Type #2	Other Strategy Type (if any)	Setting	Speed (km/h) 50	60 - 70	80 - 90	> 100	Collision Types Addressed
International Road Safety Engineering Countermeasures and their Applications in the Canadian Context									
Audio Tactile Line Marking (ATLM)	**Off-road Collisions**			Rural					All
Safety Edge	**Off-road Collisions**			Rural					
Freeway Median Cable Barrier Systems	**Off-road Collisions**			Rural					Other

Collision Severity	Collision Reduction	Other Collision Information	Source	Costs	Proven Measure?	Notes
All	50%	CRF estimated was between 29% to 71% reduction, with the most likely reduction at 50%. (ICBC Study, 2002)	International Road Safety Engineering Countermeasures and their Applications in the Canadian Context - Page 33	Low	Proven	"Low Cost (i.e. <$5,000 per km)" Already used in Alberta and BC Maintenance Issues related to snow-plowing damaging the markings
		Safety effect seems to be obvious, however, no valid safety revaluation has been found. Close monitoring of the first installations will be required.	International Road Safety Engineering Countermeasures and their Applications in the Canadian Context - Page 47	Medium	Proven	"Medium Cost (i.e. $5,000 - $160,000 per km)" Successfully tested in the US
Fatality	92%	Cross-median collisions 95% of vehicles crossing into the median retained, 92% reduction in cross-median fatalities (Chandler, 2007) safety impacts of cable barrier systems on motorcyclists need further investigation	International Road Safety Engineering Countermeasures and their Applications in the Canadian Context - Page 55	Medium	Proven	"Medium Cost (i.e. $5,000 - $160,000 per km)"
Fatal + Injury	40% to 74%	40%-74% fatal and serious injury w/ cable barrier 36% fatal and serious injury w/ painted barrier reduction of 96% head-on, 17% single vehicle on 110 km/h rural highways	International Road Safety Engineering Countermeasures and their Applications in the Canadian Context - Page 80	High	Proven	"High Cost (i.e. >$160,000 per km) currently only widely implemented in Sweden increase in rear-end collisions
		40%-74% fatal and serious injury w/ cable barrier	International Road Safety Engineering			"High Cost (i.e. >$160,000 per km) currently only widely implemented in Sweden

FIGURE 4.1 SAMPLE SPREADSHEET OF COLLISION REDUCTION MEASURES

5.0 COLLISION REDUCTION MEASURE SELECTION METHODOLOGY

The research conducted by Opus identified over 200 collision reduction measures, contained in the spreadsheets in APPENDIX C. The next task was to filter these measures to extract the ones with the highest potential to target each of the objective areas.

The methodology used to filter the list of measures is described in this Section (Section 5.0), and the findings (lists of measures) are presented in Section 6.0. The selection of measures was conducted in two major stages:

Stage 1: General Effectiveness Review. The purpose of this stage was to identify the measures in literature that are proven in reducing injuries and fatalities, based on recent and specific research. This stage is further described in Section 5.1.

Stage 2: Detailed Analysis. The purpose of this stage was to further analyze the measures selected as part of the Phase 2 analysis. This included a review of the Human Factors, Alberta Applicability and Cost-Effectiveness. These analyses are described in Sections 5.2 to 5.5.

5.1 Stage 1: General Effectiveness Criteria

The measures were first filtered based on the following four criteria:

Proven: Collision reduction measures that were found to be proven effective through study. Most, but not all are proven in North America. It excludes, however, measures tried and found to be ineffective, and measures that have not yet been tried or tested.

High Severity: Only measures that were proven as moderately or highly effective in reducing the number of severe collisions (fatal and injury) were included. Collision reduction measures that only had a documented effect on property damage only collisions were excluded.

Recently Studied: Priority was given to collision reduction measures that had recent research (within the past decade, and particularly within the past five years) identifying their effectiveness. Older research may not be relevant given the changes in driver behaviour, vehicle design, engineering standards and guidelines, construction practices and traffic control devices that occur over time.

Specifically Identified: Only specific "tangible" collision reduction measures were considered. Vague improvement strategies such as "intersection improvements" were not included as they are not specific enough for evaluation and implementation. Specific measures help isolate the collision benefits come from and minimize overlapping benefits.

5.2 Stage 2: Detailed Analysis

These highly effective measures then underwent a formal evaluation of the key effectiveness criteria to estimate the overall effectiveness in Alberta. For each criterion the measures were ranked as providing a high, moderate or low benefit (with "high" being the most desirable):

Documented Injury/Fatality Reduction: In this stage, the collision reduction factors were closely analyzed with the objective of providing a more realistic assessment of the documented effectiveness. For example, collision reduction factors that applied to a larger target segment (e.g. all collisions vs. just right-turn collisions) or high severity collisions were more highly rated. Secondly, collision reduction factors with particularly high documented reductions were further researched to verify their reliability.

Human Factors Review: According to the FHWA[1], approximately 90 percent of all crashes are the direct result of driver error. The study of human factors and its role in collisions is much better understood today than it was even ten years ago. It is acknowledged that the documented reductions may not in themselves indicate the collision reduction *potential* since some human factors can be addressed through design and not others. Also, since different measures may benefit different road user groups, the human factors implications for all road user groups need to be considered. Therefore, a detailed human factors review was conducted for each of highly effective measures. The method and findings are described in Section 5.3 and the results are presented in TABLES 5.1 to 5.7. The analysis resulted in a "Human Factors Rating", included in the Section 6.0 "toolbox" tables for each measure.

Alberta Applicability Review: Each collision reduction measure was reviewed to determine how likely it is to be effective in Alberta. The criteria used to assess the applicability are discussed in Section 5.4. This resulted in an "Alberta Applicability Rating" for each measure, presented in the Section 6.0 "toolbox" tables.

[1] Intersection Safety Briefing Sheet #12 – Human Factors Issues in Intersection Safety, Federal Highway Administration and Institute of Transportation Engineers, Washington, DC, USA (2004).

The above measures led to an estimate of the overall expected effectiveness for each measure.

Benefit-Cost Review: The investment by road agencies in collision reduction measures will be based in large part on their cost-effectiveness. Therefore, a high level benefit-cost assessment was conducted for each measure. The purpose of this review was to further analyze measures with an overall rating of “medium” or “high” for prioritization. Each measure was then given a “cost-effectiveness” rating, which is considered the resultant of all of the preceding analysis. The method for this assessment is further described in Section 5.5.

Climate Change Review: In addition to the safety effectiveness and further to the requests of the Steering Committee, a high-level review of the climate change implications of implementing each measure was also conducted by the study team. Collision reduction measures that have the potential to reduce greenhouse gas emissions (such as reducing vehicle delays) could be promoted based on their environmental benefits in addition to their road safety benefits. Likewise, measures that have the potential to increase greenhouse gas emissions may not be as favourable to implement from an environmental standpoint. This analysis was not used in the prioritization of safety measures, but may be used by Alberta Transportation to further justify the funding of some of the measures.

5.3 Human Factors Review

Since collision reduction measures are only as effective as they are to the users of the road system, a human factors review was conducted to further evaluate the list of items. This analysis was conducted to better understand the:

- positive influence of each measure on the behaviours of and safer accommodation of various road user groups and profiles (e.g. increased caution, lower speeds, accommodation of aging visual limitations or slow pedestrian crossing speeds); and
- potential issues that each measure may create within the roadway environment (e.g. increased complexity, inconsistency, etc). Understanding these linkages allow us to better predict which types of measures will be most effective.

It is understood that some of these human factors issues are addressed through the identification of appropriate land use and speed environments, and through development of proper application guidelines (Phase 2 of this study) and their consistent application.

According to the recently released TRB publication *Human Factors Guidelines for Road Systems* (NCHRP 600A)[2] "design and operational solutions must be jointly developed by highway designers and traffic engineers with both totally aware and cognizant of the needs of all road users. In effect they must incorporate into their joint solutions human factors principles that are in keeping with the needs of all road users."

The human factors review methodology which has been conducted as part of this study is based on the research contained within NCHRP 600A, the *Canadian Guide to In-Service Road Safety Reviews*, and a literature review[3] conducted by FHWA. The methodology has taken into consideration the following human factors principles.

- ***Expectancy*** – Road safety is maintained when the roadway conveys messages in a clear and timely manner, and is consistent with road user expectations, i.e. it does not present surprises or contradictions. The review of this criterion took into account the principles of warning, familiar patterns and consistency. Devices that are new and unfamiliar may be rated lower. An example of a measure with a high expectancy rating is Advance Warning Flashers and other warning devices. This criterion also includes the element of "creating expectancy" of downstream features, e.g. gateway treatments to convey the need for lower speeds. Items that address driver impatience and frustration, which can lead to speeding and unsafe maneuvers were rated more highly in terms of expectancy, and items with the potential to create frustration and reduce safety further downstream were given a moderate rating.

- ***Clarity/Simplicity -*** Given the short time drivers have to process a large amount of information, road designs and traffic control devices that provide clear, accurate and unambiguous information for road users support road safety. An example of a measure that promotes simplicity is protected left-turn phases and dedicated lanes, which remove the complexity of judging gaps in traffic or competing with other movements on the approaches. Improvements to delineation and channelization are also positive. If the measure increases the driver workload, then it will be rated lower.

- ***Conspicuity* -** Vision is the most important information reception characteristics for road users. Features of vision which are related to specific design elements are listed below.
    - Visual Acuity

[2] NCHRP 600A
[3] Kludt, K., et al; *Human Factors Literature Reviews of Intersections, Speed Management, Pedestrians, Bicycles and Visibility,* FHWA-HRT-06-034, Federal Highway Administration, Washington, DC, USA (2006).

- Contrast Sensitivity
- Color Vision
- Visual Field/Peripheral Vision
- Scan Patterns
- Motion Judgment/Angular Movement
- Movement in Depth
- Visual Illusions
- Depth Perception
- Eye Movement
- Glare Sensitivity

Examples of measures with high levels of conspicuity include: illumination at crosswalks, flashing beacons, fluorescent sheeting and durable pavement markings.

- ***Sensory Influence*** **-** How roadway elements may appeal to the senses, particularly the senses other than vision (which are largely captured in the “conspicuity” criterion described below), such as sound and feel. Examples are accessible pedestrian signals, and rumble strips.

Each of the collision reduction measures was reviewed from the perspective of all road users to assess the impact of the road environment and road user characteristics on expected performance. It is noted that the review was conducted at a relatively high level, with the understanding that human factors needs to be reconsidered as part of the development of specific application guidelines for the selected measures.

For example, mass implementation of many of the collision reduction measures may dilute their effectiveness. For example, while stop ahead signs are extremely effective at stop-controlled intersections, they are most effective where there is a documented sight distance deficiency. If stop ahead signs were to be installed in advance of all stop signs, drivers may stop paying attention to the message as most stop signs were visible thus diluting its impact at the locations with sight distance restrictions.

The findings of the human factors review process are described in TABLE 5.1 to 5.7. The measures were rated as follows:

- ✓ indicates positive implications for the human factors criterion
- X indicates negative implications to the human factors criterion
- -- indicates minor or negligible implications for the human factors criterion, or non-applicability

In general, the majority of measures had positive implications for several of the criteria. In the remainder of cases, the implications were not discernable enough. In a handful of cases, the measures had a negative rating in one of the four criteria.

A combined "human factors" rating is provided for each measure, based on the summation of the specific criterion ratings in the following tables:

- If there were at least two more positives than negatives, the combined rating was "high".
- If there was one more positive than negative or they were equal, the overall rating was "moderate".
- If there were more criteria rated negative than positive, the overall rating was "low".

In cases where the measure was rated to be high for the specific target (e.g. pedestrians, major street vehicles) but lower for other road users or movements, the human factors rating was typically moderate.

The measures within each table have also been grouped into "strategies" to acknowledge that some of them address a similar issue.

