Government of Alberta
Transportation

METHODS OF REDUCING COLLISIONS ON ALBERTA ROADS

PHASE 2: PREPARATION OF APPLICATION GUIDELINES AND IMPLEMENTATION STRATEGIES

FINAL REPORT

NOVEMBER 2010

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November 2010

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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EXECUTIVE SUMMARY

1. Background and Objectives

Alberta Transportation (TRANS) commissioned Opus International Consultants (Canada) Limited (herein 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 many 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 Province is currently developing new targets for 2015 to reflect the update to Transport Canada's Road Safety Vision.

The primary objective of this project is to develop proven, 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;
- 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 less;
- 60 km/h to 70 km/h;
- 80 km/h to 90 km/h; and
- 100 km/h or more.

Phase 1 of MORCOAR identified 33 collision reduction measures as *Highly Effective Measures,* including eight of the most effective (Priority 1), for the development of more detailed guidance. This report documents the Phase 2 findings: including application guidance for these measures, the costs and benefits of each, and a suggested 20-year implementation strategy.

2. Alberta Road Agency Survey

Alberta Transportation and several municipal road agencies were contacted at the outset of Phase 2 to determine the extent to which each of the *Highly Effective Measures* are currently in use, and the effectiveness of each measure within their jurisdiction and whether the application guidance they have is sufficient. This information was used to modify and finalize the list of *Highly Effective Measures*.

3. List of Measures by Context

The 33 *Highly Effective* Measures were divided among the appropriate *land use* and *speed* contexts. The purpose of distinguishing the measures in this manner was to encourage that they be implemented in the most effective way in order to maximize their 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. *Suburban* roads were also identified as containing a hybrid of urban and rural characteristics. The speed categories are defined in Section 1 above. TABLE ES.1 lists all thirty-three measures by applicable context.

One-page guidelines were then prepared for each of the *Highly Effective Measures*. These guidelines act as 'quick references' for application guidance, costs and likely benefits. They also provide references to the best current industry application and implementation guidance. Note that of the seven objective areas; only Vehicle-Wildlife Collisions did not have any measures to be considered as highly effective, since they rarely result in human injury or fatality.

TABLE ES.1 33 HIGHLY EFFECTIVE MEASURES BY LAND USE AND SPEED CONTEXT

COLLISION REDUCTION MEASURE	URBAN SPEED LIMIT (km/h)				RURAL SPEED LIMIT (km/h)			
	≤50	60-70	80-90	≥100	≤50	60-70	80-90	≥100
Speed Management								
1. Consistent speed limits	✓	✓	✓	✓	✓	✓	✓	✓
2. Gateway treatments						✓	✓	✓
3. Transverse pavement markings	✓	✓	✓		✓	✓	✓	
4. Variable speed limits			✓	✓			✓	✓
Unsignalized Intersections								
5. Advance warning on major road							✓	✓
6. Conversion to roundabout	✓	✓	✓	✓	✓	✓	✓	✓
7. Flashing beacon on stop sign							✓	✓
8. Left-turn lanes on major road	✓	✓	✓	✓		✓	✓	✓
9. Removal of obstructions	✓	✓	✓	✓	✓	✓	✓	✓
10. Transverse rumble strips							✓	✓
Signalized Intersections								
11. Advance warning flashers		✓					✓	
12. Conversion to roundabout	✓	✓	✓		✓	✓	✓	
13. Dedicated left-turn lane / phasing	✓	✓	✓		✓	✓	✓	
14. Positive offset left-turn lanes	✓	✓	✓					
15. Protected only left-turn phases		✓	✓			✓	✓	
16. Removal of unwarranted signals	✓	✓	✓		✓	✓	✓	
17. Signal back plates	✓	✓	✓		✓	✓	✓	
18. Smart right-turn channel	✓	✓						
Off-Road Movements								
19. Advance curve warning signs				✓		✓	✓	✓
20. High-tension cable barrier systems		✓	✓	✓		✓	✓	✓
21. Horizontal and vertical realignments				✓			✓	✓
22. Impact attenuators							✓	✓
23. Removal of fixed objects		✓	✓	✓		✓	✓	✓
24. Rumble strips (shoulder/centreline)						✓	✓	✓
Roadways (Links)								
25. Delineator posts						✓	✓	✓
26. Edgelines and centrelines	✓	✓	✓	✓	✓	✓	✓	✓
27. High-visibility pavement markings	✓	✓	✓	✓	✓	✓	✓	✓
28. Increased sign retroreflectivity	✓	✓	✓	✓	✓	✓	✓	✓
29. Linear delineation systems		✓	✓	✓		✓	✓	✓
30. Wider pavement markings			✓	✓			✓	✓
Vulnerable Road Users								
31. New/upgraded intersection lighting	✓	✓	✓	✓	✓	✓	✓	✓
32. Pedestrian countdown signals	✓	✓						
33. Wider sidewalk / paved shoulder	✓	✓	✓	✓	✓	✓	✓	✓
TOTAL NUMBER OF MEASURES	19	23	17	15	14	16	27	22

4. Detailed Application Guidelines

Of the 33 *Highly Effective* Measures, eight were deemed to be the most effective (Priority 1) due to their high cost-effectiveness and high overall effectiveness. The Priority 1 measures are as follows:

- Gateway Treatments;
- Variable Speed Limits;
- Conversion of Stop-controlled Intersections to Roundabouts;
- Positive Offset Left-turn Lanes;
- Protected-only Left-turn Phasing;
- High-Tension Cable Barrier Systems;
- Removal of Fixed Objects; and,
- Pedestrian Countdown Signals.

The eight Priority 1 measures were then described in detail, with the following sub-sections:

- Background and Definitions;
- Current Status in Alberta;
- Example Applications;
- Benefits and Costs;
- Existing Application Guidance (Provincial, National and International);
- Recommended Application Guidance;
- Applicability (Land Use and Speed Context);
- Recommended Procedures and Implementation Considerations;
- Human Factors; and,
- Maintenance Considerations.

5. Benefit-Cost Evaluation

The benefits (expected collision reduction ranges for Alberta) and life-cycle costs of each of the *Highly Effective Measures* were derived, then a range of Benefit Cost Ratio (BCR) values were calculated and compared to produce an implementation strategy. The highest and lowest BCRs for each of the 33 countermeasures were determined as follows:

BCR_{Low}=Lowest Expected Benefit / Highest Expected Cost
BCR_{High}=Highest Expected Benefit / Lowest Expected Cost

The BCR range for each of the thirty-three countermeasures is provided in TABLE ES.2 by objective area.

TABLE ES.2 BENEFITS AND COSTS OF COUNTERMEASURES

Countermeasure	Benefit Range*	Annual Life Cycle Cost Range	BCR Range
Speed Management			
Consistent Speed Limits	10% - 16% of all injury collisions	$1,050 - $1,100	9.1 - 15.2
Gateway Treatments	25%-50% of serious injury/fatal collisions	$2,700 - $52,500	0.5 - 18.5
Transverse Pavement Markings	20% - 44% of all fatal and injury collisions	$4,000 - $7,000	2.9 - 11.0
Variable Speed Limits	10% - 16% of all injury collisions	$2,600 - $32,500	0.3 - 6.2
Unsignalized Intersections			
Advance Intersection Warning on Major Road	15% - 30% of all injury collisions	$1,030 - $1,160	12.9 - 29.1
Conversion of Stop Controlled Intersections to Roundabouts	57.6% - 69.6% of all fatal and injury collisions	$15,500 - $28,000	2.1 - 4.5
Dedicated Left Turn Lanes on Major Road Approaches	29% - 35% of all fatal and injury collisions	$3,000 - $7,500	3.9 - 11.7
Flashing Beacon on Stop Sign	15% - 30% of all injury collisions	$1,550 - $1,700	8.8 - 19.4
Removal of Obstructions Within Sight Triangle	20% - 37% of all injury collisions	$2,516 - 19,166	>50
Transverse Rumble Strips	10% - 22% of all injury collisions	$2,900 - $3,700	2.7 - 7.6
Signalized Intersections			
Advance Intersection Warning Flashers	20% - 44% of all injury collisions	$3,100 - $3,700	5.4 - 14.2
Conversion of Signalized Intersections to Roundabouts	30% - 62.4% of all fatal and injury collisions	$16,750 - $28,000	1.1 - 3.7
Dedicated Left-turn Lanes With Phasing	30% - 58% of all injury collisions	$3,250 - $8,000	3.8 - 17.8
Positive Offset Left-turn Lanes	20% - 40% of injury collisions	$3,500 - $8,000	2.5 - 11.4
Protected Only Left-turn Phase	8% - 16% of injury collisions	$2,515 - $2,560	3.1 - 6.4
Removal of Unwarranted Traffic Signals	25% - 53% of all injury collisions	$1,066 - $1,216	20.5 - 49.7

Signal Back Plates	15% - 32% of all injury collisions	$1,550 - $2,700	5.6 - 20.6
Smart Right-turn Channel	65% - 80% of all injury collisions	$3,250 - $5,000	13.0 - 24.6
Off-Road Movements			
Advance Curve Warning Signs	5% - 13% of all injury collisions	$1,090 - $1,240	4.0 - 11.9
Cable Barriers	15% - 35.2% reduction of run-off-road injury collisions (roadside) 36% - 72% reduction of head-on injury collisions (median)	$4,700 - $7,500	2.0 - 7.5 (roadside) 4.8 - 15.3 (median)
Horizontal and Vertical Realignments	50% - 73% of all injury collisions	$3,500 - $34,333	1.5 - 20.9
Impact Attenuators	35% - 75% of injury collisions	$5,500 - $8,500	4.1 - 13.6
Removal of Fixed Objects	15% - 30% of all injury collisions	$2,003 - $52,000	0.3 - 15.0
Shoulder Rumble Strips	10% - 18% of all injury collisions	$2,530 - $2,560	3.9 - 7.1
Centreline Rumble Strips	BCR calculations to be determined at a later date		
Roadways (Links)			
Delineator Posts	5% - 11% of all injury collisions	$1,150 - $1,200	4.2 - 9.6 (assume 10 posts)
Edgelines and Centrelines	10% - 19% of all injury collisions	$1,584 - $1,758	5.7 - 12.0
High-visibility Pavement Markings	10% - 19% of injury collisions	$1,600 - $1,800	5.6 - 11.9
Increased Sign Retroreflectivity	25% - 42% of all injury collisions	$1,100 - $1,320	18.9 - 38.2
Linear Delineation Systems	-	$1,800 - $81,500	-
Wider Pavement Markings	10% - 16% of all injury collisions	$1,600 - $1,800	5.6 - 10.0
Vulnerable Road Users			
New or Upgraded Intersection Lighting	39% - 78% of all injury collisions	$2,600 - $3,500	11.1 - 30.0
Pedestrian Countdown Signals	15% - 25% of all pedestrian collisions	$2,080 - $2,200	6.8 - 12.0
Wider Sidewalk or Paved Shoulder	65% -89% of all pedestrian collisions	$13,000 - $52,000	1.3 - 6.8 (assume 1km length)

*Note: "all" (in terms of collision type) is assumed to refer to the preventable collisions, or collisions within the affected area only: e.g. gateway treatments are only effective in the vicinity of the gateway treatment, and the reductions associated positive offset left-turn lanes refer only to left-turn collisions in the direction of application.

6. Implementation Strategy

An implementation strategy was developed to facilitate the timely and optimal implementation of the highly effective measures identified in this study. Implementability depends on numerous factors, and is presented for the consideration of each agency and for discussion between agencies. Three time frames were identified at the outset of the study (Immediate, 1-7 years, and 7-20 years).

The following countermeasures are recommended for implementation in the immediate time frame ("quick wins"):

Speed Management:	*Consistent Speed Limits*
Signalized Intersections:	*Removal of Unwarranted Traffic Signals; Smart Right-Turn Channels*
Unsignalized Intersections:	*Removal of Sight Obstructions; Advance Intersection Warning on Major Road; Flashing Beacon on Stop Sign*
Roadways (Links):	*Edgelines and Centrelines*
Run-off-Road:	*Cable Barriers*
Vulnerable Road Users:	*New or Upgraded Intersection Lighting; Pedestrian Countdown Signals*

The 1 – 7 year strategies are as follows, by each objective area:

Speed Management:	*Gateway Treatments, Transverse Pavement Markings; Variable Speed Limits*
Unsignalized Intersections:	*Dedicated Left-Turn Lanes; Transverse Rumble Strips; Conversion to Roundabouts*
Signalized Intersections:	*Signal Back Plates; Advance Warning Flashers; Dedicated Left Turn Lanes and Phasing; Positive Offset Left-Turn Lanes; Protected-only Left-Turn Phasing*
Roadways (Links):	*Increased Sign Retro-reflectivity; High Visibility Pavement Markings; Wider Pavement Markings*
Run-off-Road:	*Impact Attenuators, Curve Warning Signs; Rumble Strips (shoulder/centreline)*
Vulnerable Road Users:	*Wider Sidewalks or Paved Shoulders*

The measures identified for implementation in the longer term (7 to 20 years) are as follows:

Speed Management:	none
Unsignalized Intersections:	none
Signalized Intersections:	*Conversion to Roundabouts*
Roadways (Links):	*Linear Delineation Systems, Delineator Posts*
Run-off-Road:	*Horizontal and Vertical Realignments; Removal of Fixed Objects*
Vulnerable Road Users:	none

The success of several of the measures will depend on the level of public education delivered and the extent of enforcement conducted. Legislative changes may also be required to enforce some of the recommended countermeasures.

The success of any collision reduction initiatives can only be assessed if a clear and effective monitoring and evaluation plan is put into place. It is suggested that *fatal and injury collisions* be used as the primary source of data, to measure the success of implementing the measures identified in this study.

While activities should be monitored on an ongoing basis, it is recommended that the effectiveness of the enhancements be formally evaluated at pre-determined intervals:

Quick wins: after one year and subsequently every three years thereafter;

1-7 Year Strategies: within three years, and then within seven years of implementation; and,

7-20 Year Strategies: formal evaluations should be conducted every three years.

7. Next Step and Possible Further Work

To maximize the value of this study, TRANS and the Engineering Committee can consider the following follow-up actions:

- Circulate study deliverables to road agencies;
- Provide training to industry and stakeholders in Alberta;
- Incorporate measures into existing processes and budgets;
- Adapt guidelines to current policies and standards; and,
- Set up evaluation and monitoring program.

Subsequent to (or in parallel with) the above "next steps", TRANS and the Engineering Committee may consider the following work items, either internally or through engaging a qualified consultant:

- Conduct another agency survey to prioritize the need for detailed guidance for other 25 Highly Effective Measures;
- Develop application guidance for other HEMs;
- Initiate the development of national guidance;
- Provide updates as important new guidance gets released;
- Prepare supporting implementation guidance;
- Incorporate new HSM information and new Canadian CMFs;
- Prepare Alberta-specific collision prediction models; and,
- Conduct another comprehensive MORCOAR study in 5 years (2015), to capture new national and provincial priorities and 2020 targets.