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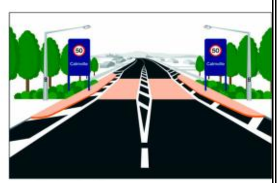
TABLE 5.1 TOP SPEED RELATED COUNTERMEASURES HUMAN FACTORS REVIEW

STRATEGY	COUNTERMEASURE	PHOTO	EXPECTANCY	SIMPLICITY / CLARITY	CONSPICUITY	SENSORY INFLUENCE	OVERALL
Transitional Measures	Gateway treatments		✓	—	✓	—	High
Measures to Reduce Design Speed	Road narrowing measures (physical or perceptual)		✓	—	✓	—	High
	Traffic calming measures		—	—	X	✓	Moderate
Perceptual Measures	Transverse pavement markings		✓	—	—	✓	High
	Three-dimensional pavement markings		—	X	✓	—	Moderate
Speed Limits	Consistent speed limits		✓	✓	—	—	High

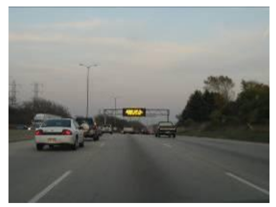
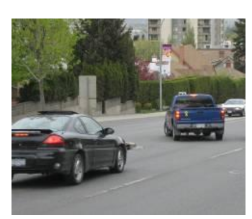
	Variable speed limits		✓	—	✓	—	High
	Variable message sign		✓	X	—	—	Moderate
	Speed Display Signs		✓	—	✓	—	High

TABLE 5.2 TOP UNSIGNALIZED INTERSECTION COUNTERMEASURES HUMAN FACTORS REVIEW

STRATEGY	COUNTERMEASURE	PHOTO	EXPECTANCY	CLARITY / SIMPLICITY	CONSPICUITY	SENSORY INFLUENCE	OVERALL RATING
Traffic Control Measures	Convert four-way stop controlled intersection to Roundabout		—	x	—	✓	Moderate
	Advance intersection warning on major road		✓	—	✓	—	High
	Convert 2-way stop control to 4-way stop control		—	x	—	—	Low
Geometric Measures	Remove obstructions within sight triangles		✓	—	—	—	Moderate
	Dedicated right-turn lanes on major road approaches		—	✓	—	—	Moderate
	Dedicated left-turn lanes on major road approaches		—	✓	—	—	Moderate

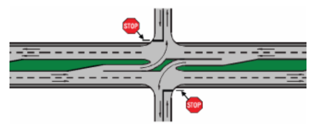
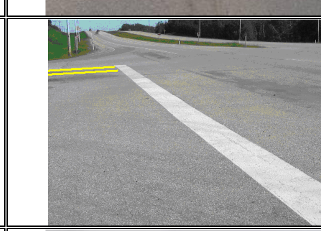
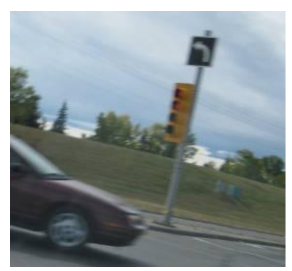
	New or upgraded intersection lighting		—	—	✓	—	Moderate
	Directionalized Median Openings		X	x	—	—	Low
Minor Approach Enhancements	Transverse rumble strips		✓	—	—	✓	High
	Flashing beacon on stop sign		✓	X	✓	—	Moderate
	STOP and STOP AHEAD pavement markings		—	—	✓	—	Moderate
	Stop bar with short segment of centreline		—	✓	—	—	Moderate
	Increase size of stop sign		—	—	✓	—	Moderate

TABLE 5.3 TOP SIGNALIZED INTERSECTION COUNTERMEASURES HUMAN FACTORS REVIEW

STRATEGY	COUNTERMEASURE	PHOTO	EXPECTANCY	CLARITY/SIMPLICITY	CONSPICUITY	SENSORY INFLUENCE	OVERALL
Traffic Operational Measures	Convert signalized intersection to Roundabout		—	X	—	✓	Moderate
	Remove unwarranted traffic signals		✓	—	X	—	Moderate
	Provide protected only left-turn phase		—	✓	—	—	Moderate
	Advance intersection warning flashers		✓	—	✓	—	High
Geometric Measures	Provide dedicated right turn lane		—	✓	—	—	Moderate

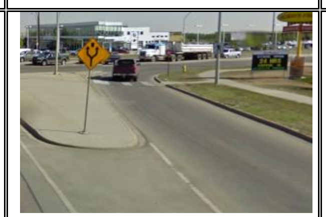
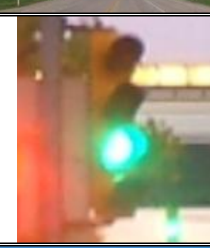
	Provide dedicated left turn lane with phasing		✓	✓	—	—	High
	Provide positive offset left-turn lanes		—	✓	✓	—	High
	Aussie Right* (channelized right-turn lane)		—	✓	✓	—	High
	New or upgraded intersection lighting		—	—	✓	—	Moderate
Signal Conspicuity Measures	Larger signal heads		—	✓	✓	—	High
	Additional primary signal heads		—	✓	✓	—	High
	Provide signal back plates (could include the addition of reflective strips)		—	✓	✓	—	High

TABLE 5.4 TOP VEHICLE-WILDLIFE COUNTERMEASURES HUMAN FACTORS REVIEW

STRATEGY	COUNTERMEASURE	PHOTO	EXPECTANCY	CLARITY / SIMPLICITY	CONSPICUITY	SENSORY INFLUENCE	OVERALL
Fencing-Based Measures	Fence with underpass/overpass		✓	—	—	—	Moderate
	Fence with gap and Wildlife Detection System		✓	X	—	—	Moderate
	Fence with gap and crosswalk		—	—	—	—	Moderate
	Fencing only (both sides)		—	—	—	—	Moderate
Warning Measures	Wildlife Detection Systems		✓	X	—	—	Moderate
	Seasonal Warning signs		✓	—	—	—	Moderate
Other Preventive Measures	Vegetation Removal		—	—	—	—	Moderate

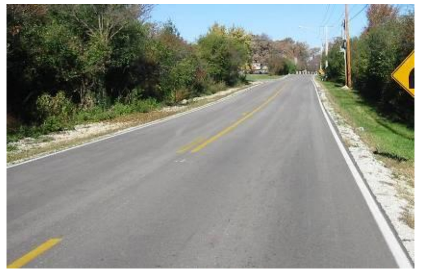
TABLE 5.5 TOP ROADWAY (LINK) COUNTERMEASURES HUMAN FACTORS REVIEW

STRATEGY	COUNTERMEASURE	PHOTO	EXPECTANCY	CLARITY/SIMPLICITY	CONSPICUITY	SENSORY INFLUENCE	OVERALL
Roadside Safety Measures	Cable barrier systems		—	—	—	—	Moderate
	Improved or added lighting.		—	—	✓	—	Moderate
Sign Enhancements	Advance curve warning signs.		✓	—	—	—	Moderate
	Increase sign retroreflectivity		—	—	✓	—	Moderate
	Linear delineation systems		—	✓	✓	✓	High
Delineation Devices	Wet Night High Visibility Pavement Markings		—	✓	✓	—	High

	Wider pavement markings (from 4" to 6")		—	✓	✓	—	High
Surface Measures	Implement maintenance and bituminous overlay.		—	—	—	—	Moderate
	Increase width of paved shoulder to four feet or greater.		—	—	—	—	Moderate
	Install centreline rumble strips.		—	—	—	✓	Moderate
School and Playground Zones	30 km/hr School and Playground zones		X	—	—	—	Low

Operational Measures	Narrow cross-section (4 to 3 lanes with two-way left-turn lane)		X	—	—	✓	Moderate
	Install passing/climbing lanes		✓	—	—	—	Moderate

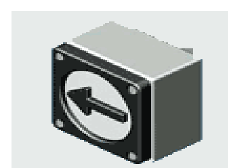
TABLE 5.6 TOP RUN-OFF-ROAD COUNTERMEASURES HUMAN FACTORS REVIEW

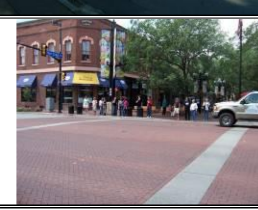
STRATEGY	COUNTERMEASURE	PHOTO	EXPECTANCY	CLARITY / SIMPLICITY	CONSPICUITY	SENSORY INFLUENCE	OVERALL
Delineation Measures	Delineators		—	✓	✓	—	High
	Edgelines and centrelines		—	✓	✓	—	High
Design Improvements	Horizontal and vertical realignments		✓	✓	—	✓	High
Surface Treatments	Shoulder and centreline rumble strips		✓	—	—	✓	High

	Increased pavement friction		—	—	—	✓	Moderate
	Audio Tactile Line Markings		✓	—	✓	✓	High
	Safety Edge		—	—	—	—	Moderate
Shoulder Improvements	Increased Shoulder Width (to four feet or greater)		—	—	—	—	Moderate
	Paved shoulder		—	—	—	—	Moderate

Roadside Protection	Median cable barrier systems		—	—	—	—	Moderate
	Impact attenuators		—	—	—	—	Moderate
	Removal of fixed objects from the clear zone		—	—	—	—	Moderate

TABLE 5.7 TOP VULNERABLE ROAD COUNTERMEASURES HUMAN FACTORS REVIEW

STRATEGY	COUNTERMEASURE	PHOTO	EXPECTANCY	CLARITY / SIMPLICITY	CONSPICUITY	SENSORY INFLUENCE	OVERALL
Traffic Signal Measures	Exclusive pedestrian phasing		—	✓	—	—	Moderate
	Pedestrian countdown signals		✓	✓	✓	—	High
	Accessible pedestrian signals		✓	✓	—	✓	High
	Puffin (Pedestrian User Friendly Intelligent) Crossing		X	—	✓	—	Moderate
	Extended Walk and Flashing Don't Walk phase		—	—	—	—	Moderate
Visibility Improvements	New or upgraded intersection lighting		✓	—	✓	—	High

	Improved sight distance to intersections with crossings		✓	—	—	—	Moderate
Dedicated Facilities	Pedestrian underpass/overpass		✓	—	—	—	Moderate
	Bicycle lanes		X	✓	✓	—	Moderate
	Sidewalk or provide paved shoulder (at least 4 feet wide) for pedestrians		✓	✓	—	—	High
	Raised median		—	✓	—	—	Moderate
	Raised pedestrian crossing		X	—	✓	✓	Moderate

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5.4 Alberta Applicability Criteria

After the review of the initial criteria, the collision reduction measures were further filtered based on their applicability (potential effectiveness) within Alberta. Measures previously tested within Alberta with positive results and measures expected to address the trends and issues outlined in Section 3.0 were given a higher priority. Five other factors were taken into consideration when determining the suitability and effectiveness of the measures in the Alberta context.

1. Cultural Considerations

- To what degree will the measure command respect, with achievable education or enforcement? Factors to consider include the industrial orientation and the higher posted speeds and driver aggressiveness that prevail in Alberta.

2. Compatibility with Standards

- Is it compatible with existing standards? If not, does it have the potential to build on existing standards?
- Is it relatively compatible with standards in the neighbouring provinces? Will it confuse or present a safety risk for drivers visiting from other provinces?
- Can it be easily retrofitted at locations?

3. Cost

- Are construction and/or maintenance costs much higher or lower in Alberta, which would significantly affect its cost-effectiveness?

4. Jurisdictional / Legislative Considerations

- Is it legally enforceable? Does it increase agency liability?
- Is it possible to provide for consistent application between highways and municipal roads, as well as adjacent provinces?
- Are there institutional issues that would limit its implementability or effectiveness?

5. Climate-Appropriateness

- Could the presence of snow and ice on the road, blizzard conditions, snow removal requirements, snow stack locations, or Alberta's freeze-thaw cycles adversely affect the performance of the countermeasure? What about the amount of sunshine, which causes both glare and fading of markings?

5.5 Expected Safety Effectiveness

As briefly described in Section 5.2, based on the review of the key criteria, an *Expected Overall Effectiveness* ranking was estimated. This overall ranking was estimated using the Documented Injury/Fatality Reduction ranking as a starting point and then adjusted upward or downward depending on the results of the Human Factors and Alberta Applicability analysis.

The *Expected Cost Effectiveness* of each measure was estimated based on the *Expected Overall Effectiveness* ranking and the range of cost. Measures that typically require widening or aligning the roadway or need to be provided over a long stretch of roadway would likely result in cost-effectiveness being *lower* than the overall effectiveness. Measures that can be easily implemented at spot locations, such as signs, transverse markings and modifications to traffic signals would likely result in a cost-effectiveness *higher* than the overall effectiveness.

The more cost effective collision reduction measures received a higher ranking. Given that the objective of this study is to identify *cost-effective* measures, it is suggested that the *Expected Cost Effectiveness* be taken as the primary indicator of the top measure, but the overall effectiveness can also be considered due to its more direct correlation with the actual impact on crashes in Alberta.

The *Expected Overall Effectiveness* and *Expected Cost Effectiveness* rankings for each countermeasure are provided in the tables for each objective area, presented in Section 6.0 of this report. Measures that rated "low" in more than two criteria were removed from the lists. Approximately 90 measures were formally evaluated, and this led to the removal of approximately 15 countermeasures (which are still included in the CRM database).

5.6 Climate Change Rating

Further to the request of the Project Steering Committee, a "Climate Change" rating was developed and evaluated for each measure. This rating is based on a very high-level analysis of the influence of the measure in promoting non-motorized travel, on vehicle delays, detours, stopping/starting (e.g. 4-way stops) and energy consumption (e.g. new lighting or traffic signals). Measures anticipated to have a negligible impact were rated as "moderate".

This rating is completely independent of the safety effectiveness ratings, and was not used in the prioritization of collision reduction measures. TRANS can use this measure as it sees fit.

6.0 TOOLBOX OF COLLISON REDUCTION MEASURES

Based on the selection criteria identified and described in Section 5.0, the top collision reduction measures for each objective area were identified. The seven tables presented in this section can be referred to as Alberta's "Toolbox" of collision reduction measures. The tables are presented in Sections 6.1 to 6.6.

All of the countermeasures have been grouped into different "strategies" to acknowledge that some of them address a similar issue. For example, increasing the size of traffic signal lenses and providing traffic signal back plates both increase the conspicuity of the traffic signals. In some instances it may be redundant and ineffective to implement all of the measures within a particular strategy as there will be some overlap in their effectiveness.

A brief summary of the appropriate application for each measure is provided along with the expected effectiveness of the measure. This will be refined during Phase 2.

A photo has been provided for each measure for clarity.

The collision reduction factors found in literature are shown, along with footnotes of the sources, where applicable or available. Collision reduction factors that are based on evidence-based research were given higher priority. Measures proven based on studies with a higher number of observations were also given a higher priority.

It should be noted that many of the top collision reduction measures are already in use in Alberta to varying degrees. The fact that a measure is widely used does not preclude it from the list. Including these measures on the list promotes their continued and possibly more widespread use.

It is noted that each of the measures in the toolbox may have non-safety implications other than the climate change implications indicated on the tables. For example, several of the measures are likely to have operational implications, such as reduced capacity or access. All speed management measures are expected to increase travel time and reduce capacity to some extent, and all measures that increase safety and capacity for left-turn movements and pedestrian movements at intersections are likely to decrease the overall *capacity* of the intersection for other movements/modes.