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1.0 INTRODUCTION

1.1 Study Background

The Alberta Traffic Safety Plan (ATSP), first published in 2006, outlines 2010 collision reduction targets for the Government of Alberta and identifies a wide range of traffic safety strategies to meet these targets. The Traffic Safety Action Plan (2007) identifies short-term activities and strategic objectives, focused on the improvement of Alberta'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 ATSP.

Alberta Transportation (TRANS) commissioned Opus International Consultants (Canada) Limited (herein referred to as Opus) to investigate and develop methods (engineering measures and strategies) to address the collision patterns on all Alberta highways and streets. These roadways are operated by many 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 ATSP, 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 ATSP is currently being updated to indicate priorities and targets for the next few years, in support of Transport Canada's updated Road Safety Vision.

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 ATSP. 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. Seven "objective areas" have been clearly defined. Due to the differences in measures for signalized and unsignalized intersections, these have been separated into two, for a total of seven objective areas.

- 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 less;
- 60 km/h to 70 km/h;
- 80 km/h to 90 km/h; and
- 100 km/h or more.

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 2 final report. This report presents recommended guidelines and outlines an implementation strategy.

- Section 2.0 presents a revised version of the list of the 33 *Highly Effective Measures* generated in Phase 1, and basic application guidance for each;
- Section 3.0 provides detailed application guidance for the 8 measures considered to be the most effective and in need of guidance;
- Section 4.0 ranks the 33 measures based on a benefit-cost analysis;
- Section 5.0 provides a 20-year implementation strategy; and,
- Section 0 identifies further work to build on this study and achieve success.

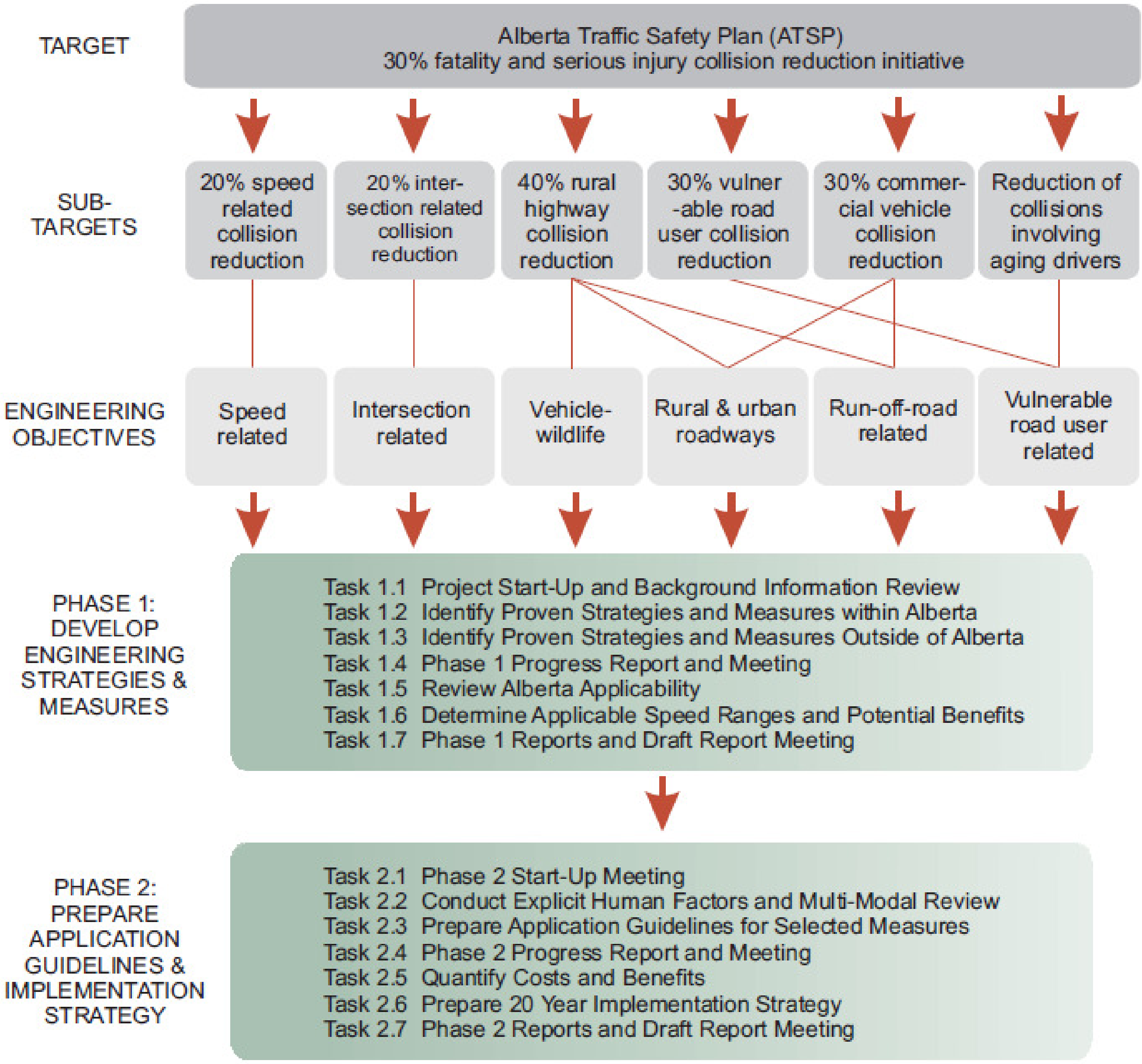

FIGURE 1.1 STUDY OBJECTIVES, PHASES AND TASKS

2.0 HIGHLY EFFECTIVE MEASURES

In Phase 1 of *MORCOAR*, 33 collision reduction measures as *Highly Effective Measures* were selected based on the evaluation of a much longer list of measures. Section 2.1 presents the results of a survey of Alberta road agencies regarding the use and effectiveness of these measures. Section 2.2 lists the 33 measures by land use and speed context. Section 2.3 contains basic application guidance for each of the 33 *Highly Effective Measures*.

2.1 Alberta Road Agency Survey

Alberta Transportation and a handful of municipal road agencies were contacted in order to determine which of the *Highly Effective Measures* they currently use, the extent of their application, guidelines dictating their application, and their measured (or perceived) effectiveness. The agencies contacted are as follows:

- Alberta Transportation;
- The City of Calgary;
- The City of Edmonton; and
- Strathcona County.

It was evident from the survey that:

- There is a wide variety in current practices, which presents an excellent opportunity for the sharing of knowledge and information between agencies.
- Most municipalities follow *Transportation Association of Canada* practices, which in most cases differ from Provincial practices. This can present challenges in design consistency between highways and municipal roads.
- Some of the current practices are currently internal documents, which contain more context-sensitive guidance than provincially or nationally published guidance.
- The performance of most measures has generally not been formally evaluated.

The survey responses indicated the following:

- Physical or perceptual road narrowings, transverse pavement markings and gateway treatments all help to lower speeds;
- The consistent application of speed limits was viewed anecdotally as being highly effective;

- Limited guidance for the conversion of intersections to roundabouts limits installation, in spite of the high collision reduction potential;
- Warning signs used by all agencies based on existing guidelines or 'as needed';
- The removal of sight obstructions near intersections is already practiced regularly;
- 'Smart' right turn channels considered successful based on recent pilots in Edmonton;
- Current guidance for positive offset left turn lanes is inadequate;
- Protected only left turn phases are viewed as highly successful;
- Wildlife fencing and overpasses are considered too expensive;
- Rumble strips (shoulder and centreline) are of limited use in urban areas;
- Cable barriers and linear delineation systems have potential, but guidelines insufficient;
- Increased sign retroreflectivity is deemed effective;
- Painted edgelines and centrelines both seen as highly effective, and widely used;
- Guidance for the removal of fixed objects was found to be lacking; and,
- Most agencies would welcome additional guidelines for pedestrian countdown signals.

The full results of the survey are provided in APPENDIX A.

2.2 List of Measures by Context

As the starting point for context sensitive application, the appropriate *land use* and *speed* contexts for the 33 *Highly Effective* Measures were identified. It is surmised that applications within these contexts will be more effective and encourage greater consistency for road users.

The land use contexts identified for this study are "Urban" and "Rural". For the purpose of this study, *urban* roads generally refer to lower speed roads with urban cross sections (e.g. curb and gutter) and *rural* roads are defined as higher speed roads with grass ditches and/or medians. TABLE 2.1 lists the 33 measures by context.

The check marks (✓) indicate the contexts with the best applications, based on literature and experience. However, they may also be considered on a case-by-case basis for other contexts, where unique circumstances exist or other measures have already been tried unsuccessfully. The speed and land use contexts for each measure are further discussed in Section 2.3 in this report.

TABLE 2.1 33 HIGHLY EFFECTIVE MEASURES BY LAND USE AND SPEED CONTEXT

COLLISION REDUCTION MEASURE	URBAN SPEED LIMIT (km/h)				RURAL SPEED LIMIT (km/h)			
	≤50	60-70	80-90	≥100	≤50	60-70	80-90	≥100
Speed Management								
1. Consistent speed limits	✓	✓	✓	✓	✓	✓	✓	✓
2. Gateway treatments						✓	✓	✓
3. Transverse pavement markings	✓	✓	✓		✓	✓	✓	
4. Variable speed limits			✓	✓			✓	✓
Unsignalized Intersections								
5. Advance warning on major road							✓	✓
6. Conversion to roundabout	✓	✓	✓	✓	✓	✓	✓	✓
7. Flashing beacon on stop sign							✓	✓
8.Left-turn lanes on major road	✓	✓	✓	✓		✓	✓	✓
9. Removal of obstructions	✓	✓	✓	✓	✓	✓	✓	✓
10. Transverse rumble strips							✓	✓
Signalized Intersections								
11.Advance warning flashers		✓					✓	
12. Conversion to roundabout	✓	✓	✓		✓	✓	✓	
13. Dedicated left-turn lane / phasing	✓	✓	✓		✓	✓	✓	
14.Positive offset left-turn lanes	✓	✓	✓					
15.Protected only left-turn phases		✓	✓			✓	✓	
16.Removal of unwarranted signals	✓	✓	✓		✓	✓	✓	
17. Signal back plates	✓	✓	✓		✓	✓	✓	
18. Smart right-turn channel	✓	✓						
Off-Road Movements								
19.Advance curve warning signs				✓		✓	✓	✓
20.High-tension cable barrier systems		✓	✓	✓		✓	✓	✓
21.Horizontal and vertical realignments				✓			✓	✓
22.Impact attenuators							✓	✓
23.Removal of fixed objects		✓	✓	✓		✓	✓	✓
24. Rumble strips (shoulder/centreline)						✓	✓	✓
Roadways (Links)								
25.Delineator posts						✓	✓	✓
26.Edgelines and centrelines	✓	✓	✓	✓	✓	✓	✓	✓
27.High-visibility pavement markings	✓	✓	✓	✓	✓	✓	✓	✓
28.Increased sign retroreflectivity	✓	✓	✓	✓	✓	✓	✓	✓
29.Linear delineation systems		✓	✓	✓		✓	✓	✓
30.Wider pavement markings			✓	✓			✓	✓
Vulnerable Road Users								
31.New/upgraded intersection lighting	✓	✓	✓	✓	✓	✓	✓	✓
32.Pedestrian countdown signals	✓	✓						
33.Wider sidewalk / paved shoulder	✓	✓	✓	✓	✓	✓	✓	✓
TOTAL NUMBER OF MEASURES	19	23	17	15	14	16	27	22

2.3 Basic Application Guidance

This section provides basic application guidance for the 33 *Highly Effective Measures* by objective area. This guidance was designed to provide practitioners a quick reference to determine the suitability of the measure for the range of Alberta road contexts. Each measure is presented in a one-page, easy to follow format, containing:

- A photo that illustrates the measure;
- An "objective" that briefly explains what the measure is supposed to do, i.e. what problem it is trying to solve and how, in human factors terms, it attempts to do this;
- Application guidance that describes the circumstances in which to apply the measure;
- The applicable land use and posted speed categories;
- The status of the use of the measure in Alberta, based on the road agency survey;
- The documented collision reductions (injury reductions where available), based on experience in Alberta or other jurisdictions, and the benefit range derived from this study is also provided in *italics*;
- Typical installation costs (construction and operational), separately for new and retrofit situations – methodology is explained in Section 4.2, and cost details are provided in APPENDIX B;
- Further guidance: where further detailed application and implementation guidance can be found; and,
- Other highly effective strategies and enhancements that can be considered to address similar issues, or to further enhance the effectiveness of the measure.

For the eight measures that the Project Steering Committee agreed require additional guidance, links to the more detailed guidance is provided on the one-page summaries.

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BASIC APPLICATION GUIDELINES FOR SPEED RELATED COLLISION REDUCTION MEASURES

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Consistent Speed Limits

Land Use

Urban	√
Suburban	√
Rural	√

Posted Speeds

≤50 km/h	√
60-70 km/h	√
80-90 km/h	√
≥100 km/h	√

Alberta Status

	N	L	C	P
Large Municipalities			√	√
Small Municipalities		√		
Highways			√	√

N=None; L=Limited; C=Common; P=Proven

Application Guidance

Objective: **to consistently apply regulatory speed limits throughout a road network to better reflect the design speed and the inherent risks, as well as to increase motorist compliance, reduce speed variance and reduce collision severity.**

Speed limits should be established based on the following principles for a road segment:

- Horizontal alignment
- Average lane width
- Roadside hazards
- Pedestrian and cyclist exposure
- Pavement surface
- Intersections and driveways
- On-street parking

A systematic method for incorporating these criteria to arrive at a speed limit value is provided in the TAC *Guidelines for Establishing Posted Speed Limits*. The determined value should be compared with the prevailing 85th percentile speed, if known.

This measure is relatively easy to implement, but may also require road agencies to review their speed limit setting policies and bylaws.

Documented Benefits

Unknown CRF, although studies have shown consistent speeds have lower crash rates[1]

10% - 16% of all injury collisions

Typical Installation Cost

	Units	Cost Range*	
		Low	High
Retrofit	Each	$25	$500
Ne	-	-	-

*New projects should not result in any additional capital costs.

Further Guidance

MUTCDC [Section A2.3]

TAC Canadian Guidelines for Establishing Posted Speed Limits

Other Effective Strategies and Enhancements

- Gateway treatments
- Transverse pavement markings
- Variable speed limits
- Revise speed limit policy

[1] Garber, NJ and R Gadirau (1988). Speed Variance and its Influence on Accidents. AAA Foundation for Traffic Safety, Washington DC.

Gateway Treatments

Land Use

Urban	
Suburban	√
Rural	√

Posted Speeds

≤50 km/h	
60-70 km/h	√
80-90 km/h	√
≥100 km/h	√

Alberta Status

	N	*L*	*C*	*P*
Large Municipalities		√		
Small Municipalities	√			
Highways	√			

N=None; L=Limited; C=Common; P=Proven

Application Guidance

Objective: **to define and emphasize the transition between a higher-speed and lower-speed environment.**

Gateway Treatments are more common outside of Canada, and there is no specific guidance for their application within Canada. Detailed guidelines have been prepared in the document *Application Guidelines for Gateway Treatments* as part of the study on *Methods of Reducing Collisions on Alberta Roads (Section 3.1).* Gateway treatments are encouraged:

- Where there is a transition in the land use (rural to suburban, or suburban to urban;
- Where the speed limit changes by 20 km/h or more;
- Where collisions are concentrated near this transition (including collisions involving vulnerable road users);

The detailed application guidelines provide guidance on the various types of gateway treatments for each land-use and speed limit category. In general, the effectiveness of a gateway treatment is maximized when it contains a combination of both horizontal and vertical features. They also contain a number of implementation details, including instructions for the placement of gateway treatments.

Documented Benefit

25% of all injury collisions[2]

50% of all fatal and serious injury collisions[2]

25%-50% of serious injury/fatal collisions

Typical Installation Cost

	Unit	Cost Range*	
		Low	High
Retrofit	each	$2000	$500,000
New	each	$2000	$500,000

*Large cost ranges due to variability of treatment types.

Further Guidance

FHWA *Determining Effective Roadway Design Treatments for Transitioning from Rural Areas to Urban Areas on State Highways* (2008)

LTSA *Guidelines for Urban-Rural Speed Thresholds RTS 15* (2002)

Other Effective Strategies and Enhancements

- New or upgraded intersection lighting
- Advance intersection warning on major road
- Transverse pavement markings
- Wider Sidewalk or Paved Shoulder
- Conversion of Signalized Intersection to a Roundabout
- Conversion of Unsignalized Intersection to a Roundabout

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[2] Wheeler, A.H. and Taylor M.C. Accident reduction resulting from village traffic calming, European Transport Conference, Cambridge. Proc. Seminar J. Assoc. for European Transport, 2000.

Transverse Pavement Markings

Land Use

Urban	√
Suburban	√
Rural	√

Posted Speeds

≤50 km/h	√
60-70 km/h	√
80-90 km/h	√
≥100 km/h	

Application Guidance

Objective: **to reduce motorists' speeds by creating the perception that the road is narrowing.**

Transverse pavement markings are placed within a travel lane along roadway segments. Transverse markings aim to reducing speeds by providing less space between successive transverse markings. This creates the perception that the lane or cross-section is narrowing, and can result in motorists subconsciously lowering their speeds.

Previous applications of transverse markings indicate that they are most effective on the approaches to horizontal curves, both on freeways and non-freeways. They are also commonly provided on the approaches to intersections, but can be marked along other road sections, including transition zones.

The markings can vary in appearance from side-hatching (pictured) to thicker bars placed across an entire travel lane.

Transverse pavement markings are generally easy and inexpensive to implement.

Alberta Status

	N	L	*C*	*P*
Large Municipalities	√			
Small Municipalities	√			
Highways	√			

N=None; L=Limited; C=Common; P=Proven

Documented Benefits

57% of all loss of control collisions[3]

55% of all fatal and injury collisions[4]

20% - 44% of all fatal and injury collisions

Typical Installation Cost

	Units	Cost Range	
		Low	High
Retrofit	m	$2	$5
New	m	$2	$5

Further Guidance

FHWA *<u>Low Cost Treatments for Horizontal Curve Safety</u>* *(2006) [Chapter 7]*

MUTCD [Section 3B.22]

Other Effective Strategies and Enhancements

- Gateway treatments
- Consistent speed limits
- Horizontal and vertical realignments
- Advance curve warning signs
- Advance intersection warning on major road
- High-visibility pavement markings

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[3] Helliar – Symons, R.D. Yellow Bar Experimental Carriageway Markings: Accident Study, Transport and Road Research Laboratory, Supplementary Report 1010, Crowthorne, UK, 1981.

[4] Griffin, L.I. and Reinhardt, R.N., "A Review of Two Innovative Pavement Patterns that Have Been Developed to Reduce Traffic Speeds and Crashes." Washington, D.C. AAA Foundation for Traffic Safety (1996)

Variable Speed Limits

Land Use

Urban	√
Suburban	√
Rural	√

Posted Speeds

≤50 km/h	
60-70 km/h	
80-90 km/h	√
≥100 km/h	√

Alberta Status

	N	L	C	P
Large Municipalities	√			
Small Municipalities	√			
Highways	√			

N=None; L=Limited; C=Common; P=Proven

Application Guidance

Objective: **to provide safer and more appropriate speed limits that reflect real-time traffic, road surface and weather conditions.**

Variable speed limits (VSLs) have been successfully applied in Europe and other parts of the world. However, legislation does not currently permit these signs to be enforceable in Alberta or other provinces. Due to their significant safety benefits, VSLs are now gaining more attention. The document *Safety Benefits of Variable Speed Limits* has been prepared as part of the study on *Methods of Reducing Collisions on Alberta Roads (Section 3.2)*, to synthesize these benefits, and to identify the barriers towards implementing VSL on Alberta's roadways.

The above document also provides some basic guidance on appropriate applications for VSLs. They are typically provided on freeways, where movement is free-flow outside of peak traffic periods and not influenced by traffic control devices such as traffic signals. They would be most commonly provided for congestion relief in more urbanized areas, for weather/road conditions in more rural areas, and where road incidents could result in major disruptions to the traffic and secondary incidents.

Once legislation is in place, extensive review of individual locations would need to be undertaken to determine the safe and appropriate speed to display.

Documented Benefits

45% of all collisions[5]

20% of all injury collisions[6]

10% - 16% of all injury collisions

Typical Installation Cost

	Units	Cost Range*	
		L□w	High
Retrofit	each	$1200	$300,00
New	each	$1000	$300,000

*Large cost ranges due to variability in sign types (side-mounted vs. overhead). 'Retrofit' slightly higher due to the removal of existing sign.

Further Guidance

MUTCD [Section 2B.13]

Other Effective Strategies and Enhancements

- Consistent speed limits
- Transverse pavement markings
- Horizontal and vertical realignments
- Gateway treatments

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[5] Abdel-Aty, M., et.al. Considering Dynamic Variable Speed Limit Strategies for Real-Time Crash Risk Reduction on Freeways, Transportation Research Board (TRB) Annual Meetings, Washington DC, 2008.

[6] Lind, G., and Linkvist, A. Traffic Controlled Variable Speed Limits, Sweden. TEMPO Evaluation Expert Group, European Commission, 2009

BASIC APPLICATION GUIDELINES FOR UNSIGNALIZED INTERSECTION COLLISION REDUCTION MEASURES

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Advance Intersection Warning on Major Road

Land Use

Urban	
Suburban	√
Rural	√

Posted Speeds

≤50 km/h	
60-70 km/h	
80-90 km/h	√
≥100 km/h	√

Application Guidance

Objective: **to provide advance warning of possible crossing movements ahead.**

The use of an advance warning sign (either of the ones shown) above aims to make drivers anticipate crossing vehicles, so as to allow more time to make evasive manoeuvres, such as braking or swerving. These signs are particularly effective where stopping sight distances are limited.

Alberta Transportation has a Recommended Practice for both signs. A Concealed Road sign (MUTCDC WA-11 to WA-15) should be used where sight distance is limited due to geometry, whereas an IMPORTANT INTERSECTION AHEAD sign (Alberta Transportation Sign Catalogue WA-144) should be used at an isolated major junction of two highways.

Where either sign is warranted, a distance tab is often provided. An advance street-name tab should be considered as a more effective alternative to the distance tab. Tabs should have 200 mm letters, and can be the same colour as the sign (yellow) or green.

These signs should contain highly reflective sheeting, and be provided at both the roadside and in the median on divided highways.

Alberta Status

	N	L	*C*	*P*
Large Municipalities			√	
Small Municipalities		√		
Highways			√	

N=None; L=Limited; C=Common; P=Proven

Documented Benefits

30% of all rural intersection collisions[7]

15% - 30% of all injury collisions

Typical Installation Cost

	Units	Cost Range*	
		Low	High
Retrofit	each	$150	$250
New	each	$450	$800

*'Retrofit' is cost of the tab; 'New' is cost of the tab and sign.

Further Guidance

Alberta Transportation *<u>Recommended Practices for Warning Signs</u>* *(2006)*

MUTCDC [Section A3.3]

Other Effective Strategies and Enhancements

- Transverse rumble strips
- Flashing beacon on stop sign
- Removal of obstructions within sight triangles
- Dedicated left-turn lanes on major road approaches
- Gateway treatments

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

Conversion of Stop-Controlled Intersections to Roundabouts

Land Use

Urban	√
Suburban	√
Rural	√

Posted Speeds

≤50 km/h	√
60-70 km/h	√
80-90 km/h	√
≥100 km/h	√

Application Guidance

Objective: **to reduce conflicting movements and collision severity at stop-controlled intersections through horizontal deflection, reduced speeds and simple yield-control.**

A high proportion of the rural fatalities and major injuries around the province occur at stop controlled intersections, and enhancements to the stop control have resulted in only limited effectiveness. A well designed modern roundabout can improve the safety of some of these intersections by more effectively reducing speeds and eliminating conflict points.

Detailed application guidelines have been prepared as part of the *Methods of Reducing Collisions on Alberta Roads* study, and are documented in *Application Guidelines for the Conversion of Stop-Controlled Intersections to Roundabouts (Section 3.3)*.

In general, conversion to a roundabout should be considered along higher-speed non-freeway roads in all cases where:

- the need to provide a higher degree of traffic control than a "stop control" is established; and
- there is a clear economic benefit based on safety and other considerations under current traffic conditions.

Roundabouts are discouraged along existing or future freeways, national highway routes, and at other locations where through volumes are dominant and left-turning volumes are minimal.

If a roundabout is to be installed, implementation guidance (for the layout, signing and marking) are described in Roundabouts: An Informational Guide (Publication No. FHWA-RD-00-067), USDOT, FHWA.

Alberta Status

	N	*L*	*C*	*P*
Large Municipalities		√		
Small Municipalities		√		
Highways		√		

N=None; L=Limited; C=Common; P=Proven

Documented Benefits

18% - 72% of all collisions[8]

72% - 87% of all fatal and injury collisions[8]

57.6% - 69.6% of all fatal and injury collisions

Typical Installation Cost

	Units	Cost Range	
		Low	High
Retrofit	LS	$250,000	$275,000
New*	-	-	-

*'Retrofit' is expected to be slightly more expensive than 'New' due to the added costs of removing existing signs and possible regrading.

Further Guidance

Alberta Transportation Roundabout Design Guidelines on Provincial Highways (Design Bulletin #68/2010)

TAC's *Synthesis of North American Roundabout Practice* (2008)

Other Effective Strategies and Enhancements

- Transverse rumble strips
- New or upgraded intersection lighting
- Gateway treatments
- Advance intersection warning on major road
- Removal of obstructions in sight triangle

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

Flashing Beacon on Stop Sign

Land Use

Urban	
Suburban	
Rural	√

Posted Speeds

≤50 km/h	
60-70 km/h	
80-90 km/h	√
≥100 km/h	√

Application Guidance

Objective: to emphasize the stop condition at collision-prone rural highway intersections.

The MUTCDC permits the use of flashing beacons in conjunction with stop signs provided they are in constant use (not turned off at certain times). Flashing beacons can increase the conspicuity of a stop sign and an intersection from a much longer distance than a stop sign alone.

Flashing beacons should only be considered at isolated rural intersections where there is a high frequency of collisions involving vehicles failing to stop at the stop sign, and where stop sign enlargements, warning signs, transverse rumble strips and enhanced pavement markings have proven ineffective. Flashing beacons are less appropriate within urbanized areas, due to the distraction caused to residents during night-time conditions.

A potentially more effective version of the beacon involves a strobe light, which can be visible from a significant distance and particularly during foggy conditions. Another alternative to the beacon is the use of LED technology to outline the border of the stop sign and flash.

Regarding installation, backboards can be provided to further increase conspicuity. If no power source is nearby, it may be more economical to use solar panels.

Alberta Status

	N	*L*	*C*	*P*
Large Municipalities		√		
Small Municipalities		√		
Highways			√	

N=None; L=Limited; C=Common; P=Proven

Documented Benefits

30% of failure to stop collisions[9]

15% - 30% of all injury collisions

Typical Installation Cost

	Units	Cost Range	
		Low	High
Retrofit	each	$500	$750
New	each	$1000	$2000

Further Guidance

Alberta Transportation Recommended Practices for Safety Measures at Rural Stop Control Intersections (2006)

Hamilton-Finn Enhancement of Stop Control at Rural Highway Intersections (2005)

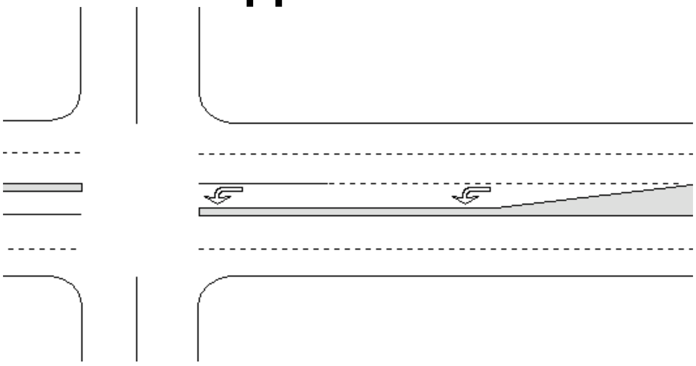
MUTCDC [Section B1.5.3.2]

Other Effective Strategies and Enhancements

- Conversion to roundabout
- Transverse rumble strips
- Removal of obstructions within sight triangles
- Advance intersection warning on major road

9 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).

Left Turn Lanes on Major Road Approaches



Land Use

Urban	√
Suburban	√
Rural	√

Posted Speeds

≤50 km/h	
60-70 km/h	√
80-90 km/h	√
≥100 km/h	√

Application Guidance

Objective: **to separate approach movements and provide unobstructed sight distance for left-turning traffic.**

Dedicated left-turn lanes should be provided at locations with a history of left-turn collisions, or rear-end collisions involving left-turning vehicles.

Left turn lanes should also be provided wherever possible on high speed roadways, and particularly (but not limited to) locations where traffic volumes are high. These volume thresholds are defined in the applicable provincial and municipal guidelines.

A raised median island (as shown in the above graphic) provides greater separation and can more effectively achieve a positive offset of the opposing left-turn lanes. It is more appropriate in suburban and urban environments.

Left-turn lanes are most effective when they are properly signed and marked, both at the immediate location and in advance.