6.1 Speed Related Collision Reduction Measures

There is plenty of research available regarding speed related collision reduction measures. However, the majority of the research identifies the impact on vehicle speeds rather than the impact on collisions. The top measures selected were based on a proven reduction in collisions in addition to vehicle speeds. Reducing vehicle speeds and reducing collision risk are often interrelated. However, this is not always the case as reducing speed differentials is also an important factor in reducing the collision risk.

The steering committee raised the concept of uncontrolled intersections as a strategy to reduce speed related collisions. No specific research was found by the team for this measure (speed related or otherwise). The Alberta applicability of uncontrolled intersections is expected to be low, as they are not currently used. Unfamiliar drivers might assume they have the right-of-way, which could significantly increase the frequency of intersection collisions.

Posting reduced speed zones can be highly effective. However, the effectiveness strongly depends on how appropriate the posted speed is for the design speed. Studies have found that drivers tend to drive close to the design speed of a road, regardless of the posted speed limit. Therefore, motorists may not comply with posted speed limits that are not appropriate for the design speed, which may result in speed differentials.

Speed related collision reduction measures have been divided into four strategy areas:

- Transitional treatments;
- Reduced design speed;
- Perceptual devices; and
- Speed limits.

A total of 9 specific measures were identified and are summarized in TABLE 6.1.

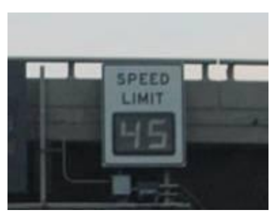
TABLE 6.1 TOOLBOX OF SPEED RELATED COLLISION REDUCTION MEASURES

STRATEGY	COLLISION REDUCTION MEASURE	PHOTO	APPLICATION	COLLISION REDUCTION FACTORS FOUND IN LITERATURE	SAFETY RATINGS *(HIGHER = BETTER)*					CLIMATE CHANGE RATING *(HIGHER = BETTER)*
					DOCUMENTED INJURY/FATALITY REDUCTION	HUMAN FACTORS RATING	ALBERTA APPLICABILITY RATING	EXPECTED OVERALL EFFECTIVENESS	EXPECTED COST EFFECTIVENESS	
Transitional Measures	Gateway treatments		▪ Consider upon entry into municipalities or from rural to more urban areas, especially if there is a reduction in posted speed limit ▪ Best applied in locations with speed transitions.	▪ 25% of all injury collisions[4] ▪ 50% of all fatal and serious injury collisions[4] TRB is doing a synthesis right now and a full research study is planned for 2010.	HIGH	high	high	HIGH	HIGH	*moderate*
Measures to Reduce Design Speed	Road narrowing measures (physical or perceptual)		▪ Typically along sections with slower posted speed limits ▪ Need to ensure adequate geometry, not increasing risk of leaving lanes ▪ Can be physical (curbs) or marked ▪ Generally easy to implement ▪ Inexpensive if done with pavement markers	▪ 5% of all collisions[5]	LOW	high	moderate	MODERATE	MODERATE	*moderate*
	Traffic calming measures		▪ Typically provided on low volume local roads in urban settings ▪ Need to ensure measures do not become fixed object risks ▪ Can be incorporated with municipal plans ▪ Speed-related benefits well documented ▪ Implemented in Alberta	▪ 5% of all collisions[5]	LOW	moderate	moderate	MODERATE	MODERATE	*low*
Perceptual Measures	Transverse pavement markings		▪ Transverse markings are placed on the roadway to give the driver the impression that their speed is increasing. ▪ Effective on the approaches to curves on both freeways and non-freeways. ▪ Typically on approaches to intersections, but can be marked on sections ▪ Varies from side hatching to bars across entire lane ▪ Generally easy to implement ▪ Inexpensive if done with pavement markers	▪ 30% of all collisions[4] ▪ 55% of all fatal and injury collisions[6] ▪ Unsuccessful in BC	MODERATE	high	moderate	MODERATE	HIGH	*moderate*

[4] International Road Safety Engineering Countermeasures and their Applications in the Canadian Context

[5] NCHRP Report 500

[6] Federal Highways Administration (FHWA), Desktop Reference for Crash Reduction Factors, Report N. FHWA-SA-08-011 (2008).

STRATEGY	COLLISION REDUCTION MEASURE	PHOTO	APPLICATION	COLLISION REDUCTION FACTORS FOUND IN LITERATURE	SAFETY RATINGS *(HIGHER = BETTER)*					CLIMATE CHANGE RATING *(HIGHER = BETTER)*
					DOCUMENTED INJURY/FATALITY REDUCTION	HUMAN FACTORS RATING	ALBERTA APPLICABILITY RATING	EXPECTED OVERALL EFFECTIVENESS	EXPECTED COST EFFECTIVENESS	
Perceptual Measures	Three-dimensional pavement markings		▪ Consists of markings that appear to be an object; makes motorists slow as if it is a potential obstacle ▪ Can be easy to implement ▪ Inexpensive	▪ Unknown (experimental)[4]	LOW	moderate	moderate	LOW	MODERATE	*moderate*
Speed Limits	Consistent speed limits		▪ Can be applied to all sections, but further study on applicability and enforcement needs to be done to ensure compliance ▪ Easy to implement ▪ Inexpensive ▪ Potential high collision reduction factor	▪ Unknown, although studies indicate consistent speeds have lower crash rates[7]	MODERATE	high	high	MODERATE	HIGH	*high*
	Variable speed limits		▪ Varies speed limit based on local- or time-specific road conditions ▪ Typically implemented with enforcement	▪ 45% of all collisions[6]	MODERATE	high	low	MODERATE	MODERATE	*moderate*
	Variable message/education sign		▪ Provides moral messages ▪ Relatively easy to implement ▪ Implemented in Alberta ▪ Can potentially have the effect of diluting other messages used for traffic management	▪ Unknown, but generally positive public feedback	LOW	moderate	high	MODERATE	LOW	*low*
	Speed feedback display board		▪ Can be permanent or portable ▪ More applicable in urban areas and work zones, but could also be used in rural areas ▪ Units require power source and regular maintenance	▪ No collision reduction rates found in literature. However, have been found to reduce vehicle speeds.	LOW	high	high	MODERATE	MODERATE	*moderate*

[7] Baruya, A.; "Speed-Accident Relationships on European Roads", 9th International Conference on Road Safety in Europe, Sept. 21-23, 1998, Germany.

6.2 Intersection Collision Reduction Measures

Due to the significant differences between signalized and unsignalized intersections and the abundance of measures in the toolbox, intersection collision reduction measures have been divided into unsignalized and signalized:

A. Unsignalized Intersection Measures

There are numerous studies available that provide evidence-based collision reduction factors for unsignalized intersection measures. Although the majority of these studies were conducted in the United States, the majority of the measures are applicable to the Alberta context. Majority of the top unsignalized intersection measures selected have been previously implemented in Alberta. A summary of the top unsignalized intersection measures is provided in TABLE 6.2. A total of 13 specific measures were identified, and represent three strategies:

- Traffic Control Measures;
- Geometric Measures; and
- Minor Approach Enhancements.

Collisions at unsignalized intersections are of higher than average severity. The potential for high severity collisions is primarily due to the risk of right-angle collisions involving high speed through traffic. Therefore, the majority of the collision reduction measures selected attempt to reduce the risk of this collision type.

Five of the highly effective measures involve alerting motorists on the stop (or yield) controlled approaches of the need to stop (or yield) to through traffic. This reduces the risk that motorists on the minor road will enter the intersection when it is unsafe.

Two of the measures (providing left and right-turn lanes) separate slower moving turning traffic and faster moving through traffic on the major road. This reduces the risk of high speed rear-end collisions and reduces the risk of unsafe turns that may result in right-angle collisions.

Three of the measures (advance warning signs, removing obstructions from within the site triangle and providing new or upgraded intersection lighting) improve the conspicuity of the intersection on both the minor and major approaches. Increasing the conspicuity of the intersections helps motorists anticipate and identify conflicting vehicles. Motorists on the minor road are more likely to stop or yield and motorists on the major road are more likely to anticipate a conflicting vehicle, such that they can take evasive action if required. Improving the sight distance to the intersection also helps traffic on the minor road identify acceptable gaps in traffic to enter or cross the major road.

Converting a two-way stop controlled intersection to a four-way stop or a roundabout represents a change in the intersection traffic control. Roundabouts have been proven to provide a significant reduction in fatal and injury collisions by reducing speeds and the risk of right-angle collisions.

Other unsignalized intersection measures were raised by the steering committee. This included implementing yield signs on all approaches to an unsignalized intersection. No research was found on the safety benefits of all-way yield control intersections, although these have been implemented in other jurisdictions. In the opinion of the Opus study team, all-way yield control intersections create more of a safety risk than a safety benefit. This traffic control scheme would not convey a clear and simple message to motorists as to who has the right-of-way at an intersection. Yield signs typically indicate that a motorist must yield to uncontrolled through traffic. This would not be the case if all approaches were yield-controlled. Although no research was found, a discussion of this issue was found on a Federal Highways Research Board forum:

(http://knowledge.fhwa.dot.gov/cops/OpsPublic.nsf/discussionDisplay?Open&id=6FC9747078874D268525724B00058391&Group=Signs&tab=DISCUSSION).

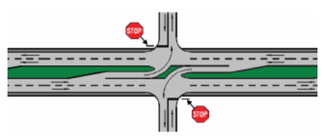
The majority of the respondents felt that all-way yield controlled intersections created a safety risk rather than a benefit.

Other measures raised in neighbouring provinces but without documented safety benefits include overhead stop signs, and flashing amber warning beacons on the major street approaches.

TABLE 6.2 TOOLBOX OF UNSIGNALIZED INTERSECTION COLLISION REDUCTION MEASURES

STRATEGY	COLLISION REDUCTION MEASURE	PHOTO	APPLICATION	COLLISION REDUCTION FACTORS FOUND IN LITERATURE	SAFETY RATINGS (*HIGHER = BETTER*)					CLIMATE CHANGE RATING (*HIGHER = BETTER)*
					DOCUMENTED INJURY/FATALITY REDUCTION	HUMAN FACTORS RATING	ALBERTA APPLICABILITY RATING	EXPECTED OVERALL EFFECTIVENESS	EXPECTED COST EFFECTIVENESS	
Traffic Control Measures	Conversion of four-way stop to roundabout		• Can be implemented in urban and rural environments. • Expensive to implement. • Should only be implemented at locations where the turning movement volumes are appropriate	• 44% of all collisions[6] • 74% of urban fatal and injury collisions[6] • 87% of rural fatal and injury collisions[6]	HIGH	moderate	moderate	HIGH	HIGH	*high*
Traffic Control Measures	Advance intersection warning on major road		• More applicable in rural areas, but can be used in urban situations • Particularly effective where stopping sight distances are limited	• 30% of all rural collisions[6]	MODERATE	high	high	HIGH	HIGH	*moderate*
Traffic Control Measures	Conversion of two-way stop to four-way stop		• Can be implemented in urban and rural environments. • Should only be implemented when warranted based on traffic volumes.	• 47% of all intersection collisions[16] • 72% of right angle collisions[12]	MODERATE	low	moderate	MODERATE	MODERATE	*low*
Geometric Measures	Removal of obstructions within sight triangles		• Can range from low cost (tree removal, parking restrictions) to high cost (road realignment). • Effective in both urban and rural contexts.	• 37% of injury collisions[8*] • 56% of fatal collisions[8*]	HIGH	moderate	high	HIGH	MODERATE	*moderate*
Geometric Measures	Dedicated right-turn lanes on major road approaches		• Separates right-turn and through traffic. • May reduce right-turn delays. • Can be implemented in urban and rural environments. • On unsignalized intersections it is suggested that offset right-turn lanes be provided as opposed to parallel right-turn lanes to reduce the potential of the shadow effect.	• 33% of all rural intersection collisions[9]	MODERATE	moderate	high	MODERATE	MODERATE	*moderate*

[8] FHWA, Signalized Intersections: Informational Guide, Report No. FHWA-HRT-04-091 (2004) (*Collision Reduction Factors based on signalized intersections. However, similar reduction factors are expected for unsignalized intersections)
[9] FHWA, Safety Effectiveness of Intersection Left- and Right-Turn Lanes, Report No. FHWA-RD-02-089 (2002).