Alberta Status

	N	L	*C*	*P*
Large Municipalities			√	
Small Municip□lities			√	
Highways			√	

N=None; L=Limited; C=Common; P=Proven

Documented Benefits

35% of rural fatal and injury intersection collisions[10]

29% of fatal and injury urban intersection collisions[10]

29% - 35% of all fatal and injury collisions

Typical Installation Cost

	Units	Cost Range	
		Low	High
Retrofit	LS	$15k	$100k
New	LS	$10k	$25k

Further Guidance

Alberta Highway Geometric Design Guide [D.7.6]

TAC Geometric Design Guide for Canadian Roads [Section 2.3.8]

Other Effective Strategies and Enhancements

- Advance intersection warning on major road
- Removal of obstructions within sight triangles
- Wider pavement markings

[10] FHWA, Safety Effectiveness of Intersection Left- and Right-Turn Lanes, Report No. FHWA-RD-02-089 (2002)

Removal of Obstructions Within Sight Triangles

Sight obstruction

Land Use

Urban	√
Suburban	√
Rural	√

Posted Speeds

≤50 km/h	√
60-70 km/h	√
80-90 km/h	√
≥100 km/h	√

Application Guidance

Objective: **to provide unobstructed sight lines at intersections.**

This is normally part of good design practice. However, obstructions are sometimes introduced during construction, or appear over time, during upgrades or private development.

The most significant sight obstructions are typically related to the intersection geometry, due to horizontal or vertical curvature, or skewness. Other sight obstructions can range from fences, trees and shrubs to utility poles, signs, signposts, and parked vehicles. Sometimes multiple obstructions act together to create a larger obstruction.

Where significant sight obstructions are identified, they should be removed immediately. This may involve relocating, lowering or trimming the object. All new intersections should be constructed with unobstructed views between motorists on conflicting approaches as well as pedestrians.

Where sight triangles cannot be provided per the published standards, the posted speed limit should be lowered and/or warning should be provided.

Alberta Status

	N	L	*C*	*P*
Large Municipalities			√	
Small Municipalities		√		
Highways			√	

N=None; Limited; C=Common; P=Proven

Documented Benefits

37% of injury collisions[11]

56% of fatal collisions[11]

*Collision Reduction Factors based on signalized intersections. However, similar reduction factors are expected for unsignalized intersections.

20% - 37% of all injury collisions

Typical Installation Cost

	Units	Cost Range*	
		Low	High
Retrofit	each	$500	$500k
New	-	-	-

*Can range from low cost (tree removal, parking restrictions) to high cost (road realignment).

Further Guidance

Alberta Highway Geometric Design Guide [D.4.2]

TAC Geometric Design Guide for Canadian Roads [Section 2.3.3]

Other Effective Strategies and Enhancements

- Advance intersection warning
- Positive offset left-turn lanes
- Horizontal and vertical realignments
- Removal of fixed objects from clear zone

[11] FHWA, Signalized Intersections: Informational Guide, Report No. FHWA-HRT-04-091 (2004)

Transverse Rumble Strips

Land Use

Urban	
Suburban	
Rural	√

Posted Speeds

≤50 km/h	
60-70 km/h	
80-90 km/h	√
≥100 km/h	√

Alberta Status

	N	L	C	P
Large Municipalities		√		
Small Municipalities		√		
Highways			√	

N=None; L=Limited; C=Common; P=Proven

Application Guidance

Objective: **to alert drivers of need to stop at the upcoming intersection.**

Rumble strips provide a vibro-tactile (feel) and auditory (hear) cue to enhance intersection awareness for the drivers approaching on the stop-controlled legs.

Rumble strips are used where engineering judgment indicates a special need due to stopping sight distance restrictions, high approach speeds, or a history of stop sign violation crashes.

They should be installed on the stop-controlled approaches to intersections, and are particularly effective where motorists have not been required to stop for a significant distance. They can be enhanced with paint markings. They require regular monitoring to maintain their effectiveness.

Transverse rumble strips may not be appropriate in residential areas due to noise and vibration concerns. In addition to the effective strategies and enhancements listed below, Stop Ahead signs, larger Stop signs, and secondary median Stop signs may be used as supplementary measures.

Documented Benefits

28% of failure to stop collisions[7]

10% - 22% of all injury collisions

Typical Installation Cost

	Units	Cost Range	
		Low	High
Retrofit	set	$2000	$6000
New	set	$2000	$5000

Further Guidance

TAC Best Practice Guidelines for the Design and Application of Transverse Rumble Strips [Section 4.0]

Alberta Highway Geometric Design Guide [Section C3.1]

Other Effective Strategies and Enhancements

- Advance intersection warning on major road
- Flashing beacon on stop sign
- Removal of obstructions within sight triangles
- Dedicated left-turn lanes on major road approaches
- Transverse pavement markings

BASIC APPLICATION GUIDELINES FOR SIGNALIZED INTERSECTION COLLISION REDUCTION MEASURES

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Advance Intersection Warning Flashers

Land Use

Urban	√
Suburban	√
Rural	√

Posted Speeds

≤50 km/h	
60-70 km/h	√
80-90 km/h	√
≥100 km/h	

Application Guidance

Objective: **to alert drivers of the onset of the red traffic signal indication at an upcoming signalized intersection.**

Advance Warning Flashers (AWF's) provide highly conspicuous advance warning of a signalized intersection ahead. They are timed with the signal so that the stop decision can occur well before the intersection, to prevent right angle and rear end crashes.

Advance warning flashers are more effective:

- where limited sight distances are available;
- on higher speed roads;
- at isolated intersections;
- on roads with high truck volume;
- on steep approach grades;
- at intersections with a collision history; and,
- at intersections with high minor road volumes.

Advance warning flashers can also be used at gateways, such as the first signalized intersection at the outskirts of a city.

Guidance for the application, placement and timing of AWF's is provided in the TAC document referenced below.

Alberta Status

	N	L	C	P
Large Municipalities			√	√
Small Municipalities			√	
Highways			√	√

N=None; L=Limited; C=Common; P=Proven

Documented Benefits

18% of total collisions[12]

44% of all fatal and injury collisions[11]

20% - 44% of all injury collisions

Typical Installation Cost

	Units	Cost Range	
		Low	High
Retrofit	each	$1,500	$3,000
New	each	$1,500	$3,000

Further Guidance

MUTCDC [Section A3.6.4]

TAC <u>Advance Warning Flashers: Guidelines for Application and Installation</u> [Section 5.2]

Other Effective Strategies and Enhancements

- Removal of obstructions within sight triangles
- New or upgraded intersection lighting
- Transverse pavement markings
- Increased sign retroreflectivity
- Horizontal and vertical realignments
- Gateway treatments
- Positive offset left-turn lanes

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

Conversion of Signalized Intersection to Roundabout

Land Use

Urban	√
Suburban	√
Rural	√

Posted Speeds

≤50 km/h	√
60-70 km/h	√
80-90 km/h	√
≥100 km/h	

Application Guidance

Objective: **to reduce conflicting movements, through vehicle speeds and collision severity at signalized intersections.**

Signalized intersections can be relatively high in complexity, due to the several phases and conflict points and are typically where most crashes in a road network are concentrated. Where space permits, traffic signals can be upgraded to modern roundabouts. A well designed modern roundabout can improve the safety of intersections by reducing speed and speed differentials at intersections and by eliminating or altering conflict points.

Due to high construction costs, roundabouts should only be implemented at locations where there is a high rate of right angle, head-on, left turn across path or u-turn crashes, or in the absence of crash data, where left-turn volumes are high. They can also be effective as gateway treatments.

Roundabouts should only be applied if grades are minimal, and adequate sight distances can be provided. Their effectiveness is highly dependent on their design features, such as the diameter, entrance angle, and central island treatments.

Preferences for the practices for the layout, signing and marking are described in FHWA's Roundabouts: An Informational Guide.

Alberta Status

	N	L	*C*	*P*
Large Municipalities		√		
Small Municipalities	√			
Highways		√		

N=None; L=Limited; C=Common; P=Proven

Documented Benefits

40% - 48% of all collisions[8]

78% of all fatal and injury collisions[8]

30% - 62.4% of all fatal and injury collisions

Typical Installation Cost

	Units	Cost Range	
		Low	High
Retrofit	LS	$275,000	$500,000
New*	-	-	-

*'Retrofit' is expected to slightly be more expensive than 'New' due to added costs of removing of existing signs and signals and possible regrading.

Further Guidance

NCHRP Report 572: Roundabouts in the United States

Alberta Transportation Roundabout Design Guidelines on Provincial Highways (Design Bulletin #68/2010)

Other Effective Strategies and Enhancements

- Transverse rumble strips
- New or upgraded intersection lighting
- Gateway treatments
- Advance intersection warning on major road
- Removal of unwarranted signals

Dedicated Left-turn Lane with Phasing

Land Use

Urban	√
Suburban	√
Rural	√

Posted Speeds

≤50 km/h	√
60-70 km/h	√
80-90 km/h	√
≥100 km/h	

Application Guidance

Objective: **to separate left-turn movements from through vehicles on the approach and in the signal sequence, to provide assured gaps.**

A high proportion of the injury and fatal collisions that occur at signalized intersections involve left turn movements. Separating left-turn movements on the approach can reduce conflicts with through movements, and provide greater flexibility with regards to dedicated signal phasing and displays.

Left-turn lanes should be provided at all major intersections with high left turning traffic volumes, and where space permits. On highways, left turn lanes should be used according to TRANS' Highway Geometric Design Guide.

Where left-turn lanes are warranted at a traffic signal, it is suggested that protected left-turn phasing be provided whenever possible, where operational efficiency can be maintained.

The benefits of dedicated left-turn lanes and phasing can be more fully realized by including the following features:

- Consider providing protected-only left-turn phasing
- Ensure left-turn indications are positioned so as to not be confused with the through movements.

Alberta Status

	N	L	*C*	*P*
Large Municipalities			√	√
Small Municipalities		√		
Highways			√	√

N=None; L=Limited; C=Common; P=Proven

Documented Benefits*

58% all collisions[13]

*Although not explicitly stated, the collision reduction is assumed to be just for the approaches that the treatment was applied.

30% - 58% of all injury collisions

Typical Installation Cost

	Units	Cost Range	
		Low	High
Retrofit	LS	$20k	$100k
New	LS	$15k	$30k

Further Guidance

MUTCDC [Section B4.6.6]

Alberta Highway Geometric Design Guide [D.7.6]

TAC Geometric Design Guide for Canadian Roads [Section 2.3.10]

Other Effective Strategies and Enhancements

- Signal back plates
- New or upgraded intersection lighting
- Protected only left-turn phase
- Positive offset left-turn lanes

[13] Thomas, G., and D. Smith. Effectiveness of Roadway Safety improvements. Center for Transportation Research and education, 2001

Positive Offset Left-turn Lanes

Land Use

Urban	√
Suburban	√
Rural	√

Posted Speeds

≤50 km/h	√
60-70 km/h	√
80-90 km/h	√
≥100 km/h	

Application Guidance

***Objective:* to improve sight distance for permissive left-turn movements at signalized intersections.**

Positive offset left-turn lanes (aligning opposing left-turn lanes to the left-of one another) can help provide an unobstructed view of opposing traffic, to assist drivers in successfully accepting a safe gap in traffic. This measure has been found to be extremely beneficial for older drivers.

In general, it is suggested that positive-offset left-turn lanes be provided wherever space exists and permissive left-turn movements are provided. *Guidelines for the Application of Positive Offset Left-turn Lanes* have been prepared as part of the study on *Methods of Reducing Collisions on Alberta Roads (Section 3.4)*. The key installation criteria include:

- Safety: presence of left-turn collisions
- Signal phasing: where it may not be possible to provide protected left-turn phasing
- Median width: at least 10.8 metres

The offset is much more effective with raised separation, but can also be applied using depressed island or pavement markings. The detailed guidelines referred to above include recommended positive offset distances.

Alberta Status

	N	*L*	*C*	*P*
Large Municipalities			√	
Small Municipalities		√		
Highways		√		

N=None; L=Limited; C=Common; P=Proven

Documented Benefits*

20%-40% of left-turn across path injury/fatal collisions[14]

*Although not explicitly stated, the collision reduction is assumed to be just for the approaches that the treatment was applied.

20% - 40% of injury collisions

Typical Installation Cost

	Units	Cost Range	
		Low	High
Retrofit	LS	$10k	$100k
New	LS	$25k	$100k

Further Guidance

TAC Geometric Design Guide for Canadian Roads [Section 2.3.8.7]

Alberta Highway Geometric Design Guide, Urban Supplement [Section U.D.1.4]

Key Related Strategies and Enhancements

- Protected only left-turn phase
- New or upgraded intersection lighting
- Dedicated left-turn lane with phasing
- Traffic signal backboards

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

Protected Only Left-turn Phase

Land Use

Urban	√
Suburban	√
Rural	√

Posted Speeds

≤50 km/h	
60-70 km/h	√
80-90 km/h	√
≥100 km/h	

Alberta Status

	N	*L*	*C*	*P*
Large Municipalities			√	√
Small Municipalities		√		
Highways			√	

N=None; L=Limited; C=Common; P=Proven

Application Guidance

Objective: **to provide assured gaps for left-turn vehicles at signalized intersections.**

Protected-only left-turn phasing is clearly associated with a reduction in injury and fatal collisions at signalized intersections. Current guidance from the Transportation Association of Canada covers only left-turn protection and not specifically protected-only phasing. *Application Guidelines for Protected-only Left-turn Phasing* have now been prepared as part of the study on *Methods of Reducing Collisions on Alberta Roads (Section 3.5)*. These guidelines suggest reviewing the need for protected-only left-turn phase based on 24 hour conditions in addition to peak hour conditions. Protected-only phasing is encouraged where:

- Visibility for left-turn movements does not allow for adequate gap assessment;
- Left-turns cross three (3) or more opposing through lanes, or where the speed limit along the roadway is 70 km/h or greater;
- Left-turns are permitted from two or more left-turn lanes on one approach; unless opposing through traffic volumes are very low;
- Left-turn across path collisions exceed seven (7) over a three-year period for an approach where protected/ permissive phasing is in use.

Documented Benefits*

30% - 36% of all collisions[7]

16% of urban fatal and injury left-turn across path collisions[7]

19% of urban fatal and injury angle collisions[7]

*Above reductions are for protected/ permissive phasing. Protected-only is expected to yield greater reductions.

8% - 16% of injury collisions

Typical Installation Cost

	Units	Cost Range	
		Low	High
Retrofit	each	$400	$1200
New	each	$300	$800

Further Guidance

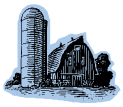
TAC *Manual of Uniform Traffic Control Devices for Canada* (1998) [Sec B4.4]
Alberta Highway Geometric Design Guide [Sec D.4.3]

Other Effective Strategies and Enhancements

- Positive offset left-turn lanes
- New or upgraded intersection lighting
- Pedestrian countdown signals

Removal of Unwarranted Traffic Signals

Land Use



Urban	√
Suburban	√
Rural	√

Posted Speeds

≤50 km/h	√
60-70 km/h	√
80-90 km/h	√
≥100 km/h	

Application Guidance

Objective: **to ensure that traffic signals are provided only if they continue to be warranted for operational or safety reasons.**

Studies show that traffic signals typically only improve safety at locations where they are warranted according to accepted engineering practices.

Several conditions could prompt the need to review the continued appropriate use of a traffic signal, including a drop in traffic volumes (particularly minor street volumes), which may be related to changes in traffic patterns due to development, roadway re-classification or the removal of certain movements. Aside from responding to changes, road agencies may also choose to review the need for all of its traffic signals as a regular course of business (for example, every two years).

The recommended practice for identifying locations for traffic signal removal is documented in the Institute of Transportation Engineers guidelines referred to below.

The signals should be placed on flash mode prior to the decommissioning. During an interim stage after removal, the use of a 'New' sign (WD-182) and any applicable tabs should be used. The unused signal structures need to be completely removed so as to avoid confusing drivers.

Alberta Status

	N	L	C	P
Large Municipalities		√		
Small Municipalities		√		
Highways			√	

N=None; L=Limited; C=Common; P=Proven

Documented Benefits

53% of urban fatal and injury collisions[15]

25% of all urban collisions[15]

25% - 53% of all injury collisions

Typical Installation Cost

	Units	Cost Range	
		Low	High
Retrofit	LS	$2000	$6500
New	-	-	-

Further Guidance

ITE <u>Guidelines for the Activation, Modification, or Removal of Traffic Control Signals</u> (2005)
Alberta Transportation <u>Recommended Practices for Advance Warning of a Traffic Control Change</u>

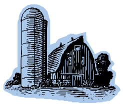
Other Effective Strategies and Enhancements

- Conversion signalized intersection to roundabout
- Increased sign retroreflectivity
- Removal of obstructions within sight triangles

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

Signal Back Plates

Land Use



Urban	√
Suburban	√
Rural	√

Posted Speeds

≤50□km/h	√
60-70 km/h	√
80-90 km/h	√
≥100 km/h	

Alberta Status

	N	L	*C*	*P*
Large Municipalities			√	√
Small Municipal□ties			√	
Highways			√	

N=None; L=Limited; C=Common; P=Proven

Application Guidance

Objective: **to improve the conspicuousness of traffic signal displays.**

Traffic signal back plates (or "backboards") provide a border around traffic signal lenses that helps to reduce sun glare problems and background distractions.

Back plates should be provided on all primary signal heads, but can also be effective with secondary or tertiary heads. The backboard is particularly effective during sun glare or where there are background distractions such as trees or mountains.

Back plates should be yellow, with reflective characteristics, but black can also be used. Yellow is more effective at night, to contrast from the dark background. If black is used, a yellow reflective strip around the backboard can be highly effective.

Signal back plates represent a highly cost-effective measure that should be implemented consistently throughout a road jurisdiction.

Documented Benefits

32% of right-angle collisions[11]

15% - 32% of all injury collisions

Typical Installation Cost

$	Units	Cost Range	
		Low	High
Retrofit	each	$1000	$5000
New	each	$500	$1000

Further Guidance

MUTCDC [Section B3.2.3]

TAC <u>Synthesis of Current Practices for Enhancing Traffic Signal Conspicuity</u>, 2005

Other Effective Strategies and Enhancements

- New or upgraded intersection lighting
- Advance warning flashers
- Protected only left-turn phase

Smart Right-turn Channel

Land Use

Urban	√
Suburban	√
Rural	

Posted Speeds

≤50 km/h	√
60-70 km/h	√
80-90 km/h	
≥100 km/h	

Application Guidance

Objective: **to reduce rear-end and pedestrian collisions by revising the geometry to better reflect the yield condition.**

In the modification of existing and construction of new yield-controlled right-turn channels, "smart right-turn channels" (also known as "Aussie Right" and the "High Entry-Angle Design") can be considered. These designs have been developed and tested by agencies including the City of Ottawa and the City of Edmonton.

Compared to the traditional right-turn configurations, this design aims to reduce driver workload by reducing the angle drivers must turn their heads to check for traffic, improving visibility of pedestrians, and reducing the turning speed to be more compatible with a yield condition. Therefore, the design represents a compromise between providing the superior visibility of a simple radius design and the capacity and truck turning accommodation of a higher-speed design. Multiple designs have been endorsed by the City of Edmonton.

Therefore, smart right-turn channels should be considered at all locations where both pedestrians and trucks are present, since it contains features intended to accommodate both. It is ideally suited where cross-street traffic volumes and truck turning volumes are relatively low.

Alberta Status

	N	L	*C*	*P*
Large Municipalities		√		√
Small Municipalities		√		
Highways	√			

N=None; L=Limited; C=Common; P=Proven

Documented Benefits

No formal study with quoted collision reduction factor (CRF), but recent Edmonton experience shows a reduction in collision rate of 65-80%.

65% - 80% of all injury collisions

Typical Installation Cost

	Units	Cost Range	
		Low	High
Retrofit	each	$15k	$50k
New	each	$15k	$25k

Further Guidance

City of Edmonton <u>Integrated Corridor Safety Project Report</u> (2009) [Section 3]

ITE <u>Urban Street Geometric Design Handbook</u> [Section 4.5.6]

Other Effective Strategies and Enhancements

- Removal of obstructions from sight triangles
- New or upgraded intersection lighting
- Wider sidewalk or paved shoulder
- Pedestrian countdown signals

BASIC APPLICATION GUIDELINES FOR RUN-OFF-ROAD MOVEMENTS COLLISION REDUCTION MEASURES

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Advance Curve Warning Signs

Land Use

Urban	
Suburban	√
Rural	√

Posted Speeds

≤50 km/h	
60-70 km/h	√
80-90 km/h	√
≥100 km/h	√

Application Guidance

Objective: **To inform motorists of an impending change in the road alignment.**

Advance curve warning signs inform motorists of an upcoming change in the horizontal alignment of the road and the potential need to adjust their speed.

Curve warning signs should be provided for all curves with radii lower than the threshold values provided in the MUTCDC Section A3.2.1 for various design speeds. Sign WA-3 is provided for gentler curves, WA-2 for sharper curves, and WA-1 for turns.

Advisory speed tabs should be provided when the curve has a safe speed of at least 20 km/h below the posted speed. Where these signs have proven ineffective, an amber flashing beacon above the sign can also be considered.

If successive curves/turns in opposite directions are less than 150m apart, reverse Curve/Turn or Winding Road signs should be used.

Implementation guidance can be found in the Alberta Transportation Recommended Practices for Turn and Curve Signs. The signs should be located 50m - 150m in advance of the curve.

Alberta Status

	N	L	*C*	*P*
Large Municipalities			√	
Small Municipalities			√	
Highways			√	

N=None; L=Limited; C=Common; P=Proven

Documented Benefits

10% reduction (all fatal and injury collisions, sign only)[7]
29% reduction (all head-on collisions, sign only) [7]
30% (all ROR collisions, sign only) [7]
13% reduction (all injury collisions, sign with advisory speed tab) [7]
30% reduction (all collisions, sign with advisory speed tab or flashing beacon)[7]

5% - 13% of all injury collisions

Typical Installation Cost

	Units	Cost Range	
		Low	High
Retrofit	each	$425	$600
New	each	$425	$600

Further Guidance

Alberta Transportation Recommended Practices: Turn and Curve Signs

MUTCDC [Section A3.2.1]

Other Effective Strategies and Enhancements

- Delineator posts
- Edgelines and centrelines
- High-visibility pavement markings
- Rumble strips (shoulder/centreline)
- Horizontal and vertical realignments

High-Tension Cable Barrier Systems

Land Use

Urban	√
Suburban	√
Rural	√

Posted Speeds

≤50 km/h	
60-70 km/h	√
80-90 km/h	√
≥100 km/h	√

Application Guidance

***Objective:* to minimize the severity of median crossover collisions and run-off-road collisions.**

High tension cable barriers are intended to reduce the risk of cross-median collisions and run-off-road collisions with significant hazards. While they have recently been implemented successfully in median applications in Alberta, greater use for roadside applications is encouraged (to protect a roadside hazard such as a fixed object, steep embankment or a water body). The feasibility of removing or relocating hazards should be considered prior to providing a barrier.

Detailed application guidance is provided in *Guidelines for the Application of High Tension Cable Barrier Systems*, prepared by Opus as part of the study *Methods of Reducing Collisions on Alberta Roads (Section 3.6)*. For median applications, the need is based on a combination of traffic volume and median width. For roadside applications, factors that are to be considered include:

- Clear zones
- Presence of hazards
- Steepness of sideslopes
- Presence of obstacles and water bodies

Alberta Status

	N	*L*	*C*	*P*
Large Municipalities	√			
Small Municipalities	√			
Highways		√		√

N=None; L=Limited; C=Common; P=Proven

Documented Benefits

44% reduction of run-off-road fatal collisions (roadside guardrail)[16]

90% reduction of head-on injury collisions (median barrier)[17]

91% reduction of head-on fatal collisions (median barrier)[18]

15% - 35.2% reduction of run-off-road injury collisions (roadside)

36% - 72% reduction of head-on injury collisions (median)

Typical Installation Cost

	Units	Cost Range Low	Cost Range High
Retrofit	m	$110	$250
New	m	$110	$220

Further Guidance

Alberta Transportation's Roadside Design Guide (2007) [Ch H-5]

TAC Geometric Design Guide for Canadian Roads [Section 3]

Other Effective Strategies and Enhancements

- Advance curve warning signs
- Horizontal and vertical realignments
- Linear delineation systems
- Removal of fixed objects from the clear zone

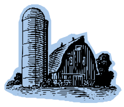
[16] Bahar, G., Parkhill, M., Hauer, E., Council, F., Persaud, B., Zegeer, C., Elvik, R., Smiley, A., and Scott, B. "Prepare Parts I and II of a Highway Safety Manual: Knowledge Base for Part II". Unpublished material from NCHRP 17-27. (2007)

[17] Washington State Department of Transportation, *Washington State Cable Median Barrier In-Service Study* (2003)

[18] Chandler, Brian: *Eliminating Cross-Median Fatalities: Statewide Installation of Median Cable Barrier in Missouri* (2007)

Horizontal and Vertical Realignments

Land Use



Urban	
Suburban	√
Rural	√

Posted Speeds

≤50 km/h	
60-70 km/h	
80-90 km/h	√
≥100 km/h	√

Application Guidance

Objective: **to reduce the likelihood of run-off-road movements by addressing roadway alignment issues.**

A high proportion of single-vehicle fatal and injury collisions in Alberta occur at locations with horizontal curves, and others along uphill and downhill grades. A significant proportion of these involve driver-related factors, such as speeding, fatigue and loss of control due to road surface conditions or swerving manoeuvres to avoid other collisions. Most of these cannot be prevent through road engineering.

The most effective method for road agencies to address collisions on curves is to avoid introducing sudden changes in the roadway that cannot be sufficiently anticipated by drivers. Where significant clusters of collisions occur, opportunities can be taken to smooth the curves.

Horizontal and vertical alignments should provide sufficient sight distance based on the design speed. Simultaneous changes in horizontal and vertical alignment should be avoided wherever possible. Also, design consistency should be provided as much as possible, i.e. avoid providing curves with successively tighter radii.

Realignments are typically costly to implement, but they result in the most significant collision reductions.

Alberta Status

	N	L	*C*	*P*
Large Municipalities		√		
Small Municipalities		√		
Highways			√	√

N=None; L=Limited; C=Common; P=Proven

Documented Benefits

73% all collisions along curve[7]

50% of all collisions along curve[19]

50% - 73% of all injury collisions

Typical Installation Cost

	Units	Cost Range*	
		Low	□igh
Retrofit	km	$75k	>$5M
New	-	-	-

*New projects should not result in any additional capital costs.

Further Guidance

Alberta Highway Geometric Design Guide [B.3/4]

TAC Geometric Design Guide for Canadian Roads [Section 2.1.2-4]

Other Effective Strategies and Enhancements

- Delineator posts
- Edgelines and centrelines
- High-visibility pavement markings
- Advance curve warning signs
- Rumble strips (shoulder/centreline)
- Removal of fixed objects from the clear zone

[19] Agent, K. R., Stamatiadis, N., and Jones, S., "Development of Accident Reduction Factors." *KTC-96-13*, Kentucky Transportation Cabinet, (1996)

Impact Attenuators

Land Use

Urban	
Suburban	
Rural	√

Posted Speeds

≤50 km/h	
60-70 km/h	
80-90 km/h	√
≥100 km/h	√

Application Guidance

Objective: **to minimize the severity of a run-off-road collision by absorbing its impact.**

An impact attenuator (crash cushion) is a safety device intended to reduce the damage caused to vehicles, and to motorists resulting from a run-off-road movement, particularly with the end of a barrier. Collisions with the side of a crash attenuator can also help to redirect the vehicle away from a roadside structure.

If a hazard (such as a bridge pier), cannot be eliminated, full barriers should be provided. Where full barriers cannot be provided to reduce the severity of the impact with a roadside structure, it is recommended that crash impact attenuators be provided along all highways with an AADT greater than 10,000. This is less than the recommended minimum of 50,000 by the TRANS Roadside Design Guide for QuadGuard barriers.

Alberta Status

	N	L	*C*	*P*
Large Municipalities		√		
Small Municipalities		√		
High□ay			√	

N=None; L=Limited; C=Common; P=Proven

Documented Benefits

75% of fatal collisions with fixed object[7]

35% - 75% of injury collisions

Typical Installation Cost

	Units	Cost Range	
		Lo	High
Retrofit	each	$15k	$30k
New	each	$15k	$25k

Further Guidance

Alberta Transportation Roadside Design Guide [Section H3.2.3.2]

Other Effective Strategies and Enhancements

- Cable barrier systems
- Removal of fixed objects from the clear zone

Removal of Fixed Objects

Land Use

Urban	√
Suburban	√
Rural	√

Posted Speeds

≤50 km/h	
60-70 km/h	√
80-90 km/h	√
≥100 km/h	√

Application Guidance

***Objective:* to minimize the likelihood of colliding with a fixed object once drivers leave the roadway and enter the roadside area.**

Fixed objects can result in high-severity collisions. Most road agencies have policies and/or guidelines that discourage the design and construction of fixed objects near the roadside. Policies and processes to *identify and remove* fixed objects that end up at the roadside after construction are, however, not as common. *Guidelines for the Removal of Fixed Objects* have now been prepared as part of the study on *Methods of Reducing Collisions on Alberta Roads (Section 3.7).*

The Guidelines build on the existing definitions of fixed objects to include other hazards, such as culverts, ditches, steep slopes and water bodies. They recommend that the procedures in the *Alberta Roadside Design Guide (2007)* be followed to mitigate hazards, starting with removal. Since removal is the most effective way of dealing with hazards, the new guidelines provide more guidance to trigger the removal process. A "roadside safety assessment" is one of the tools recommended as part of the ongoing maintenance program. The document lists the types of changes in the roadway environment that would trigger such an assessment, and provides example collision thresholds for removal, protection and prevention.

Alberta Status

	N	L	C	P
Large Municipalities		√		
Small Municipalities	√			
Highways			√	√

N=None; L=Limited; C=Common; P=Proven

Documented Benefits

50% of all fatal collisions[7]

30% of all injury collisions[7]

88% of fixed object collisions[7]

15% - 30% of all injury collisions

Typical Installation Cost

	Units	Cost Range*	
		Low	High
Retrofit	LS	$500	>$1M
New	LS	$100	>$1M

*Large cost ranges due to variability of objects within clear zones. Generally lower costs for new projects.