STRATEGY	COLLISION REDUCTION MEASURE	PHOTO	APPLICATION	COLLISION REDUCTION FACTORS FOUND IN LITERATURE	SAFETY RATINGS *(HIGHER = BETTER)*					CLIMATE CHANGE RATING *(HIGHER = BETTER)*
					DOCUMENTED INJURY/FATALITY REDUCTION	HUMAN FACTORS RATING	ALBERTA APPLICABILITY RATING	EXPECTED OVERALL EFFECTIVENESS	EXPECTED COST EFFECTIVENESS	
Geometric Measures	Dedicated left-turn lanes on major road approaches		▪ Separates left-turn and through traffic. ▪ May improve intersection capacity. ▪ Can be implemented in urban and rural environments. ▪ At unsignalized intersections, left-turn lanes should at a minimum have no offset and preferably positive offset. ▪ It is suggested that negative offset left-turn lanes not be provided.	▪ 35% of rural fatal and injury intersection collisions[9] ▪ 29% of fatal and injury urban intersection collisions[9]	HIGH	moderate	high	HIGH	MODERATE	*moderate*
	New or upgraded intersection lighting		▪ Increases the visibility of the intersection and conflicting vehicles. ▪ Applicable to both rural and urban situations.	▪ 21% of all night-time collisions[10] ▪ 29% of all night-time injury collisions[10] ▪ 6% of all injury collisions[6]	MODERATE	moderate	high	MODERATE	MODERATE	*low*
	Directionalized median openings		▪ Useful tool to improve access management on urban corridors with medians. ▪ Appropriate on high speed divided expressways.	▪ 92% of all collisions[11] ▪ 100% of right-angle collisions[11] ▪ 100% of fatal/injury collisions[11]	HIGH	low	moderate	MODERATE	MODERATE	*low*
Minor Approach Enhancements	Transverse rumble strips		▪ Install on the stop-controlled approaches to intersections ▪ Applicable to rural areas away from residential dwellings ▪ Particularly effective when motorists have not been required to stop for a significant distance or where there is limited stopping sight distance. ▪ Uses sensory appeal to inform drivers that they have left the roadway.	▪ 28% of failure to stop collisions[12]	MODERATE	high	moderate	MODERATE	HIGH	*moderate*
	Flashing beacon on stop sign		▪ Applicable to isolated rural intersections ▪ Consider where there is a high frequency of failure to stop collisions. ▪ Many agencies provide black back plates on the beacon to increase conspicuity.	▪ 30% of failure to stop collisions[6]	MODERATE	moderate	high	MODERATE	HIGH	*low*

[10] National Cooperative Highway Research Program (NCHRP), Accident Modification Factors for Traffic Engineering and ITS Improvements, Report 617 (2008).

[11] Centre for Transportation Research and Education (CRTE) and Iowa Department of Transportation, The J-Turn Intersection, Design Concept Basics, (2008)

[12] Gan, A., Shan, J. and Rodriguez, A., Update of Florida Crash Reduction Factors and Countermeasures to Improve the Development of District Safety Improvement, Florida Department of Transportation (2005).

STRATEGY	COLLISION REDUCTION MEASURE	PHOTO	APPLICATION	COLLISION REDUCTION FACTORS FOUND IN LITERATURE	SAFETY RATINGS *(HIGHER = BETTER)*					CLIMATE CHANGE RATING *(HIGHER = BETTER)*
					DOCUMENTED INJURY/FATALITY REDUCTION	HUMAN FACTORS RATING	ALBERTA APPLICABILITY RATING	EXPECTED OVERALL EFFECTIVENESS	EXPECTED COST EFFECTIVENESS	
Minor Approach Enhancements	STOP and STOP AHEAD pavement markings		▪ More applicable in rural areas. ▪ Particularly effective where stopping sight distances are limited	▪ 31% of rear-end and right-angle collisions[13]	LOW	moderate	moderate	LOW	MODERATE	*moderate*
	Stop bar with short segment of centreline		▪ Applicable to urban and rural locations with paved approaches to the stop control. ▪ Identifies the ideal location for motorists to stop.	▪ 10% - 20% of all collisions[14] ▪ 47% of right-angle collisions[14]	LOW	moderate	moderate	LOW	MODERATE	*moderate*
	Increased stop sign size		▪ More applicable to rural applications. ▪ Implementation should be limited to select locations in order to increase their effectiveness.	▪ 19% of all collisions[6]	LOW	moderate	moderate	LOW	MODERATE	*moderate*

[13] FHWA, Safety Evaluation of STOP AHEAD Pavement Markings, FHWA Publication No. FHWA-HRT-08-045 (2008).

[14] Institute of Transportation Engineers, "Toolbox of Countermeasures and Their Potential Effectiveness to Make Intersections Safer." Briefing Sheet 8, ITE, FHWA, (2004)

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B. Signalized Intersection Measures

As is the case with unsignalized intersections, there are numerous evidence-based studies that provide collision reduction factors for signalized intersection measures. Again, the majority of these studies were conducted in the United States, but most are applicable to the Alberta context. All of the top signalized intersection measures selected have been previously implemented in Alberta. A summary of the top signalized intersection measures is provided in TABLE 6.3. A total of 12 specific measures were identified, in three strategic areas:

- Traffic Operational Measures;
- Geometric Measures; and
- Signal Conspicuity Measures.

Although traffic signals separate conflicting movements, there is the potential that motorists will intentionally or unintentionally disobey the traffic control. This increases the risk of high severity collisions as conflicting vehicles may be travelling at high speeds and motorists may not anticipate a conflict due to the presence of a traffic signal.

Several of the highly effective measures selected attempt to increase drivers' awareness of the intersection by providing advance warning and increasing the conspicuity of the intersection. The goal of these countermeasures is to reduce the risk of a driver failing to comply with the signal phasing (either unintentionally or deliberately).

Providing dedicated left and right-turn lanes separate slower moving turning traffic and faster moving through traffic, which reduces the risk of high speed rear-end collisions and reduces the risk of unsafe turns that may result in right-angle collisions. Providing a positive offset left-turn lane further increases the safety benefit as the sight distance for left-turn traffic is improved and the potential for inadequate gap acceptance is reduced

Providing a protected left-turn phase (either protected only or permissive/protected) also provides a safety benefit in that it reduces the risk of left-turn across path collisions, which can be severe. Providing a protected-only phase provides a much higher benefit than permissive/protected.

A common misconception is that traffic signals always improve safety at intersections. However, studies have shown that in general that where unwarranted traffic signals are installed, the collision risk increases. Therefore, removing unwarranted traffic signals can potentially reduce the frequency and severity of collisions.

Finally, converting signalized intersections to a roundabout represents a significant change in the intersection traffic control. Roundabouts have been proven to provide a significant reduction in fatal and injury collisions by reducing speeds and the risk of right-angle collisions.

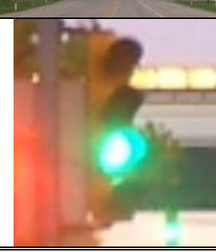
TABLE 6.3 TOOLBOX OF SIGNALIZED INTERSECTION COLLISION REDUCTION MEASURES

STRATEGY	COLLISION REDUCTION MEASURE	PHOTO	APPLICATION	COLLISION REDUCTION FACTORS FOUND IN LITERATURE	SAFETY RATINGS *(HIGHER = BETTER)*					CLIMATE CHANGE RATING *(HIGHER = BETTER)*
					DOCUMENTED INJURY/FATALITY REDUCTION	HUMAN FACTORS RATING	ALBERTA APPLICABILITY RATING	EXPECTED OVERALL EFFECTIVENESS	EXPECTED COST EFFECTIVENESS	
Traffic Operational Measures	Conversion of signalized intersection to roundabout		• Can be implemented in urban and rural environments. • Expensive to implement. • Should only be implemented at locations where the turning movement volumes are appropriate	• 40% - 48% of all collisions[15] • 78% of all fatal and injury collisions[15]	HIGH	moderate	moderate	HIGH	MODERATE	*moderate*
	Removal of unwarranted traffic signals		• Consider if traffic volumes are inappropriate for a traffic signal • ITE has a recommended practice for identifying locations for traffic signal removal. • Signing and removing unused signal heads needs to be provided as drivers may not expect the change.	• 53% of urban fatal and injury collisions[16] • 25% of all urban collisions[16]	HIGH	moderate	high	HIGH	HIGH	*high*
	Protected only left-turn phases		• Consider with high frequency of left-turn across path collisions. • Need to consider the impact on the intersection level of service. • Consider including red arrows in the top signal section to better distinguish from through signals (new US MUTCD requirement).	• 30% - 36% of all collisions[12] • 16% of urban fatal and injury left-turn across path collisions[12] • 19% of urban fatal and injury angle collisions[12]	HIGH	moderate	high	HIGH	HIGH	*low*
	Advance intersection warning flashers		• AWF are more effective: ○ where limited sight distances are available ○ on higher speed roads ○ at isolated intersections	• 18% of total collisions[17] • 44% of all fatal and injury collisions[8]	HIGH	high	high	HIGH	HIGH	*low*

15 National Cooperative Highway Research Program (NCHRP), Roundabouts in the United States, Report 572 (2007)

16 NCHRP, Crash Reduction Factors for Traffic Engineering and Intelligent Transportation System (ITS) Improvements: State-of-Knowledge Report (2005).

17 Sayed, T., Homayoun, V., Rodriguez, F., Advance Warning Flashers, Do They Improve Safety? (2000).

STRATEGY	COLLISION REDUCTION MEASURE	PHOTO	APPLICATION	COLLISION REDUCTION FACTORS FOUND IN LITERATURE	SAFETY RATINGS (*HIGHER = BETTER*)					CLIMATE CHANGE RATING (*HIGHER = BETTER*)
					DOCUMENTED INJURY/FATALITY REDUCTION	HUMAN FACTORS RATING	ALBERTA APPLICABILITY RATING	EXPECTED OVERALL EFFECTIVENESS	EXPECTED COST EFFECTIVENESS	
Geometric Measures	Dedicated right turn lane		▪ Separates right-turn and through traffic. ▪ May reduce right-turn delays. ▪ Can be implemented in urban and rural environments. ▪ Can negatively impact pedestrians by increasing crossing length.	▪ 9% of fatal and injury collisions[6] ▪ 4% - 8% of all collisions[6]	LOW	moderate	high	LOW	LOW	*moderate*
	Dedicated left turn lane with phasing		▪ Separates left-turn and through traffic. ▪ May improve intersection capacity. ▪ Can be implemented in urban and rural environments. ▪ Can be low-cost if within existing pavement width	▪ 58% all collisions[8]	HIGH	high	high	HIGH	MODERATE	*low*
	Positive offset left-turn lanes		▪ Provides better sight distances for left-turn traffic. ▪ Has been found to be extremely useful for older drivers.	▪ 34% of all collisions[18] ▪ 36% of injury collisions[15]	HIGH	high	high	HIGH	HIGH	*moderate*
	Smart Right-Turn Channel ("Aussie" Right)		▪ Reduces pedestrian crossing distance and increases pedestrian visibility ▪ Improves sight lines for turning traffic (easier to see approaching traffic) ▪ Slower speeds more appropriate for the yield controlled intersection.	▪ No quoted CRF, but recent Edmonton study shows reduction in collision rate	MODERATE	high	high	HIGH	MODERATE	*high*
	New or upgraded intersection lighting		▪ Increases the visibility of the lane configuration and conflicting vehicles.	▪ 30% of all collisions[8] ▪ 43% of fatal collisions[8] ▪ 50% of night-time collisions[8]	HIGH	moderate	high	HIGH	MODERATE	*low*
Signal Conspicuity Measures	Larger signal heads		▪ Increases the conspicuity of traffic signals ▪ Revisions to signal support may be required due to increased weight	▪ 7% of all collisions[19]	LOW	high	high	LOW	LOW	*low*

[18] FHWA, Techbrief: Safety Evaluation of Offset Improvements for Left-Turn Lanes. FHWA Publication No.: FHWA-HRT-09-036

[19] Sayed, T., et. al. "Evaluating Impact on Safety of Improved Signal Visibility at Urban Signalized Intersections", Transportation Research Record 2019 (2007).

STRATEGY	COLLISION REDUCTION MEASURE	PHOTO	APPLICATION	COLLISION REDUCTION FACTORS FOUND IN LITERATURE	SAFETY RATINGS *(HIGHER = BETTER)*					CLIMATE CHANGE RATING *(HIGHER = BETTER)*
					DOCUMENTED INJURY/FATALITY REDUCTION	HUMAN FACTORS RATING	ALBERTA APPLICABILITY RATING	EXPECTED OVERALL EFFECTIVENESS	EXPECTED COST EFFECTIVENESS	
Signal Conspicuity Measures	Additional primary signal heads		• Increases the conspicuity of traffic signals • Consider one primary signal head per lane. • Revisions to signal support may be required due to increased weight	• 10% - 25% of fatal and injury collisions[20] • 15 - 45% of all angle collisions[20]	MODERATE	high	high	MODERATE	MODERATE	*low*
	Signal back plates (could include the addition of reflective strips)		• Increases the conspicuity of traffic signals • Particularly effective where the background camouflages the signal heads.	• 32% of right-angle collisions[8]	MODERATE	high	high	MODERATE	HIGH	*moderate*

20 G.D. Hamilton Associates Consulting Ltd., Safety Benefits of Additional Primary Signal Heads (1998).

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6.3 Vehicle-Wildlife Collision Reduction Measures

The special frequencies of vehicle-wildlife collisions are highly variable in nature[21]. A successful vehicle-wildlife collision mitigation strategy requires detailed and location-specific analysis and often involves a combination of various mitigation measures. However, wildlife fences (with or without crossings) have been known to reduce vehicle-wildlife collisions substantially (over 80 percent and 94-96 percent collision reduction for large mammals and ungulates, respectively) and are among the most cost-effective measures. Nevertheless, the environmental impacts of fencing on habitat connectivity across the highway are an undesirable effect associated with this measure. In efforts to alleviate this issue, wildlife crosswalks, animal detection systems and grade-separated crossings have been used with success to facilitate connectivity across the highway.

Research, field study, and long term monitoring of measures is still required to advance the state of practice as results may be variable depending on type of problem, the species involved and local circumstances. Therefore, long term monitoring is necessary to accumulate this knowledge. The collision reduction research revealed that a number of collision reduction measures applied in the past are now considered ineffective. This includes standard deer warning signs, wildlife reflectors, and deer whistles.

A summary of the top vehicle-wildlife measures is provided in TABLE 6.4. A total of 7 measures are provided, in support of 3 strategies:

- Fencing-Based Measures;
- Warning Measures; and
- Other Preventive Measures.

The effectiveness of animal fencing is directly related to the home range of the species the fence is aimed at protecting. White-tailed deer, for example, have a relatively small home range of approximately 70 hectares, while elk are much more mobile, actively living in areas often greater than 5,000 hectares. Therefore, the effectiveness of a collision reduction measure such as animal overpasses with fencing is dependent on the length of the adjacent fencing. Analysis of the wildlife herding and migratory patterns should be completed in addition to the identification of collision trends when considering these measures.

[21] Huijser, M.P., P. McGowen, J. Fuller, A. Hardy, A. Kociolek, A.P. Clevenger, D. Smith & R. Ament. 2007. Wildlife-Vehicle Collision Reduction Study, Report to congress. U.S. Department of Transportation, Federal Highway Administration, Washington D.C., USA.

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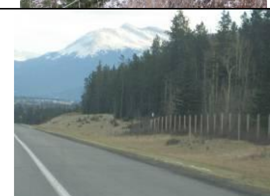
TABLE 6.4 TOOLBOX OF VEHICLE-WILDLIFE COLLISION REDUCTION MEASURES

STRATEGY	COLLISION REDUCTION MEASURE	PHOTO	APPLICATION	COLLISION REDUCTION FACTORS FOUND IN LITERATURE	SAFETY RATINGS *(HIGHER = BETTER)*					CLIMATE CHANGE RATING *(HIGHER = BETTER)*
					DOCUMENTED INJURY/FATALITY REDUCTION	HUMAN FACTORS RATING	ALBERTA APPLICABILITY RATING	EXPECTED OVERALL EFFECTIVENESS	EXPECTED COST EFFECTIVENESS	
Fencing-Based Measures	Fence with underpass/ overpass		• Consider along high volume roadways	• 80% of ungulate-vehicle collisions[22]	MODERATE	moderate	high	MODERATE	LOW	*moderate*
	Fence with gap and Wildlife Detection System		• Estimated cost $50,000 per km • Hardware must be carefully selected	• 82% of all vehicle wildlife collisions[23]	MODERATE	moderate	moderate	MODERATE	MODERATE	*moderate*
	Fence with gap and crosswalk		• Consider along lower volume roadways • Drivers may not understand the meaning of an animal crosswalk.	• 40% of all vehicle wildlife collisions[23]	MODERATE	moderate	moderate	MODERATE	LOW	*moderate*
	Fencing only (both sides)		• Provide in combination with crossings or overpasses/underpasses to prevent habitat separation • Provide escape opportunities for wildlife such as jump-out, 1-way gate • Estimated cost US$5,000 – 10,000 per km (both sides of roadway)	• 87% of all vehicle wildlife collisions[23]	MODERATE	moderate	high	MODERATE	MODERATE	*moderate*
Warning Measures	Wildlife Detection Systems		• Estimated cost US$40,000–96,000 per km	• 82% of all vehicle wildlife collisions[23]	MODERATE	moderate	moderate	MODERATE	MODERATE	*low*
	Seasonal Warning signs		• Consider at locations where wildlife migration is a factor • Warning signs must be removed outside of the migration period	• 26% of all vehicle wildlife collisions[23]	LOW	moderate	high	LOW	MODERATE	*moderate*
Other Preventive Measures	Vegetation Removal		• Consider along corridors with high incidence of vehicle-wildlife collisions along roadways where fencing is not economically feasible	• 38% of all vehicle wildlife collisions[23]	LOW	moderate	high	LOW	MODERATE	*moderate*

[22] Clevenger, A.P., Chruszcz, B. & Gunson, K. 2001. Highway mitigation fencing reduces wildlife-vehicle collisions. Wildlife Society Bulletin 29:646-653.
23 M.P. Huijser, P. McGowen, A.P. Clevenger, and R. Ament. Wildlife–vehicle Collision Reduction Study: Best Practices Manual. June 2008.

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6.4 Roadway (Link) Collision Reduction Measures

The majority of evidenced-based collision reduction factors roadway measures originate from studies based in the United States. Many of these measures, however, are highly applicable to the Alberta context. All of the top measures have been previously implemented in Alberta. A summary of 13 measures in the following 4 areas is provided in TABLE 6.5:

- Roadside Safety Measures;
- Sign Enhancements;
- Delineation Devices;
- Surface Treatments; and
- Operational Measures.

High vehicle speeds and fixed-object collisions or vehicle rollovers are common at mid-block location, and increase the risk that off-road movements will result in high severity collisions. The top roadway measures attempt to reduce vehicle speeds where required, keep motorists on the roadway and reduce the collision risk for vehicles that exit the roadway by creating a more forgiving roadside.

Three of the top measures involve improvements to the roadway surface. By providing centreline rumble strips, drivers are served with an auditory reminder that they are wandering from their lane, decreasing the risk of sideswipe and head-on collisions. Improving the friction of the roadway allows for greater control in inclement weather, reducing the risk of vehicles losing control and leaving their lane.

Collision reduction measures like median cable barriers have been proven to dramatically reduce fatalities resulting from head-on collisions.

Several measures involve either the addition of travel lanes (installing passing or climbing lanes) or their removal (road diets from four lanes to three). Passing lanes reduce driver impatience and the risk of drivers frustrated by slower moving vehicles from making risky passing manoeuvres. The removal or dieting of lanes can work to decrease mean vehicle speeds and reduce turning conflicts by providing a two-way left-turn lane.

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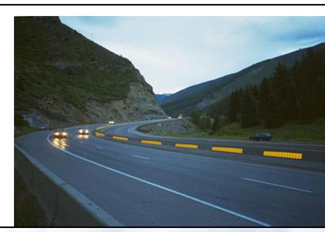
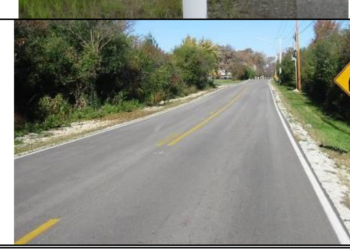
TABLE 6.5 TOOLBOX OF ROADWAY (LINK) COLLISION REDUCTION MEASURES

STRATEGY	COLLISION REDUCTION MEASURE	PHOTO	APPLICATION	COLLISION REDUCTION FACTORS FOUND IN LITERATURE	SAFETY RATINGS *(HIGHER = BETTER)*					CLIMATE CHANGE RATING *(HIGHER = BETTER)*
					DOCUMENTED INJURY/FATALITY REDUCTION	HUMAN FACTORS RATING	ALBERTA APPLICABILITY RATING	EXPECTED OVERALL EFFECTIVENESS	EXPECTED COST EFFECTIVENESS	
Roadside Safety Measures	Improved or added lighting		• urban and rural applications	• 28% to 31% reduction (injury collisions)[24] • 20% to 45% reduction (all night-time collisions)[12]	MODERATE	moderate	high	MODERATE	MODERATE	*low*
Sign Enhancements	Increased sign retroreflectivity		▪ urban and rural application (most effective in unlit areas) ▪ high benefit cost ratio	▪ 25-42% of all collisions[25]	MODERATE	moderate	high	MODERATE	HIGH	*high*
Delineation Devices	Linear delineation systems		▪ Urban and rural applications ▪ Most effective in unlit areas	▪ Studies have shown reduction in collisions. However, no formal collision reduction factors have been established.[26]	LOW	high	high	MODERATE	HIGH	*high*
	Delineator Posts		▪ Most effective on horizontal curves, but can also be used on tangent sections.	▪ 67% of head-on collisions ▪ 67% of sideswipe collisions ▪ 34% of ROR collisions ▪ 25% of night-time collisions ▪ 11% of all collisions	MODERATE	high	high	MODERATE	HIGH	*high*
	Edgelines and centrelines		▪ Urban and rural applications ▪ Defines lanes and provides delineation	▪ 24% of injury collisions	MODERATE	high	moderate	MODERATE	HIGH	*high*

24 Bahar, G., Parkhill, M., Hauer, E., Council, F., Persaud, B., Zegeer, C., Elvik, R., Smiley, A., and Scott, B. "Prepare Parts I and II of a Highway Safety Manual: Knowledge Base for Part II". Unpublished material from NCHRP Project 17-27. (May 2007)

25 Ripley, D. A., "Safety Effects of Traffic Sign Upgrades" ITE (2004)

26 Haas, Kevin. "Evaluation of 3M Scotchlite Linear Delineation System". Oregon Department of Transportation, (2004).

STRATEGY	COLLISION REDUCTION MEASURE	PHOTO	APPLICATION	COLLISION REDUCTION FACTORS FOUND IN LITERATURE	SAFETY RATINGS *(HIGHER = BETTER)*					CLIMATE CHANGE RATING *(HIGHER = BETTER)*
					DOCUMENTED INJURY/FATALITY REDUCTION	HUMAN FACTORS RATING	ALBERTA APPLICABILITY RATING	EXPECTED OVERALL EFFECTIVENESS	EXPECTED COST EFFECTIVENESS	
Delineation Devices	Wet night high visibility pavement markings		▪ More applicable to rural locations, but can also be used in urban areas. ▪ Particularly useful in dark areas, such as locations with no street or ambient lighting.	▪ No specific studies, but expected to provide at least the same collision reduction factor (24% of injury collisions) as regular pavement markings.	MODERATE	high	moderate	MODERATE	HIGH	*high*
	Wider pavement markings (from 4" to 6")		▪ Urban and rural applications	▪ 20% reduction (all injury and fatal collisions)[27]	MODERATE	high	moderate	MODERATE	HIGH	*moderate*
Surface treatments	Maintenance and bituminous overlay		▪ urban and rural applications	▪ 37% reduction (fatal and injury left-turn collisions)[12] ▪ 33% reduction (fatal and injury pedestrian collisions)[12] ▪ 31% reduction (all head-on collisions)[12] ▪ 21% reduction (fatal and injury rear-end collisions)[12] ▪ 19% reduction (fatal and injury ROR collisions)[12] ▪ 16% reduction (fatal and injury angle collisions)[12]	MODERATE	moderate	high	MODERATE	MODERATE	*moderate*
	Widen paved shoulder (to four feet or greater)		▪ rural applications only	▪ 35% reduction (all collisions)	LOW	moderate	moderate	LOW	LOW	*moderate*

[27] Midwest Research Institute and Missouri Department of Transportation, "Benefit-Cost Evaluation of MoDOT's Total Striping and Delineation Program", November 2008.

STRATEGY	COLLISION REDUCTION MEASURE	PHOTO	APPLICATION	COLLISION REDUCTION FACTORS FOUND IN LITERATURE	SAFETY RATINGS *(HIGHER = BETTER)*					CLIMATE CHANGE RATING *(HIGHER = BETTER)*
					DOCUMENTED INJURY/FATALITY REDUCTION	HUMAN FACTORS RATING	ALBERTA APPLICABILITY RATING	EXPECTED OVERALL EFFECTIVENESS	EXPECTED COST EFFECTIVENESS	
	Centreline rumble strips		▪ rural application only	▪ 18% reduction (all injury collisions)[28] ▪ 26% reduction (all head-on injury collisions)[29] ▪ 29% reduction (Head on and off road left crashes)[29] ▪ 68% reduction (all head-on fatal collisions)[29]	HIGH	moderate	high	HIGH	HIGH	*moderate*
School and Playground Zones	30 km/hr School and Playground zones		▪ urban applications only ▪ already implemented in most jurisdictions	▪ 60% reduction (all vehicular collisions)[4] ▪ 70% reduction (pedestrian and cyclist fatal and injury collisions)[4] ▪ More local studies show minimal speed and collision reductions	MODERATE	low	moderate	MODERATE	MODERATE	*moderate*
Operational Measures	Road Diets (4 to 3 lanes with two-way left-turn lane)		▪ urban application only	▪ 37% in angle collisions ▪ 31% in rear-end collisions ▪ 24% in left-turn opposing collisions ▪ 29% in all collisions	MODERATE	moderate	low	MODERATE	MODERATE	*moderate*
	Passing / climbing lanes		▪ rural applications only	▪ 25% to 35% reduction (all collisions)[30]	MODERATE	moderate	high	MODERATE	MODERATE	*moderate*

[28] Sayed, de Leur and Pump “Impact of Rumble Strips on Collision Reduction on BC Highways: A Comprehensive Before and After Safety Study”, TRB 2010 Annual Meeting

[29] Hirasawa, M., Takuda, T., Asano, M., and Saito, K., "Developing Optimal Centreline Rumble Strips and Evaluating Their Safety Benefits on National Highways in Hokkaido, Japan." 2006 TRB 85th Annual Meeting: Compendium of Papers CD-ROM, Vol. TRB#06-1968, Washington,D.C. , (2006)

[30] FHWA et. al. “Update and Enhancement of ODOT’s Crash Reduction Factors” page 29. (2006)

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6.5 Run-Off-Road Collision Reduction Measures

Several evidence-based collision reduction factors for off-road collisions were identified and all of the top run-off-road measures selected have been previously implemented in Alberta. A summary of the top run-off-road measures is provided in TABLE 6.6. 11 measures are provided in 5 strategic areas:

- Warning Devices;
- Design Improvements;
- Surface Treatments;
- Shoulder Improvements; and,
- Roadside Protection.

High severity injuries or fatalities are relatively common in off-road collisions. The presence of fixed objects and steep embankments close to the roadway can dramatically increase the severity of collisions involving vehicles leaving the roadway. Thus, the majority of the top run-off-road measures attempt to keep vehicles on the roadway and reduce the collision risk for those that travel off-road.

Three of the top collision reduction measures involve increasing the conspicuity of the roadway and its laning. Roadside delineators and prominent centreline and edgelines help to clearly define the roadway and keep vehicles in their lanes.