Further Guidance

Alberta Transportation *__Roadside Design Guide__* *(2007) [Ch H-3]*

__Alberta Highway Geometric Design Guide__ *[Section C5]*

Other Effective Strategies and Enhancements

- Cable barriers
- Delineator Posts
- Horizontal and vertical realignments
- Rumble strips (shoulder)

Shoulder Rumble Strips

Land Use

Urban	
Suburban	
Rural	√

Posted Speeds

≤50 km/h	
60-70 km/h	√
80-90 km/h	√
≥100 km/h	√

Application Guidance

Objective: **to reduce run-off-road collisions by alerting drivers when they begin to travel off-road.**

Along highways, shoulder rumble strips provide an auditory warning to drivers who have veered out of the travel lane and are encroaching on the shoulder. Since many run-off-road collisions involve fatigue, the auditory warning provides drivers the opportunity to regain their alertness and take the necessary corrective action.

Rumble strips have proven highly cost-effective in British Columbia and Alberta. They are relatively inexpensive to implement and reduce the likelihood and severity of run-off-road collisions. Therefore, they should be provided continuously along all highways. In terms of priority, they should first be provided along highways with higher speed limits, greater curvature, steeper side slopes, and where fixed objects are located within the clear zone.

Along highways, they should only be avoided along bridge decks and overpasses, or where there are no paved shoulders. In residential areas or other parts of urban areas where there are noise concerns, rumble strips should be avoided.

Shoulder rumble strips can be grooved or milled. They can also be painted to provide added visual delineation. Shoulder rumble strips need to be re-applied regularly to maintain their effectiveness.

Alberta Status

	N	L	*C*	*P*
Large Municipalities	n/a			
Small Municipalities	n/a			
Highways			√	√

N=None; L=Limited; C=Common; P=Proven

Documented Benefits

18% of all injury collisions[20]

26% reduction (Off road right collisions)[20]

10% - 18% of all injury collisions

Typical Installation Cost

	Units	Cost Range*	
		Low	High
Retrofit	km	$2000	$3000
New	km	$1500	$2000

*Assumed two strips

Further Guidance

Alberta Highway Geometric Design Guide [Section C.3.1]

TAC Best Practices for the Implementation of Shoulder and Centreline Rumble Strips [Section 1]

Other Effective Strategies and Enhancements

- Delineator posts
- Edgelines and centrelines
- Linear delineation systems
- High-visibility pavement markings
- Advance curve warning signs
- Removal of fixed objects from the clear zone
- Centreline rumble strips

[20] 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

Centreline Rumble Strips

Land Use

Urban	
Suburban	
Rural	√

Posted Speeds

≤50 km/h	
60-70 km/h	√
80-90 km/h	√
≥100 km/h	√

Application Guidance

Objective: **to reduce run-off-road-left and head-on collisions by alerting drivers when they begin to travel across the centreline.**

Along highways, centreline rumble strips provide an auditory warning to drivers who have veered out of the travel lane and into the path of opposing traffic. Since many head-on and off-road-left collisions involve fatigue, the auditory warning provides drivers the opportunity to regain their alertness and take the necessary corrective action.

Rumble strips are relatively inexpensive to implement and reduce the likelihood of head-on collisions. Therefore, they should be provided continuously along all undivided highways. In terms of priority, they should first be provided along highways with higher speed limits, greater curvature, steeper side slopes, and where there is a history of head-on collisions.

Along highways, they should be avoided along sections that permit passing (broken centreline), as well as in residential areas or other parts of urban areas where there are noise concerns.

Centreline rumble strips need to be re-applied regularly to maintain their effectiveness.

Alberta Status

	N	L	*C*	*P*
Large Municipalities	n/a			
Small Municipalities	n/a			
Highways			√	√

N=None; L=Limited; C=Common; P=Proven

Documented Benefits

26% reduction (all head-on injury collisions)[20]
68% reduction (all head-on fatal collisions) [20]

18% reduction (all injury collisions)[21]

Typical Installation Cost

	Units	Cost Range	
		Low	High
Retrofit	km	$1000	$1500
New	km	$800	$1000

Further Guidance

TAC Synthesis of Practices for the Implementation of Centreline Rumble Strips

TAC Best Practices for the Implementation of Shoulder and Centreline Rumble Strips

Other Effective Strategies and Enhancements

- High-visibility pavement markings
- Wider pavement markings
- Edgelines and centrelines
- Advance curve warning signs
- Shoulder rumble strips

[21] Sayed, Deleur and Pump "Impact of Rumble Strips on Collision Reduction on BC Highways: A Comprehensive Before and After Safety Study", TRB 2010 Annual Meeting

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BASIC APPLICATION GUIDELINES FOR ROADWAYS (LINKS) COLLISION REDUCTION MEASURES

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Delineator Posts

Land Use

Urban	
Suburban	
Rural	√

Posted Speeds

≤50 km/	
60-70 km/h	√
80-90 km/h	√
≥100 km/h	√

Alberta Status

	N	L	C	P
Large Municipalities	n/a			
Small Municipalities	n/a			
Highways			√	

N=None; L=Limited; C=Common; P=Proven

Application Guidance

Objective: **to emphasize the roadway alignment, particularly during dark conditions.**

Delineator posts, sometimes referred to as roadside delineators or delineator markers, are typically plastic posts with reflectorized strips mounted at multiple locations along a horizontal curve or at an intersection to outline at the edge of the roadway. They are particularly effective during snow-covered conditions, night-time conditions and where it is infeasible to provide lighting.

Along highways, they can be provided at any location, but it is suggested that their use be reserved for horizontal curves, or along straight sections where the road alignment is unclear at night.

They are not to be used in place of any warning signs. Delineator posts can be used in conjunction with chevron alignment signs for further emphasis.

Installation details, such as the recommended spacing in advance of and along horizontal curves, are provided in Table A3-4 of the MUTCDC.

Documented Benefits

67% of head-on collisions[7]
67% of sideswipe collisions[7]
34% of ROR collisions[7]
25% of night-time collisions[7]
11% of all collisions[7]

5% - 11% of all injury collisions

Typical Installation Cost

	Units	Cost Range Low	Cost Range High
Retrofit	each	$75	$100
New	each	$75	$100

Further Guidance

MUTCDC [Section A3.4.12]

Alberta Highway Pavement Marking Guide [Section C7.2.2]

Other Effective Strategies and Enhancements

- Edgelines
- Increased sign retroreflectivity
- Linear delineation systems
- High-visibility pavement markings
- Cable barrier systems

Edgelines and Centrelines

Land Use

Urban	√
Suburban	√
Rural	√

Posted Speeds

≤50 km/h	√
60-70 km/h	√
80-90 km/h	√
≥100 km/h	√

Alberta Status

	N	L	C	P
Large Municipalities			√	√
Small Municipalities			√	
Highways			√	√

N=None; L=Limited; C=Common; P=Proven

Application Guidance

Objective: **to enhance the delineation of lanes and the roadway.**

Edgelines and centrelines provide clarification along undivided roadways, and along low-volume roads, particularly during dark conditions and when drivers are fatigued or inattentive, assist drivers to remain within the travel lane.

Based on TRANS' Highway Geometric Design Guide, lane (Section C.2), and shoulder (Section C.3) widths vary depending on the Design Designation, and should be marked accordingly.

Centrelines should always be yellow, while edgelines should be white when located on the right hand side of the road, and yellow when on the left side of a divided highway.

Where paved shoulders of adequate width cannot be provided, edgelines can provide very effective delineation, even adjacent to raised curbs in urban situations.

Documented Benefits

24% of injury collisions[22]

10% - 19% of all injury collisions

Typical Installation Cost

	Units	Cost Range	
		Low	High
Retrofit	km	$850	$2600
New	km	$850	$2600

Further Guidance

MUTCDC [Section C1.4.2]

Alberta Highway Pavement Marking Guide [Figure TCS-C-201]

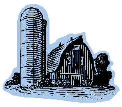
Other Effective Strategies and Enhancements

- Rumble Strips (Shoulder & Centreline)
- Delineator posts
- Linear delineation systems
- High-visibility pavement markings
- Wider pavement markings
- Wider sidewalk or paved shoulder

[22] Elvik, R. and Vaa, T., "Handbook of Road Safety Measures." Oxford, United Kingdom, Elsevier, (2004)

High-visibility Pavement Markings

Land Use



Urban	√
Suburban	√
Rural	√

Posted Speeds

≤50 km/h	√
60-70 km/h	√
80-90 km/h	√
≥100 km/h	√

Application Guidance

Objective: **to improve delineation of lanes and roadways during night-time and/or wet conditions.**

High-visibility pavement markings (HVPMs) are more applicable to rural locations, but can also be used in urban areas. HVPMs better define opposing lanes and provide delineation of the roadway edge.

HVPMs are very low cost, especially if implemented during routine maintenance.

HVPMs are particularly useful in dark areas, such as locations with no street or ambient lighting. "Wet night" HVPMs provide better visibility of pavement markings on wet pavement.

Alberta Status

	N	L	*C*	*P*
Large Municipalities			√	
Small Municipalities			√	
Highways			√	

N=None; L=Limited; C=Common; P=Proven

Documented Benefits

No specific studies, but expected to provide at least the same collision reduction factor (24% of injury collisions) as regular pavement markings[22]

10% - 19% of injury collisions

Typical Installation Cost

	Units	Cost Range Low	Cost Range High
Retrofit	km	$1000	$3000
New	km	$1000	$3000

Further Guidance

MUTCDC [Section C1.4.2]

Alberta Highway Pavement Marking Guide
[Figure TCS-C-201]

Other Effective Strategies and Enhancements

- Delineator posts
- Linear delineation systems
- Edgelines and centerlines
- Wider pavement markings
- Cable barrier systems
- Removal of fixed objects from the clear zone

Increased Sign Retro-reflectivity

DG=Diamond Grade; HI=High-Intensity; EG=Engineering Grade

Land Use


Urban	√
Suburban	√
Rural	√

Posted Speeds

≤50 □m/h	√
60-7□ km/h	√
80-90 km/h	√
≥100 km/h	√

Alberta Status

	N	L	*C*	*P*
Large Municipalities			√	√
Small Municipalities		√		
Highways			√	

N=None; L=Limited; C=Common; P=Proven

Application Guidance

Objective: **to improve visibility of signs in low-light conditions.**

Highly reflective sheeting improves night time sign conspicuity and visibility in all driving conditions.

Diamond Grade signs provide the best retro-reflectivity and should be used for all regulatory and warning signage. High Intensity signs provide the next highest retro-reflectivity, and should be used as a minimum standard on all other signs.

The MUTCDC does not specify clear standards for retro-reflectivity; however, the U.S. MUTCD specifies, in Table 2A.3, minimum sign retro-reflectivity requirements for each sign category. Until the MUTCDC specifies new requirements, it is recommended that the U.S MUTCD requirements be followed.

Highly reflective sheeting is relatively cost-effective. Road jurisdictions should implement programs that identify how to measure retro-reflectivity and replace signs that do not meet the requirements.

Documented Benefits

25-42% of all collisions[23]

25% - 42% of all injury collisions

Typical Installation Cost

	Units	Cost Range	
		Low	High
Retrofit	each	$250	$4□0
New	ea□h	$400	$800

Further Guidance

MUTCDC [Section A1.6.7]

U.S. MUTCD 2009 (Section 2A.08)

Other Effective Strategies and Enhancements

- Delineator posts
- Edgelines and centerlines
- Linear delineation systems
- High-visibility pavement markings
- Wider pavement markings
- Cable barrier systems

[23] Ripley, D. A., “Safety Effects of Traffic Sign Upgrades” ITE (2004)

Linear Delineation Systems

Land Use

Urban	√
Suburban	√
Rural	√

Posted Speeds

≤50 km/h	
60-70 km/h	√
80-90 km/h	√
≥100 km/h	√

Application Guidance

Objective: **to provide enhanced delineation along horizontal curves.**

Linear delineation systems (abbreviated as "LDS"), are reflective aluminum strips mounted longitudinally along raised barrier systems, to emphasize the roadway alignment. They are unique in their ability to provide continuous delineation above the roadway surface. They are particular useful for low-light conditions, and in winter climates where pavement markings are covered or ineffective.

Since LDS' are typically mounted along median or roadside barriers, they are inexpensive to implement where these barriers are already in place.

Yellow reflective strips should be used on median barriers. If linear delineation is to be provided along roadside barriers, they should be white in colour.

Companies such as 3M Canada have installed LDS at various locations in Alberta, and road agencies are receiving positive feedback.

Alberta Status

	N	L	*C*	*P*
Large Municipalities		√		
Small Municipalities		√		
Highways		√		

N=None; L=Limited; C=Common; P=Proven

Documented Benefits

Studies have shown reduction in collisions. However, no formal collision reduction factors have been established.[24]

Typical Installation Cost

	Units	Cost Range*	
		Low	High
Retrofit	km	$15k	$30k
New	km	$300k	$800k

*'Retrofit' assumes barrier already in place.

Further Guidance

FHWA <u>Low Cost Treatments for Horizontal Curve Safety</u> (2006) [Chapter 4]

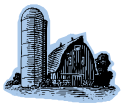
Other Effective Strategies and Enhancements

- Delineator posts
- Edgelines and centrelines
- High-visibility pavement markings
- Wider pavement markings
- Cable barrier systems

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

Wider Pavement Markings

Land Use



Urban	√
Suburban	√
Rural	√

Posted Speeds

≤50 km/h	
60-70 km/h	
80-90 km/	√
≥100 km/h	√

Alberta Status

	N	L	*C*	*P*
Large Municipalities		√		
Small Municipalities		√		
Highways			√	

N=None; L=Limited; C=Common; P=Proven

Application Guidance

Objective: **to improve the visibility of edgeline and centreline pavement markings.**

Although the current Alberta standard is 100 mm, the MUTCDC indicates that longitudinal pavement markings (edgelines, lane lines, centrelines) are typically 100 mm to 150 mm wide.

Wider pavement markings, particularly when applied using water-based paints, will likely show up better than narrower ones as the markings deteriorate.

It is suggested that 150 mm wide pavement markings should be provided at all locations where roadway width allows. Although unlikely, ensure that the reduced width between lines will not result in sub-standard lane widths. The wider markings are particularly important for centrelines and edge lines, including freeway ramp locations.

Wider pavement markings can be implemented at a relatively low cost, especially if implemented during routine maintenance.