Five measures are related to shoulders and the clear zone. Strategies such as paving and widening shoulders aim to increase the chance of recovery for a vehicle that would otherwise leave the roadway. For motorists' that do leave the roadway, relocating fixed object hazards from within the clear zone reduces the potential severity of the collision.

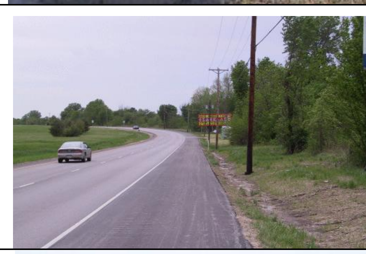
Geometric improvements, like improving the horizontal and vertical alignments of the roadway, also reduce the likelihood that a motorist will exit the roadway.

The potential benefits of Safety Rest Areas were researched in detail. However, they were not listed in any of the credible literature sources as an engineering measure. Information we reviewed from Alberta Transportation's Safety Rest Area implementation indicated a 4 percent reduction in collisions that can be expected with Safety Rest Areas, which is far lower than most of the other engineering countermeasures for off-road collisions.

However, we know that fatigue is severely under-reported as a causal factor in collisions, including fatal collisions, and that estimates by the Canadian Council of Motor Vehicle Administrators have estimated that fatigue is a contributing factor in 19% and the cause in 4% of all fatal collisions. It is noted that Alberta Transportation has a program for safety rest areas. While safety rest areas are typically regarded as more of a network planning measure than an engineering measure, we recommended that based on their potential benefits, that this program be continued and expanded, and reviewed in greater detail outside of this study.

TABLE 6.6 TOOLBOX OF RUN-OFF-ROAD COLLISION REDUCTION MEASURES

STRATEGY	COLLISION REDUCTION MEASURE	PHOTO	APPLICATION	COLLISION REDUCTION FACTORS FOUND IN LITERATURE	SAFETY RATINGS *(HIGHER = BETTER)*					CLIMATE CHANGE RATING *(HIGHER = BETTER)*
					DOCUMENTED INJURY/FATALITY REDUCTION	HUMAN FACTORS RATING	ALBERTA APPLICABILITY RATING	EXPECTED OVERALL EFFECTIVENESS	EXPECTED COST EFFECTIVENESS	
Warning Devices	Advance curve warning signs		• urban and rural applications • signs may include advisory speed tabs and/or flashing beacon	• 10% reduction (all fatal and injury collisions, sign only)[12] • 29% reduction (all head-on collisions, sign only)[12] • 30% (all ROR collisions, sign only)[12] • 13% reduction (all injury collisions, sign with advisory speed tab)[12] • 30% reduction (all collisions, sign with advisory speed tab or flashing beacon)[12]	MODERATE	moderate	high	MODERATE	HIGH	*moderate*
Design Improvements	Horizontal and vertical realignments		Urban and rural applications	▪ 73% all collisions	HIGH	high	high	HIGH	MODERATE	*moderate*
Surface Treatments	Shoulder rumble strips		▪ rural measure only	▪ 7% of ROR collisions ▪ 18% of fatal and injury ROR collisions ▪ 18% of all injury coliisions[28] ▪ 26% reduction (Off road right collisions)[28]	MODERATE	high	high	MODERATE	MODERATE	*moderate*
	Increased pavement friction		▪ overlay method	▪ 42% left-turn fatal and injury collisions ▪ 28% ROR fatal and injury collisions ▪ 19% in head-on fatal and injury collisions ▪ 12% reduction in sideswipe or rear-end fatal and injury collisions ▪ 11% in angle fatal and injury collisions	MODERATE	moderate	high	MODERATE	MODERATE	*moderate*

STRATEGY	COLLISION REDUCTION MEASURE	PHOTO	APPLICATION	COLLISION REDUCTION FACTORS FOUND IN LITERATURE	SAFETY RATINGS *(HIGHER = BETTER)*					CLIMATE CHANGE RATING *(HIGHER = BETTER)*
					DOCUMENTED INJURY/FATALITY REDUCTION	HUMAN FACTORS RATING	ALBERTA APPLICABILITY RATING	EXPECTED OVERALL EFFECTIVENESS	EXPECTED COST EFFECTIVENESS	
Surface Treatments	Audio Tactile Line Markings		▪ rural application only ▪ low cost (i.e. <$5,000 per km) ▪ already used in Alberta and BC ▪ maintenance issues related to snowplough damage	▪ 50% of all collisions	MODERATE	high	high	MODERATE	MODERATE	*moderate*
	Safety Edge		▪ rural application only ▪ Extremely effective in areas where there is no space to provide a paved shoulder.	▪ no valid safety evaluation, so first installations should be closely monitored	LOW	moderate	high	LOW	MODERATE	*moderate*
Shoulder Improvements	Increased Shoulder Width (to four feet or greater)		▪ rural applications only	▪ 35% reduction (all collisions)[31]	MODERATE	moderate	high	MODERATE	LOW	*moderate*
	Paved shoulder			▪ 15% all collisions ▪ 86% head-on collisions ▪ 62% night-time collisions	MODERATE	moderate	high	MODERATE	LOW	*moderate*

[31] Agent, K. R., Stamatiadis, N., and Jones, S., "Development of Accident Reduction Factors." KTC-96-13, Kentucky Transportation Cabinet, (1996). http://www.ktc.uky.edu/Reports/KTC_96_13.pdf

STRATEGY	COLLISION REDUCTION MEASURE	PHOTO	APPLICATION	COLLISION REDUCTION FACTORS FOUND IN LITERATURE	SAFETY RATINGS *(HIGHER = BETTER)*					CLIMATE CHANGE RATING *(HIGHER = BETTER)*
					DOCUMENTED INJURY/FATALITY REDUCTION	HUMAN FACTORS RATING	ALBERTA APPLICABILITY RATING	EXPECTED OVERALL EFFECTIVENESS	EXPECTED COST EFFECTIVENESS	
Roadside Protection	Cable barrier systems		▪ moderate cost ($5,000 - $160,000 per km) ▪ Chandler (2007) reports 95% of vehicles crossing into the median retained, with 92% reduction in cross-median fatalities. ▪ Safety impact on motorcyclists needs further investigation.	▪ 92% fatal cross-median collisions	HIGH	moderate	moderate	HIGH	HIGH	*moderate*
	Impact attenuators			▪ 75% of fatal collisions with fixed object	HIGH	moderate	high	HIGH	HIGH	*moderate*
	Removal of fixed objects from the clear zone			▪ 40-50% fatal collisions ▪ 38% fatal and injury collisions ▪ 20% urban fixed object collisions	HIGH	moderate	high	HIGH	HIGH	*moderate*

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6.6 Vulnerable Road User Collision Reduction Measures

A fair amount of research was found on pedestrians, but much less on other user groups, especially motorcyclists. There was also a general lack of evidence-based research for vulnerable road users.

A summary of the top 12 vulnerable road user collision measures is provided in TABLE 6.7 in 3 strategy areas:

- Traffic signal measures;
- Visibility improvements; and
- Dedicated facilities.

Infrastructure improvements, such as providing a pedestrian overpass/underpass, are highly effective when implemented in the appropriate application as they physically separate vehicle and pedestrian traffic. Pedestrian overpass/underpasses also have minimal impact on traffic operations, but can be very expensive to implement.

Providing dedicated facilities for vulnerable road users, such as bike lanes and sidewalks, provide a safety benefit for vulnerable road users while having a minimal impact on traffic operations. Improving the visibility of vulnerable road users though improved sight distances and new or upgraded intersection lighting reduces the collision risk for both vulnerable road users and motorists.

The collision reduction factors listed in TABLE 6.7 are for vehicle collisions involving pedestrians or bicyclists.

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TABLE 6.7 TOOLBOX OF VULNERABLE ROAD USER COLLISION REDUCTION MEASURES

STRATEGY	COLLISION REDUCTION MEASURE	PHOTO	APPLICATION	COLLISION REDUCTION FACTORS FOUND IN LITERATURE	SAFETY RATINGS *(HIGHER = BETTER)*					CLIMATE CHANGE RATING *(HIGHER = BETTER)*
					DOCUMENTED INJURY/FATALITY REDUCTION	HUMAN FACTORS RATING	ALBERTA APPLICABILITY RATING	EXPECTED OVERALL EFFECTIVENESS	EXPECTED COST EFFECTIVENESS	
Traffic Signal Measures	Exclusive pedestrian phasing		▪ Consider pedestrian demand to LOS for the intersection. ▪ Either automatic phase or done on activated demand. ▪ Can create an issue with expectancy and confusion.	▪ 34% of pedestrian collisions[6]	MODERATE	moderate	moderate	MODERATE	MODERATE	*moderate*
	Pedestrian countdown signals		▪ Set at appropriate volume to avoid noise pollution in urban areas. ▪ Low cost per signal head	▪ 25% of pedestrian collisions[6]	HIGH	high	high	HIGH	HIGH	*high*
	Accessible pedestrian signals		▪ Communicates pedestrian crossing information to the visually impaired	▪ none	LOW	high	high	LOW	LOW	*high*
	Puffin (Pedestrian User Friendly Intelligent) Crossing		▪ Urban application only ▪ Pedestrian signal mounted on same side as pedestrian ▪ Pedestrian can see both the signal and oncoming vehicles ▪ Signal visibility increased for the visually impaired	▪ 19% of all collisions[32] ▪ 27% of pedestrian collisions[32]	MODERATE	moderate	low	MODERATE	LOW	*moderate*
	Extended Walk and Flashing Don't Walk phase		▪ Particularly in areas with seniors or pedestrians with accessibility needs	▪ Not Available	LOW	moderate	high	LOW	MODERATE	*moderate*
Visibility Improvements	New or upgraded intersection lighting		▪ Increases the visibility of the intersection for motorists to see VRUs.	▪ 78% of injury pedestrian collisions[24] ▪ 42% of fatal pedestrian collisions[24]	HIGH	high	high	HIGH	MODERATE	*moderate*

[32] Routledge, I., Knight, P., Kennedy, J., "Road Safety Benefits of Puffin Facilities", TRL and IRC

STRATEGY	COLLISION REDUCTION MEASURE	PHOTO	APPLICATION	COLLISION REDUCTION FACTORS FOUND IN LITERATURE	SAFETY RATINGS (*HIGHER = BETTER*)					CLIMATE CHANGE RATING (*HIGHER = BETTER)*
					DOCUMENTED INJURY/FATALITY REDUCTION	HUMAN FACTORS RATING	ALBERTA APPLICABILITY RATING	EXPECTED OVERALL EFFECTIVENESS	EXPECTED COST EFFECTIVENESS	
Visibility Improvements	Improved sight distance to intersections with crossings		▪ Can range from low cost (tree removal) to high cost (road realignment). ▪ Effective in both urban and rural contexts. ▪ Improves visibility for all road users	▪ 49% of pedestrian collisions[14] ▪ 30% of all improper turn collisions[12]	MODERATE	moderate	high	MODERATE	MODERATE	*high*
Dedicated Facilities	Pedestrian underpass/overpass		▪ In high speed locations, with high number of pedestrian related collisions. ▪ Location where overpass does not result in significant diversion to pedestrian from their desire line	▪ 90% of pedestrian collisions[31] ▪ 90 - 100% of pedestrian and cyclist collisions[12]	HIGH	moderate	moderate	MODERATE	LOW	*moderate*
	Bicycle lanes		▪ Consider type of paint used to ensure traction is not compromised especially in wet or icy conditions. ▪ Ensure appropriate design standards and guidelines used for context sensitive solutions ▪ Ensure connectivity to cycling network	▪ 35% of all bicycle collisions[33]	MODERATE	high	moderate	MODERATE	MODERATE	*high*
	Wider sidewalk or paved shoulder (at least 4 feet wide)		▪ In areas of, or links to pedestrian demand such as schools, commercial, transit or residential areas	▪ 65 - 89% of all pedestrian collisions[12]	HIGH	moderate	high	HIGH	MODERATE	*high*
	Raised median		▪ Location of mid-block crossings compatible with pedestrian origin and destination ▪ Consider posted speed of road ▪ Do not mark crosswalks in locations where they are not warranted.	▪ 25% of all pedestrian collisions[12] ▪ 46% (marked crosswalk at unsignalized intersection)[34] ▪ 39% (unmarked crosswalk at unsignalized intersection)[34]	MODERATE	moderate	high	MODERATE	MODERATE	*high*
	Raised pedestrian crossing		▪ Location of mid-block crossings compatible with pedestrian origin and destination ▪ Consider posted speed of road	▪ 30 - 35% of fatal / injury pedestrian collisions[24] ▪ 8% of all pedestrian collisions[14]	MODERATE	moderate	moderate	MODERATE	LOW	*moderate*

[33] Rodegerdts, L. A., Nevers, B., and Robinson, B., "Signalized Intersections: Informational Guide." FHWA-HRT-04-091, (2004)

[34] Zegeer, C., Stewart, R., Huang, H., and Lagerwey, P., "Safety Effects of Marked vs. Unmarked Crosswalks at Uncontrolled Locations: Executive Summary and Recommended Guidelines," FHWA-RD-01-075, (2002).

7.0 HIGHLY EFFECTIVE COLLISION REDUCTION MEASURES

7.1 Prioritization of Highly Effective Collision Reduction Measures

The measures from the "toolboxes" in TABLES 6.1 to 6.7 that are considered the most promising, based on the rating system Opus developed, are summarized in TABLE 6.8.

TABLE 7.1 "HIGHLY EFFECTIVE" MEASURES BY PRIORITY

OBJECTIVE AREA	*Priority 1:* "High" Cost-Effectiveness *and* "High" Overall Effectiveness	*Priority 2:* "High" Cost-Effectiveness and "Moderate" Overall Effectiveness	*Priority 3:* "High" Overall Effectiveness* *and* "Moderate" Cost-Effectiveness	Number of Measures
Speed Management	• Gateway treatments	• Consistent speed limits • Transverse pavement markings	• Variable speed limits*	4
Unsignalized Intersections	• Conversion of four-way stop to roundabout • Advance intersection warning on major road	• Transverse rumble strips • Flashing beacon on stop sign	• Removal of obstructions within sight triangles • Dedicated left-turn lanes on major road approaches	6
Signalized Intersections	• Removal of unwarranted signals • Protected only left-turn phases • Advance intersection warning flashers • Positive offset left-turn lanes	• Signal back plates	• Conversion to roundabout • Dedicated left turn lane with phasing • Smart Right-Turn Channel	8
Wildlife-Related	None	None	None	0
Roadways (Links)	None	• Delineator posts • Edgelines and centrelines • Increased sign retroreflectivity • Linear delineation systems • High visibility markings • Wider markings	None	6
Off-Road Movements	• Rumble strips • Cable barrier systems • Impact attenuators • Removal of fixed objects	• Advance curve warning signs	• Horizontal and vertical realignments	6
Vulnerable Road Users	• Pedestrian countdown signals	None	• New or upgraded intersection lighting • Wider sidewalk or paved shoulder	3
TOTAL # OF MEASURES	12	12	9	33

They are prioritized as follows:

- *Priority 1*: measures rated as being "high" in terms of both cost-effectiveness *and* "overall effectiveness" (12 in total)
- *Priority 2*: measures rated as being "high" in terms of cost-effectiveness and "moderate" for overall effectiveness (12 in total)
- *Priority 3*: measures rated as being "moderate" in terms of cost-effectiveness and "high" for overall effectiveness (9 in total)

Of the 33 total measures, it is suggested that all be considered for further development and programming by road agencies in Alberta. However, to focus more immediate efforts on the most significant opportunities, it is recommended that only the Priority 1 measures be considered for further development in Phase 2 of this study. These measures may also be thought of as "quick wins". This represents a focus on the majority of fatal and severe injury collisions: *Speeds*, *Intersections* and *Run-Off-Road*.

7.2 Context Sensitive Application

Although the focus recommended for Phase 2 is the 12 *Priority 1* measures, to assist with the programming of the 33 top measures they 33 were placed into the appropriate *land use* and *speed* contexts. The purpose of distinguishing the measures in this manner is to aim for consistency with the design standard of the road and the expectation of the driver, in order to command respect, achieve compliance and maximize the benefit.

The land use contexts identified for this study are "Urban" and "Rural". For the purpose of this study, *urban* roads generally refer to low speed roads with raised curbs and *rural* roads are defined as higher speed roads with grass ditches and/or medians. While it is recognized that there are areas that contain both urban and rural characteristics, such as urban freeways with depressed medians and roadways in suburban and fringe areas, the speed limits in these areas will help dictate the appropriate application of the identified measures.

Very few of the literature sources distinguished the applicability or effectiveness of the safety measures by land use or speed context. The study team has therefore applied experience and sound engineering judgment in placing them into the land use and speed categories.

The speed limit contexts identified for this study are:

- 50 km/h or lower;
- 60 km/h to 70 km/h;
- 80 km/h to 90 km/h; and
- 100 km/h or higher.

It is acknowledged that some of the land-use speed combinations are very limited in Alberta: for example, there are few rural roads posted at 50 km/h or less, and few urban roads posted at 80 km/h or more. The exceptions are typically highways within city limits. Several of the measures are considered appropriate for several land use and speed limit combinations. TABLE 7.2 provides a list of example countermeasures by typical speed limit application.

TABLE 7.3 lists all 33 highly effective measures into applicable land use and speed categories. Analysis of TABLE 7.3 leads to the following conclusions:

- Each objective area has at least some measures that can be applied in both the urban and rural context, and in majority of the speed categories.
- Several of the identified measures are appropriate for several land use and speed limit combinations and some are applicable for ALL land use and speed combinations (such as consistent speed limits and new intersection lighting).
- Some objective areas contain measures that are more applicable in the urban and lower speed categories (e.g. signalized intersections and vulnerable road users).

TABLE 7.2 TYPICAL COUNTERMEASURES BY SPEED CATEGORY

SPEED CATEGORIES	TYPICAL COLLISION REDUCTION MEASURES
50 km/h or less	• Enhanced delineation • Road narrowing • Roundabout • Traffic calming
60 km/h to 70 km/h	• Advance curve warning signs • Clear vegetation • Exclusive turning lanes • Speed cameras
80 km/h to 90 km/h	• Advance warning flashers • Wildlife detection • Shoulder rumble strips • Improve sight distance
100 km/h or more	• Centreline rumble strips • Gateway treatment • Cable barrier systems • Pedestrian over/underpasses

TABLE 7.3 "HIGLY EFFECTIVE" MEASURES BY LAND USE AND SPEED CONTEXT

SAFETY MEASURE	URBAN SPEED LIMIT (km/h)				RURAL SPEED LIMIT (km/h)			
	<60	60-70	80-90	>90	<60	60-70	80-90	>90
Speed Management								
1. Gateway treatments							✓	✓
2. Transverse pavement markings	✓	✓	✓					
3. Consistent speed limits	✓	✓	✓	✓	✓	✓	✓	✓
4. Variable speed limits		✓	✓	✓				
Unsignalized Intersections								
5. Conversion to roundabout	✓	✓	✓	✓	✓	✓	✓	✓
6. Advance warning on major road							✓	✓
7. Transverse rumble strips							✓	✓
8. Flashing beacon on stop sign							✓	✓
9. Removal of obstructions	✓	✓	✓	✓	✓	✓	✓	✓
10.Left-turn lanes on major road	✓	✓	✓	✓		✓	✓	✓
Signalized Intersections								
11.Removal of unwarranted signals	✓	✓				✓	✓	
12.Protected only left-turn phases	✓	✓						
13.Advance warning flashers		✓					✓	
14.Positive offset left-turn lanes	✓	✓						
15. Conversion to roundabout	✓	✓			✓	✓	✓	
16. Dedicated left-turn lane / phasing	✓	✓			✓	✓	✓	
17. Signal back plates	✓	✓			✓	✓	✓	
18. Smart Right-Turn Channel	✓	✓						
Roadways (Links)								
19.Delineator posts							✓	✓
20.Edgelines and centrelines	✓	✓	✓	✓	✓	✓	✓	✓
21.Increased sign retroreflectivity	✓	✓	✓	✓	✓	✓	✓	✓
22.Linear delineation systems			✓	✓			✓	✓
23.High-visibility pavement markings	✓	✓	✓	✓	✓	✓	✓	✓
24.Wider pavement markings			✓	✓			✓	✓
Off-Road Movements								
25.Advance curve warning signs	✓	✓	✓	✓	✓	✓	✓	✓
26.Rumble strips							✓	✓
27.Cable barrier systems							✓	✓
28.Impact attenuators							✓	✓
29.Removal of fixed objects	✓	✓	✓	✓	✓	✓	✓	✓
30.Horizontal and vertical realignments	✓	✓	✓	✓	✓	✓	✓	✓
Vulnerable Road Users								
31.Pedestrian countdown signals	✓	✓	✓					
32.New/upgraded intersection lighting	✓	✓	✓	✓	✓	✓	✓	✓
33.Wider sidewalk / paved shoulder	✓	✓	✓	✓	✓	✓	✓	✓
TOTAL NUMBER OF MEASURES	19	23	17	15	14	16	27	22

Bolded items = Priority 1 Measures: High cost-effectiveness and high overall effectiveness.

7.3 Recommendations

The 33 measures listed in TABLE 7.3 are presented for further discussion, and it is recommended that specific application guidelines be prepared in Phase 2 for the Priority 1 items.

From the information collected on this during Phase 1, the measures from TABLE 7.3 expected to have the most significant impact ("high" overall effectiveness and "high" cost-effectiveness), are summarized in TABLE 7.4.

TABLE 7.4 "PRIORITY 1" COLLISION REDUCTION MEASURES FOR ALBERTA

OBJECTIVE AREA	COLLISION REDUCTION MEASURE
Speed Management	• Gateway treatments
Unsignalized Intersections	• Conversion to roundabout • Advance intersection warning on major road
Signalized Intersections	• Removal of unwarranted signals • Protected only left-turn phases • Advance warning flashers • Positive offset left-turn lanes
Off-Road Movements	• Rumble strips • Cable barrier systems • Impact attenuators • Removal of fixed objects
Vulnerable Road Users	• Pedestrian countdown signals

This Priority 1 list covers some of the most significant collision trends and issues noted in Alberta, include some of the measures that have been successfully implemented in Alberta, and introduce key opportunities to continue addressing these trends:

- *Gateway treatments* are expected to reduce speeds and collision frequency and severity not only at the transition between rural and urban areas, but within the urban area. This measure can be focused over a relatively short stretch of roadway, making it cost effective. It is noted that TRANS currently doesn't have formal application guidelines for this measure.
- *Roundabouts* have clearly proven that with careful application and design, they can yield significant reductions in injuries and fatalities, at unsignalized intersections in particular, by reducing speeds and eliminating conflict points. A policy encouraging the

extensive use of properly designed roundabouts would make a significant impact on collisions.

- Providing *Advance Intersection Warning on the Major Road* is an acknowledgement of the under-reported but significant role that inadequate gap acceptance plays in STOP sign violation crashes at highway intersections, where a significant proportion of the severe collisions in rural areas occur. Guidelines would identify the correct sign for this purpose, possibly to be supplemented by a flashing beacon.
- The *Removal of Unwarranted Traffic Signals* is a low-cost way to address high-severity rear-end collisions and right-angle collisions due to red-light violations, while the signal infrastructure may be re-used at a location where it is expected to improve safety.
- *Protected-only Left-Turn Phases* have proven to have significant reductions in high-severity left-turn collisions, which account for a significant proportion of the high-severity collisions at urban signalized intersections. Warrants may need to be revised to acknowledge the safety benefits.
- *Advance Warning Flashers* attempt to solve the problem of dilemmas on higher-speed approaches to traffic signals, significantly reducing red-light violations and rear-end collisions. Existing guidelines from TAC may be sufficient for applying AWFs.
- *Positive Offset Left-turn Lanes* improve safety at signalized or unsignalized intersections by providing a clear view on oncoming traffic and reducing severe left-turn collisions.
- *Rumble Strips*, shoulder and centreline, have shown significant reductions in off-road crashes, which accounts for majority of fatalities, by preventing off-road movements, even for impaired drivers. TRANS' policy should be reviewed to encourage more widespread application. Based on this success, extending their application to other locations, such as bridges and gore areas can be explored.
- *Cable Barrier Systems* have proven cost-effective by virtually eliminating cross-median head-on collisions. Existing guidelines for their use in Alberta can be reviewed, and opportunities to expand to other applications, such as roadside installations can be explored.
- *Impact Attenuators*, like cable barriers, can protect hazards and absorb the impact of off-road collisions.
- The *Removal of Fixed Objects* (or relocation) can prevent many fatalities, and reduce the need for other measures to protect them.
- *Pedestrian Countdown Signals* are one of the few measures proven to be effective, and guidelines for their use should be strongly encouraged to address the pedestrian fatal collisions, which account for approximately one-fourth of all fatal collisions in municipalities. Further analysis may help to verify that pedestrian collisions are clustered at signalized intersections.

It is suggested that the maximum benefit within each objective area will be attained by focusing on different strategies. For example, for off-road movements, all measures except rumble strips are in the strategy area of "Roadside Protection" (see TABLE 6.6). Therefore, it would be wise to focus on one or two of these measures. This overlap will be considered in the Cost-Benefit analysis and the Implementation Strategy in Phase 2.

It is recognized that if the above measures are applied, their benefits will typically be realized over multiple objective categories (e.g. roundabouts will both reduce speed-related and intersection collisions, and rumble strips will reduce both link and run-off-road collisions).

Further, the application guidelines developed in Phase 2 would cover the deployment of devices that may currently be in use only in limited applications (e.g. cable barrier systems extended from median to roadside protection; rumble strips extended from centreline and shoulder applications to gore and bridge applications).

8.0 SUMMARY AND NEXT STEPS

8.1 Summary

This report provides a summary of the methodology and findings of Phase 1 of the *Methods of Reducing Collisions on Alberta Roads* (MORCOAR) project. It identifies the key provincial and municipal collision trends in Alberta, describes our review of current practices in Alberta and the extensive research of recent literature. It presents:

- a comprehensive, searchable database of measures (the "CRM database");
- a "toolbox" of measures for each of the seven objective areas;
- systematic criteria for the selection of the more favourable measures (including an explicit human factors review);
- the application of these criteria to about 90 measures (resulting in the retention of 75 measures, contained in TABLES 6.1 through 6.7);
- the selection of 33 "highly effective" measures (presented in TABLES 7.1 and 7.3 and); and
- the selection of the 12 "Priority 1" measures (listed in TABLE 7.4) for immediate development and implementation.

The number of measures by objective area, as Phase 1 of the study has evolved, is summarized in TABLE 8.1.