Documented Benefits

20% reduction (all injury and fatal collisions)[25]

10% - 16% of all injury collisions

Typical Installation Cost

	Units	Cost Range	
		Low	High
Retrofit	km	$1000	$3000
New	km	$1□00	$3000

Further Guidance

MUTCDC [Section C1.4.2]

Alberta Highway Pavement Marking Guide [Figure TCS-C-201]

Other Effective Strategies and Enhancements

- Delineator Posts
- Edgelines and centrelines
- Linear delineation systems
- High-visibility pavement markings

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

BASIC APPLICATION GUIDELINES FOR VULNERABLE ROAD USERS COLLISION REDUCTION MEASURES

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New or Upgraded Intersection Lighting

Land Use

Urban	√
Suburban	√
Rural	√

Posted Speeds

≤50 km/h	√
60-70 km/h	√
80-90 km/h	√
≥100 km/h	√

Alberta Status

	N	L	*C*	*P*
Large Municipalities			√	
Small Municipalities		√		
Highways			√	√

N=None; Limited; C=Common; P=Proven

Application Guidance

Objective: **to increase the visibility of intersections and vulnerable road users.**

Proper illumination at intersections provides greater visibility for both drivers and pedestrians. Illumination should be provided at intersections where pedestrian volumes are high during low light conditions, or where there is a trend of night time collisions.

Illumination should also be provided at intersections that meet the following criteria:

- Where the potential for wrong-way movements is indicated through crash experience or engineering judgment.
- Where shifting lane alignment, turn-only lane assignment, or a pavement-width transition forces a path-following adjustment at or near the intersection.
- Where raised island or other fixed objects in the roadway exist.

Signalized intersections should always be illuminated.

Documented Benefits

78% of injury pedestrian collisions[16]

42% of fatal pedestrian collisions[16]

39% - 78% of all injury collisions

Typical Installation Cost

	Units	Cost Range	
		Low	High
Retrofit	each	$1000	$10000
New	each	$5000	$7000

Further Guidance

<u>Alberta Highway Lighting Guide</u> [Section E4.2.2]

TAC <u>Illumination of Isolated Rural Intersections</u> [Section 3.0]

Other Effective Strategies and Enhancements

- Removal of obstructions within sight triangles
- Smart right-turn channel
- Horizontal and vertical realignments
- Wider sidewalk or paved shoulder

Pedestrian Countdown Signals

Land Use

Urban	√
Suburban	√
Rural	

Posted Speeds

≤50 km/h	√
60-70 km/h	√
80-90 km/h	
≥100 km/h	

Application Guidance

***Objective:* to providing real-time meaningful information to crossing pedestrians.**

Pedestrian Countdown Signals (PCS) provide a real-time countdown informing pedestrians how much time remains to cross at an intersection. They clear up much of the confusion that is associated with the traditional "Flashing Don't Walk" display. They have generally become very well received by the public and their implementation is becoming much more widespread. While PCS is generally encouraged at every new traffic signal, more specific guidance was prepared to assist particularly in the prioritization of retrofits, in the document entitled *Guidelines for the Application of Pedestrian Countdown Signals*, as part of the study on *Methods of Reducing Collisions on Alberta Roads (Section 3.8)*.

In general, pedestrian countdown signals should be provided wherever pedestrian signal heads are provided. However, PCS should *not* be installed in rural areas, on roadways with speed limits of above 70 km/h, or where the crossing distance is very short. The priority for retrofits is as follows, using a risk-based approach:

1. History of Pedestrian Collisions/Conflicts
2. High "Vulnerable" Pedestrian Volumes
3. Locations with critical flashing do not walk intervals
4. Complex geometric or operational characteristics

Alberta Status

	N	*L*	*C*	*P*
Large Municipalities			√	
Small Municipalities		√		
Highways		√		

N=None; L=Limited; C=Common; P=Proven

Documented Benefits

25% of all pedestrian collisions[26]

15% - 25% of all pedestrian collisions

Typical Installation Cost

	Units	Cost Range	
		Low	High
Retrofit	Intersection	$4,000	$8,000
New	Signal	$400	$900

Further Guidance

TAC *An Informational Report on Pedestrian Countdown Signals (PCS)* (2008)
Manual of Uniform Traffic Control Devices [Sec 4E.7]

Other Effective Strategies and Enhancements

- Wider Sidewalk or Paved Shoulder
- Smart Right-turn Channel
- New or upgraded intersection lighting
- Removal of Obstructions from Sight Triangle

[26] Markowitz, F., Sciortino, S., Fleck, J. L., and Yee, B. M., "Pedestrian Countdown Signals: Experience with an Extensive Pilot Installation." *Institute of Transportation Engineers Journal*, Vol. January 2006, ITE, (1-1-2006) pp. 43-48

Wider Sidewalk or Paved Shoulder

No side walk or shoulder.

Land Use

Urban	√
Suburban	√
Rural	√

Posted Speeds

≤50 km/h	√
60-70 km/h	√
80-90 km/h	√
≥100 km/h	√

Alberta Status

	N	L	*C*	*P*
Large Municipalities			√	
Small Municipalities			√	
Highways			√	

N=None; L=Limited; C=Common; P=Proven

Application Guidance

Objective: **to provide greater separation between pedestrians and vehicles along road segments.**

With the increase in pedestrian activity and increased diversity of non-auto modes that use the sidewalk, it is recommended that wider sidewalks be provided.

The pedestrian through zone should have a minimum clear width of 1.8 m. In urban centres, sidewalk widths should be increased to allow for groups of pedestrians to pass each other.

In particular, in areas where there is a high pedestrian demand, such as schools, commercial areas, transit or residential areas, boulevards should provide 3.0 m clearance width for arterial streets, and 2.0 m for local streets in pedestrian districts.

The increased sidewalk corridor width should provide adequate space for pedestrians with reduced mobility, such as those using a cane or a walker, or those who are confined to a wheelchair or a scooter, to comfortably use the sidewalk with other pedestrians.

Where a sidewalk cannot be provided, paved shoulders, clearly separated with an edgeline should be provided.

Documented Benefits

65 – 89% of all pedestrian collisions[7]

65% -89% of all pedestrian collisions

Typical Cost

	Units	Cost Range	
		Low	High
Retrofit	m	$150	$500
New	m	$110	$300

Further Guidance

Alberta Highway Design Guide [Section C.7.1.2]

TAC Geometric Design Guide for Canadian Roads [Section 3.3.4.4]

Other Effective Strategies and Enhancements

- Edgelines and centrelines
- Horizontal and vertical realignments
- New or upgraded intersection lighting
- Removal of fixed objects from clear zone

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3.0 DETAILED APPLICATION GUIDELINES

Of the 33 *Highly Effective* Measures, eight were evaluated to be highly effective and cost-effective, but without sufficient application guidance to maximize the potential benefits. These are referred to in this study as "Priority 1" measures:

- Gateway Treatments;
- Variable Speed Limits;
- Conversion of Stop-controlled Intersections to Roundabouts;
- Positive Offset Left-turn Lanes;
- Protected-only Left-turn Phasing;
- High-tension Cable Barrier Systems;
- Removal of Fixed Objects; and,
- Pedestrian Countdown Signals.

The following eight sub-sections describe these eight Priority 1 measures in detail. They contain significantly greater detail than the basic guidelines:

- Several photos showing the range in applications;
- Definitions of common terms associated with the measure;
- As part of the current Alberta status, listing specific jurisdictions with experience;
- Benefits and costs, including rationale for them as well as the non-safety benefits or disbenefits;
- Implementation considerations, to keep in mind to maximize the potential benefits;
- Human factors implications, as review by a human factors expert; and
- Maintenance considerations, to maximize the safety benefits over time.

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ALBERTA TRANSPORTATION

METHODS OF REDUCING COLLISIONS ON ALBERTA ROADS

APPLICATION GUIDELINES FOR GATEWAY TREATMENTS

FINAL

Opus International Consultants (Canada) Limited

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3.1 Gateway Treatments

Unsafe speeds were the second leading cause of fatal collisions and one of the leading causes of major injury collisions in Alberta in 2007. Higher speeds typically result in higher severity collisions, particularly if vulnerable road users are involved. Speed-related collisions are frequently concentrated at transition and fringe areas, where motorists fail to make the correct adjustment to their speed and level of alertness. Gateway Treatments are aimed at reducing vehicle speeds and increasing alertness at transition points in the road network.

Gateway treatments are common in countries outside of Canada, such as the United Kingdom, New Zealand, and to a lesser extent, the United States. They have typically been applied for aesthetics or promoting community identities. This document is intended to provide systematic guidance for traffic engineers to review opportunities for gateway treatments to improve road safety, and in particular which gateway treatments are applicable for the range of conditions in Alberta. There are currently no clear guidelines in Canada or the United States for the scientific application of gateway treatments.

FIGURE 3.1 GATEWAY TREATMENT

3.1.1 Definitions

A “gateway” is a location along a roadway where there is a transition in the land use and/or speed environment. In some parts of the world gateways are referred to as “thresholds”. A “gateway treatment” (FIGURE 3.1) is a traffic calming measure that is designed to define a transition to an environment requiring a reduction in speed and an increase in attentiveness.

Gateway treatments are appropriate at most locations where the road environment or function changes. For the purpose of this document, which is aimed at selecting the locations with the highest collision reduction benefits (i.e. where the upstream speed is high and/or where the difference between the safe upstream and downstream speed is significant), gateways will refer to the following two location types:

- *Rural to Urban/Semi-Urban Transition:* the threshold between a rural and urban environment, such as the entrance to a city, town or hamlet; and
- *Urban to Suburban Transition*: the entrance to a suburb community, typically within a larger city.

This guideline refers to three different speed zones that are typically in place in the vicinity of gateways:

- *Upstream Speed Zone:* the higher-speed zone, from which a speed reduction is required;
- *Transition Speed Zone:* a short, intermediate speed zone between the upstream and downstream speed zones. A transition speed zone is generally used when large reductions in speed are required.
- *Downstream Speed zone:* the lower-speed zone, within the more urbanized area.

The two primary features that *together* constitute a gateway treatment by creating a "gateway effect" are:

- *Road Narrowing:* Road narrowing is a proven technique for reducing vehicle speeds. Sometimes referred to as a "Pinch Point", the narrowing of a roadway over a short distance causes drivers to slow down as they perceive a change in the roadway ahead. Road narrowing can be effectively accomplished with physical measures (such as curb extensions), or visual measures (such as pavement markings). Narrowings can be accomplished along highways without creating hazards or reducing capacity.
- *Conspicuous Roadside Vertical Elements:* Vertical elements (including speed limit signs mounted on both sides of the roadway) are used to identify and improve the visibility of the gateway to approaching drivers. It has also been shown that drivers will travel at slower speeds when the height of the vertical elements is greater than the width of the roadway. As with any roadside appurtenances, crashworthiness must be maintained within the clear zone.

The modern roundabout can be an effective device to encourage lower speeds at the entry to a more urbanized area, and is therefore sometimes considered a gateway treatment. However, since roundabouts are traffic control devices and their installation involves the consideration of a number of other factors, it is not formally covered in this document. Some brief guidance on how to make roundabouts function as gateway treatments is provided below. This guideline document focuses on treatments that create a "gateway effect".

3.1.2 Current Status in Alberta

Gateway treatments, based on the above definition, are currently not in use in Alberta. Some existing locations provide one of the two required treatments, but not both. Many jurisdictions and developers in Alberta have installed decorative welcome signs at the entrance of their cities, towns and communities; however, their main function is for information and aesthetics, not for speed reduction or safety. Some jurisdictions in Alberta (including Edmonton, Calgary and Strathcona County) are currently using physical road narrowing measures at entrances to subdivisions, but again primarily for community identification or aesthetics; quantifiable speed reductions have not been observed or measured at these locations.

3.1.3 Example Applications

In addition to road narrowing and conspicuous roadside vertical elements, there is a wide range of treatments that have been used in different countries to create a gateway effect. Examples of possible treatments are listed below:

- Architectural or decorative welcome signs;
- Coloured surfacing or change in pavement type;
- Overhead elements spanning the roadway;
- Countdown signs in advance of the gateway;
- Illumination;
- Distinctive vegetation; and
- Walls, rails and fences.

Example applications of gateway treatments are shown in FIGURE 3.2 to FIGURE 3.9.

FIGURE 3.2 VISUAL ROAD NARROWING THROUGH HATCHING AND PAINTED MEDIANS (NEW ZEALAND)

FIGURE 3.3 PHYSICAL ROAD NARROWING USING RAISED MEDIAN (NEW ZEALAND)

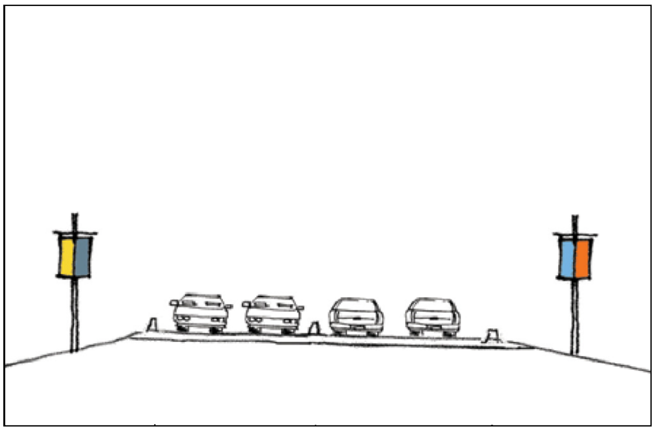


FIGURE 3.4 ROADSIDE VERTICAL ELEMENTS[27] (BRITISH COLUMBIA)

FIGURE 3.5 DUAL SPEED LIMIT SIGNS[28] (ALBERTA)

[27] http://www.th.gov.bc.ca/seatosky/Preliminary_Design/Pinecrest-Blacktusk/Preliminary_Design/Landscape_Options.pdf

[28] Transportation Infrastructure Management System (TIMS), Alberta Transportation, Accessed April 26, 2010.

FIGURE 3.6 ILLUMINATION AND DECORATIVE WELCOME SIGN
(LAC LA BICHE, AB)

FIGURE 3.7 OVERHEAD ELEMENTS SPANNING ROADWAY
(EUROPE; JASPER, AB; BONNYVILLE, AB)

FIGURE 3.8 ILLUMINATION, SURFACE TREATMENT, ROADSIDE VERTICAL ELEMENTS, PHYSICAL AND VISUAL ROAD NARROWING[29] (NEW ZEALAND)

FIGURE 3.9 CURB EXTENSIONS WITH VEGETATION (NEW ZEALAND)

3.1.4 Benefits and Costs

Benefits

Providing gateway treatments can increase safety by reducing vehicle speeds. A driver might exceed the posted speed limit for the following reasons:

- Lack of conspicuity of the posted speed limit or downstream conditions;
- Posted speed limit does not match with the driver's perception of the roadway; or
- Other human factors such as aggression, frustration, distraction or impatience.

Gateway treatments aim to address the first two of these three concerns. The effect on the third concern is limited; this issue is more effectively mitigated through education and enforcement.

An extensive literature review was conducted regarding the proven benefits of gateway treatments.

[29] LTSA

Collision Reduction

The collision reduction factors associated with the implementation of gateway treatments are summarized in TABLE 3.1.