TABLE 8.1 EVOLUTION OF PHASE 1 MEASURES BY OBJECTIVE AREA

OBJECTIVE AREA	NO. OF RESEARCH REFERENCES	NO. OF TOOLBOX MEASURES	NO. OF "HIGHLY EFFECTIVE" MEASURES	NO. OF "PRIORITY 1" MEASURES
Speed Related Measures	62	9	4	1
Unsignalized Intersection Measures	307	13	6	2
Signalized Intersection Measures	204	12	8	4
Wildlife-Vehicle Measures	27	7	0	0
Roadway (Link) Measures	201	13	6	0
Run-off-road Measures	233	11	6	4
Vulnerable Road User Measures	62	10	3	1
TOTAL	**1,096**	**75**	**33**	**12**

8.2 Next Steps

At the outset of Phase 2, a survey will be conducted of road agencies in order to confirm their experience with each of the 33 measures and the presence and status of any application guidelines that currently dictate its use. Based on this information, the list of Priority 1 measures can be refined. The scope of Phase 2 will then likely take shape as follows:

- **75 "Toolbox" Measures**: *Summarize their status* of their use in Alberta *and prepare a recommendation* on whether each measure should be newly incorporated, expanded or refined. Also, *identify the appropriate land-use and speed environment*.
- **33 "Highly Effective" Measures:** *Identify existing application guidelines* in Alberta, Canada or elsewhere that should be followed, or *identify the need to develop guidelines*. Also, *identify the specific land-use and speed limit combinations* that are appropriate for each measure. The costs and benefits and an implementation strategy will be prepared for these measures (see Tasks 2.5 and 2.6 below).
- **12 "Priority 1" Measures:** *Prepare high-level application guidelines for up to 12 of these measures* (see Task 2.3 below)

If Phase 2 proceeds, the project terms of reference specifies the following tasks:

Task 2.1: Start-up Meeting. A face-to-face start-up meeting to finalize the scope of Phase 2, including the measures and a framework and format for the development of the guidelines.

Task 2.2: Human Factors and Multi-Modal Review. Since an extensive amount of thought and analysis of human factors went into Phase 1, as agreed-upon by the Steering Committee, this task will be conducted as part of the development of guidelines for each measure (Task 2.3).

Task 2.3: Prepare Application Guidelines for Selected Measures. Application guidelines will be prepared for each of the selected measures (up to 12). This will include identifying the specific factors (in addition to land use and speed limit) that should be considered in determining the need for and the use of the measure.

Task 2.4: Progress Report and Meeting. Progress meetings will be targeted every 1-2 months.

Task 2.5: Quantify Typical Costs and Benefits. The costs and benefits of implementing the 33 "Highly Effective" measures will be quantified, to make a business case for applying them.

Task 2.6: 20-Year Implementation Strategy. The 33 measures will be divided into "quick wins", 1-7 year implementations, and 7-20 year implementations.

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APPENDIX A

STAKEHOLDER WORKSHOP PROCEEDINGS

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Methods of Reducing Collisions on Alberta Roads, August 19, 2009 Workshop
Identified Countermeasures for Consideration, in each of the seven objective areas

SPEED RELATED

Transition Areas:

- Traffic Calming
- Gateway Treatments
- Transition Speed Zones
- Traffic Signal for Speeding (used in Portugal)
- Speed Display
  - Temporary
  - Permanent
- Landscaping
- Roundabouts

Improve Roadside

- Side-slopes
- Clear zones

Access Management
Pavement Type (better friction)
Passing lanes
Road Narrowing
No Speed Limit
VMS-Moral Message
Variable Speed Limits

- Weather
- Congestion
- Real Time Speeds

Variable Speed Limits per Lane
Dummy Cameras
Synchronize Traffic Signals (ride the green wave)
Traffic Calming
On-street Parking
Context Appropriate Design Standards
Optical Speed Bars
Better Application of Speed Limits (close to design speed)
Pedestrian Countdown at Signals
Introduce Curves

SIGNALIZED INTERSECTIONS

Roundabouts
Improved Timings
Detection Systems (activated)
LED Signal Heads (snow concerns)
Protected Left Turns
Reflective Backboards
Duel Red Signal Heads
Turn Lane/Length
Slotted Left Turns
Far Left Signals
Improve Coordination
Pedestrian Signals/Ramps/Tactile Pavers/Countdowns
Swivel Base
Lens Size
Sight Distance Improvements (trees, etc.)
Pedestrian Half Signals (use pedestrian countdown)

- Confuses Traffic at Stop Control
- Problems During Peak Periods

U-turns at Signals
No Right Turn on Red
When to Use Near Side Signals

UNSIGNALIZED INTERSECTIONS

(Besides what was mentioned in signalized intersections or elsewhere):
Remove Clutter

WILDLIFE COLLISIONS

Fencing
Overpass/Underpass
Vegetation Clearing
Signs With Distance Tab
Reduced Speed Limits
Activated Warning Signs
Salt Licks (away from roads)
Animal Scarecrow
Audible Diversion
Lighting

Ineffective Measures:
- Signs
- Reflectors
- Car Whistles

URBAN AND RURAL ROAD LINKS

Rural
- Access Management
- Wet-Night Pavement Markings
- Rest Areas
- Climbing/Passing Lanes
- Centreline Rumble Strips
- Activated Overhead Warning Signs
- VHS
- Wide Medians
- Depressed vs. Raised Medians
- Medians on Curves (if cost restrictions)
- Variable Median Widths

Urban
- Wet-Night Pavement Markings
- Access Management
- Illumination
- Medians
- Advertizing/Clutter Distractions
- HOV Lanes (could create other conflicts)

RUN-OFF-ROAD

Rumble Strips
Traffic
Improve Side Slopes (>4:1)
Approach Slopes
Clear Zones
Flare Culvert Ends: Ride Over Grates
Frangible Bases
Snow Fencing (not vegetation)
Snow Maintenance

Improve Delineation

- Pavement Markings
- Delineator Posts
- Chevrons
- Curve Warning

VMS (weather conditions)

VULNERABLE ROAD USERS (Pedestrians, Cyclists, Motorcyclists)

Pedestrian Refuge Area
Clear View Fencing
Wider Sidewalks (multi-use trails)
Bike Lanes
Clear zones From Traffic
Assigning Responsibility
Pedestrian/Cyclist Grade-separated Crossings
Pedestrian/Cyclist Crossing Warning for Motorists
Smart Channels at Intersections
Adopt Slower Crossing Times (aging pedestrians)
Audible/Vibration Pedestrian Push Buttons
Tactile Pavers
Connectivity to Other Facilities and Transit
Leading Pedestrian Interval
Right Turn on Red Restrictions
Watch For Pedestrians Signs
Scramble Pedestrian Phase
Mid-block Crossings
Wide Shoulders for Cyclists (impact of rumble strips)
Pedestrian Crossing Type (flashing, zebra, signs, etc.)
Motorcyclists Don't Like

- Transverse Rumble Strips
- Cable Barriers
- Signals May Not Detect Them

Catch Basin Grates
Sharrows
Bicycle Boxes

APPENDIX B

ALBERTA-TESTED COUNTERMEASURES

Countermeasure**	Agency*	Time in Implementation	Successful in Alberta?	Before/After	Speed Category
Centerline Rumble Strips	AT (ESP & MI)	Approximately 14 years		Rumble strips are being monitored	
Shoulder Rumble Strips	AT (ESP & MI)	Approximately 14 years		Anecdotal: Assume about a 30% reduction in ROR collisions. Rumble strips are being monitored	
Modern Roundabouts	AT (ESP & MI)				
Signal Improvement (countdown for pedestrians, upgrade signals, fine tune signal timing, etc.)	AT (ESP)				
Interchanges (providing grade separation)	AT (ESP)				
Enhanced Pavement Markings (wet night, durable)	AT (ESP & MI)	Several Years	Yes	Anecdotal: Two products successful, Rainline and Pathfinder. Have been some failures with Rainline product due to improper installation. Pathfinder has performed well to date	
Enhanced Warning Signs (reflectivity, size)	AT (ESP)				
Roadway Lighting (identification lighting at isolated intersections)	AT (ESP)				
Safety Rest Areas (provide more facilities and larger parking as required)	AT (ESP & MI)				
All-weather Resource Roads	AT (ESP)				
Multi-use Pathways Across Bridges	AT (ESP)				
Animal Underpasses	AT (ESP)			Anecdotal: Some underpasses in Alberta are undergoing monitoring	

Snowplowable Pavement Markings	AT	9 years (since 2000)	Yes	The centerline markings lasted better than the shoulder markings. Products provide excellent delineation. The study is available below: http://www.transportation.alberta.ca/Content/docType241/Production/TM0206.pdf	>80 km/h
More Forgiving Barriers (flexible cable etc.)	AT				
Crashworthy Ends for Conventional Systems Instead of Turndown	AT				
Right-Turn Cut-Off Design (RT)	Edmonton	5 years	No	The City of Edmonton, Right turn alternatives for arterial intersections in the City of Edmonton, (2007) Must take into consideration different factors at each intersection. In general, the simple radius design is the preferred alternative.	60-70 km/h
Simple Radius Design (RT)	Edmonton	5 years	Yes	The City of Edmonton, Right turn alternatives for arterial intersections in the City of Edmonton, (2007) Must take into consideration different factors at each intersection. In general, the simple radius design is the preferred alternative.	60-70 km/h

Free Flow Design (RT)	Edmonton	5 years	Yes	The City of Edmonton, Right turn alternatives for arterial intersections in the City of Edmonton, (2007) Must take into consideration different factors at each intersection. In general, the simple radius design is the preferred alternative.	60-70 km/h
Western Australia Right-Turn Design (RT)	Edmonton	5 years	Yes	The City of Edmonton, Right turn alternatives for arterial intersections in the City of Edmonton, (2007) Must take into consideration different factors at each intersection. In general, the simple radius design is the preferred alternative.	60-70 km/h
Overhead Street Signs (Clearview font)	Edmonton	Ongoing		No	All
Protected left-turn	Edmonton		Yes	Anecdotal: approximately more than 90% reduction of LTAP collisions	
Dual Yield Signs on Right Turns	Edmonton		No	Anecdotal: No noticeable difference	
Roundabouts	Calgary		Yes	Anecdotal: effective, well-received	All
Portable Education Signs	Calgary		Yes	No	
Speed Limit Observation and Warning	Calgary			Anecdotal: very well-received, reduces calls from politicians, community likes to see them and be involved	
Zebra Crosswalks at all School-patrolled Crossings	Calgary			Anecdotal: well-received by schools and communities	<50 km/h, 60 km/h

Clear-view Fencing	Calgary	2-3 months	Too early to tell	Anecdotal: well-received, very effective at preventing j-walkers, need to test durability, first to be implemented in Canada	
Roadside Memorial Policy Implemented	Calgary	2-3 months	Too early to tell	No	
Intersection Illumination Improvements	Calgary			Anecdotal: difficult to measure because it was implemented over several years, was a safety-driven initiative	
Roundabouts	Strathcona County		Yes	Anecdotal: people were confused at first but now the roundabouts work well	
Quadrant Intersection	Strathcona County		Yes	Anecdotal: Improved capacity, reduced left-turn across path collisions	
Polara Pedestrian Push-Buttons at Signalized Intersections (audible)	Strathcona County			Anecdotal: blind pedestrians are happy	
Extended Walk Phases at Signalized Intersections around Homes for the Elderly	Strathcona County			Anecdotal: elderly pedestrians happy	
Red Light/Speed on Green Cameras	Strathcona County		Yes	No	
Rubberized Asphalt (increased friction)	Strathcona County		No	Anecdotal: worked out initially to increase roadway friction but didn't last because of weather conditions	
LED Lamps at Signalized Intersections	Strathcona County			No	
Fluorescent Yellow Advanced Name Signs 100s meters in Advance of Intersections	Strathcona County			Anecdotal: designed for navigation but side benefit of advanced intersection warning	
Right-turn Channels	Red Deer	Not yet implemented			

Overhead Street Name Signs with 200mm Clear View Font	Red Deer	Not yet implemented			
Increased Visibility of Signals (LED)	Red Deer	1 year	Yes	Anecdotal: Positive feedback from public	
Left-turn protected only phase	Red Deer	Varies (>10 years at some intersections)	Yes	Anecdotal: Generally are reductions in left-turn-across-path collisions, is attributed to phasing but no studies. The City of Red Deer has a warrant for installing left-turn phases, based off of Section B4.4 of the MUTCDC.	
Yellow Signal Head Backboard	Red Deer	8 years		Anecdotal: Positive feedback from public	
Operating signals for pedestrians first	Red Deer				
For Pedestrians: A light to cross. A landing to rest. A ramp to access.	Red Deer	3 years			
30-metre solid lines are painted in advance of all marked crosswalks	Red Deer				
Conducted independent safety audits for major road projects					
Chicanes	Camrose			Anecdotal: Improved Safety	
Extended Curb Faces	Camrose			No	
Roundabouts	Camrose			Anecdotal: one is aligned properly and works well, the other one is misaligned and does not work well	
Solar-powered Red Flasher and Planed Painted Lines	Camrose		Yes	Anecdotal: Reasonable effective but hard to show statistical significance, received good comments from drivers	
Reduced Speed Limits	Camrose		No	Anecdotal	

*Note: AT Alberta Transportation
ESP Engineering Strategic Plan

**Based on August 19th Workshop and calls/emails to agencies

APPENDIX C

COUNTERMEASURE SPREADSHEETS

In the interest of environmental conservation, a hard copy of APPENDIX C was not included in this bundle. APPENDIX C can be viewed in its entirety in digital format (PDF).

OPUS

- Traffic Operations
- Transportation Planning
- Road Safety Engineering
- Transit and Sustainability
- Asset Management
- Project Management