TABLE 3.1 SUMMARY OF COLLISION REDUCTION FACTORS ASSOCIATED WITH GATEWAY TREATMENTS

COLLISION TYPE	REDUCTION FACTOR	COUNTRY	CONTEXT	SOURCE
All injury collisions	25%	United Kingdom	Before-After study of schemes installed at 56 villages in the UK. 5-10 years of before collision data, 2-4 years of after collision data.	International Road Safety Engineering Countermeasures and their Applications in the Canadian Context Changes in Accident Frequency Following the Introduction of Traffic Calming in Villages (Wheeler and Taylor 2000)
All fatal and serious injury collisions	50%			

Speed Reduction

Documented speed reductions are summarized in **TABLE 3.2**.

TABLE 3.2 SUMMARY OF SPEED REDUCTIONS ASSOCIATED WITH GATEWAY TREATMENTS

<table>
<tr><th>TREATMENT TYPE</th><th>SPEED REDUCTION</th><th>COUNTRY</th><th>CONTEXT</th><th>SOURCE</th></tr>
<tr><td>Simple signing/marking</td><td>2 - 4 km/h</td><td>United Kingdom</td><td rowspan="3">Before-After study of schemes installed at 9 villages in the UK. 5 years of before collision and speed data, 1-3 years of after collision and speed data.</td><td rowspan="3">International Road Safety Engineering Countermeasures and their Applications in the Canadian Context

Traffic Calming in Villages on Major Roads: Final Report (Wheeler and Taylor 1999)</td></tr>
<tr><td>Comprehensive signing/marking with high visual impact</td><td>8 - 11 km/h</td><td>United Kingdom</td></tr>
<tr><td>Physical measures</td><td>Up to 16 km/h</td><td>United Kingdom</td></tr>
<tr><td>Layered Landscape</td><td>11.7 mph</td><td rowspan="7">United States (Oregon DOT)</td><td rowspan="7">Measured from a 55 mph sign to a 35 mph sign. This data is based on observed measurements from a simulator of rural to urban transitions</td><td rowspan="7">Determining Effective Roadway Design Treatments for Transitioning from Rural Areas to Urban Areas on State Highways (Dixon and Zhu 2008)</td></tr>
<tr><td>Gateway* with Lane Narrowing</td><td>11.9 mph</td></tr>
<tr><td>Control 2 Lane with Center Lane</td><td>12.1 mph</td></tr>
<tr><td>Median Only</td><td>13.1 mph</td></tr>
<tr><td>Median with Gateway*</td><td>14.2 mph</td></tr>
<tr><td>Medians in Series** No Crosswalks</td><td>13.1 mph</td></tr>
<tr><td>Medians in Series** with Crosswalks</td><td>13.7 mph</td></tr>
</table>

*Gateway was defined as “a physical or geometric landmark on an arterial street, which indicates a change in environment from a major road to a lower speed residential or commercial district.”
**Medians in Series were defined as “a group of medians”.

It should be noted that in larger towns and cities, vehicle speeds may increase as vehicles travel away from the gateway. In this case, certain traffic calming or other speed reduction measures may be continued through the municipality.

Costs

The costs of gateway treatments are highly variable depending on the type of treatment selected and can exceed $500,000. Roadside signs can be installed at the low end of the cost range. Using TRANS’ 2010 *Unit Price Averages Report*, the cost of supplying and installing two signs and posts was estimated to be $2000. Annual maintenance and operation (M&O) costs were assumed to be $2500.

3.1.5 Existing Application Guidance

Existing guidance provided for the application of gateway treatments is summarized in this section.

Provincial Guidance

Alberta Transportation

Alberta Transportation's *Welcome Sign Recommended Practice* (2006) provides guidance on the standards for welcome signs, the eligibility of a community to install a welcome sign, as well as guidelines for the sign's placement. Alberta Transportation has also published a document entitled *Decorative Features on Street Lights and Signal Poles Recommended Practice* (2007) which provides a list of criteria that must be met in order to install decorative features on lights and poles. Their document *Highway Beautification – Landscape Projects in the Highway Right-Of-Way Recommended Practice* (2006) provides guidance on the standards for landscaping projects, as well as guidelines for the placement of the landscaping.

No guidance on gateway treatments has been established by Alberta municipalities.

National Guidance

Transport Canada

Transport Canada's (TC) *International Road Safety Engineering Countermeasures and Their Applications in the Canadian Context* (2009), section 5.1 provides a description of various gateway treatments and their applicability in the Canadian context. This report also includes collision reduction factors for gateway treatments from various studies around the world.

US Guidance

Federal Highway Administration

The Federal Highway Administration's (FHWA) *Determining Effective Roadway Design Treatments for Transitioning from Rural Areas to Urban Areas on State Highways* (2008) provides details on a study conducted in Oregon on various speed reduction measures, including gateway treatments.

A study sponsored by the National Highway Cooperative Research Program (NCHRP) synthesizing current practices regarding gateway treatments (*Effective Speed Reduction Techniques for Rural High to Low Speed Transitions*) is currently being conducted by Intus Road Safety Engineering, based in Ontario. While the study is not yet complete, Intus provided a wealth of information to Opus for the benefit of this study.

International Guidance

New Zealand

Land Transport Safety Authority

Some of the recommended guidance in this document is based on the New Zealand Land Transport Safety Authority's (LTSA) *Guidelines for Urban-Rural Speed Thresholds RTS 15* (2002). It outlines the principles of urban-rural speed thresholds. The guidelines provide a comprehensive list of design considerations, such as location, lighting, conspicuity and traffic signs.

New Zealand Transport Agency

The New Zealand Transport Agency's (NZTA) *Manual of Traffic Signs and Markings (MOTSAM)* (2007), provides details about threshold speed signs, including the size and positioning of the sign.

United Kingdom

UK Department for Transportation

The UK Department for Transportation's (DfT) *Road Safety Good Practice Guide* () appendix A.9 provides a brief description of various gateway treatments. It also provides detailed information on two before-after studies that were conducted on the effectiveness of gateway treatments.

Some of the above guidance has been incorporated as appropriate into the recommended guidelines for Alberta.

3.1.6 Recommended Application Guidance

Recommended guidance for the appropriate application of gateway treatments in Alberta, with the objective of improving safety, has been developed by Opus, considering leading practices in other jurisdictions, road safety engineering and human factors principles, and the Alberta road and driving environment.

Applicability

Land Use

Gateway treatments are particularly applicable at the interface between urban and rural areas. Features that indicate the transition to an urbanized area include: more built-up, buildings located closer to the roadway, signage regarding facilities, closer intersection and access spacing, pedestrian/cyclist activity, and changes in roadway cross-section, landscaping and other roadside features. It is recommended that most highways that go through (do not bypass) small towns in Alberta are candidates for gateway treatments; however, some gateway treatments are also applicable for the entrances to mid-size and large cities.

Gateway treatments can also be applied at the transition of a higher roadway design class to a lower roadway design class, such as from an arterial to a collector road. Another example of such a transition is the interface of an urban and suburban environment, such as at the entrance of a suburban neighbourhood within a city. This could be characterized by a transition from a commercial or industrial land use to a residential land use. Residential land use typically includes increased pedestrian/cyclist activity, densely spaced residential buildings and driveways and increased on-street parking.

Posted Speed Limit

Gateway treatments are recommended for situations where the posted speed limit decreases by 20 km/h or greater. This may include a transition zone where the speed limit drops to an intermediate limit between the upstream limit and the downstream limit. For most Alberta highways, this will apply to most towns that have development on both sides and the speed limit typically drops from 100 km/h to 70 km/h or below.

The 20 km/h criteria is only applicable where the upstream speed limit is 60 km/h or greater. Transitions from 50 km/h to 30 km/h are rare and provide limited injury reduction benefits.

For school or playground zones, the required speed reduction extends over a short segment; therefore, gateway treatments are not applicable, but other targeted forms of traffic calming devices (such as road narrowings and crosswalks) may be considered.

Gateway treatments are also appropriate where vehicle speeds at the edges of the community or through the urban area are well in excess of the posted speed limit. Generally, average speeds in the reduced speed zone that are consistently greater than 15 km/h above the posted speed limit constitute excessive speeds. However, cases of extreme speeding may be indicative of an inappropriate speed limit that is failing to elicit respect from drivers.

The typical land use and speed environments where the installation of gateway treatments should be considered are summarized in TABLE 3.3.

TABLE 3.3 TYPICAL LAND USE AND SPEED RANGES FOR GATEWAY TREATMENTS

LAND USE TRANSITION	UPSTREAM POSTED SPEED LIMIT (km/h)			
	50 or less	60 - 70	80-90	100 or more
Rural to Urban	X	✓*	✓	✓
Urban to Suburban	X	✓*	✓	✓

*Gateways where the upstream limit is 60 km/h zones are expected to be rare since the speed limit on most major roads is 50 km/h or more; therefore the 20 km/h difference requirement will not be met.

Collision Characteristics

Collision experience itself can indicate the extent of the risks that may be present at a given speed reduction zone. In particular, gateway treatments can be considered if:

- the reported injury or fatality rates in the vicinity of the speed reduction are higher than average, or an overall reduction is desired;
- the proportion of speed-related collisions is higher than average; or
- vulnerable road users feature in the collision analysis.

In the case of a town or hamlet, a collision analysis can include the length of the highway through the community. In the case of a larger municipality, it can include the edges of the municipality. If the overall injury and fatality rate is significantly higher than the provincial averages for segments with similar characteristics, gateway treatments should be considered. Similarly, if the proportion of collisions involving vulnerable road users is greater than a provincial average, gateway treatments should also be considered.

Summary of Criteria

The applicability criteria are summarized in this section. It is recommended that gateway treatments be considered at transitions of land use and speed context where the speed limit is reduced by 20 km/h or greater, and when one or more of the three conditions below are met.

1. *Vehicle speeds at the edges of the community or through the urban area are well in excess of the posted speed limit.*
2. *The reported injury or fatality rates in the vicinity of the speed reduction are higher than average, or an overall reduction is desired.*
3. *Vulnerable road users feature in the collision analysis.*

Placement

Once it is established that a gateway treatment is necessary based on the above criteria, the selection of the appropriate treatment type can be conducted; but this depends in part on the placement of the treatment.

Gateways are located at the threshold of two speed zones. In the case where there are two thresholds due to a transition zone, the gateway may be located at:

- the threshold between the upstream speed zone and the transition speed zone; or
- the threshold between the transition speed zone and the downstream speed zone.

In the case with two possible speed zone transitions, an analysis of the historical collision trends, current travel speeds and the risks to vulnerable road users should be performed to establish the more specific location of the problem. Other placement considerations, such as gateway visibility are presented in Implementation Considerations, below.

Treatment Types

This section presents gateway treatments that can be used to create the "gateway effect". To maximize its effectiveness, it is strongly recommended that at least one treatment be chosen from the Horizontal Elements category and one (in addition to the speed limit signs) be chosen from the Vertical Elements category for every gateway. Details and implementation considerations for each treatment are available below.

TABLE 3.4 SUGGESTED APPLICATION OF TREATMENTS BY SPEED LIMIT

Treatment	Gateway Speed Zone				
	<50 km/h	60 km/h	70 km/h	80 km/h	90 km/h
Horizontal Elements					
Curb Build-Outs or	✓	✓			
Pavement Hatching	✓	✓	✓	✓	✓
Raised Median Island or	✓	✓			
Painted Median Island	✓	✓	✓	✓	✓
Vertical Elements					
Speed Limit Signs	Required	Required	Required	Required	Required
Architectural or Decorative Name Signing	✓	✓	✓	✓	✓
Illumination*	✓	✓	✓	✓	✓
Walls, Rails and Fences	○	○	○	○	○
Trees, Flag Poles and Other Vertical Features	✓	✓	✓	✓	✓
Overhead Elements	○	○			
Pavement Surface					
Pavement Colour	○	○	○	○	○
Pavement Surface Change	○	○	○	○	○
Other Treatments					
Roundabouts	○	○	○	○	○
Advance Signage	○	○	✓	✓	✓

✓ Strongly recommended enhancement

○ Optional enhancement

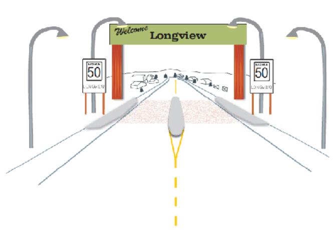
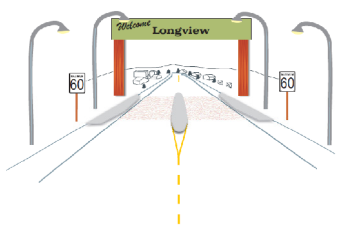
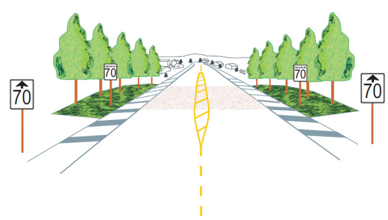
*Required if curb build-outs and/or a raised median are used.

A number of treatment combinations, or "packages", have been developed for standard speed reduction cases. The packages are meant as a starting point only; context-sensitive treatments may be considered using the guidance provided in TABLE 3.4.

Rural - Urban Transition on Undivided Highways

In Alberta, most primary highways that are undivided and on relatively level terrain are posted at 100 km/h. At many towns and villages in the province, the posted speed limit is often reduced to 70 to 50 km/h. The following table presents three packages that may be considered for these types of transitions.

TABLE 3.5 GATEWAY TREATMENTS FOR TRANSITIONS ON UNDIVIDED HIGHWAYS

Gateway Treatment Categories	**Gateway Speed Zone**		
	<50 km/h	**60 km/h**	**70 km/h**
Horizontal Gateway Elements	Curb Build-Outs Raised Median Island	Curb Build-Outs Raised Median Island	Pavement Hatching Painted Median Island
Vertical Gateway Elements	Speed Limit Signs* Architectural or Decorative Name Signing** Illumination Overhead Elements	Speed Limit Signs* Architectural or Decorative Name Signing** Illumination Overhead Elements	Speed Limit Signs Architectural or Decorative Name Signing** Trees, Flag Poles and Other Vertical Features
Pavement Surface	Pavement Colour	Pavement Colour	Pavement Colour
Other Gateway Treatments			Advanced Countdown Signs
Examples			

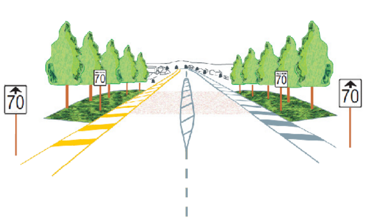
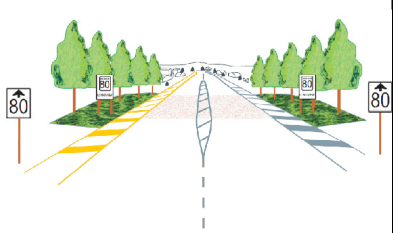
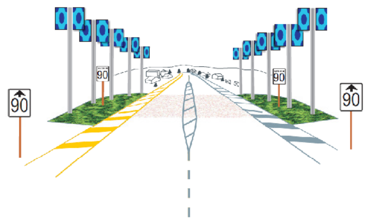
*Note that the different speed limit sign configurations are shown as an example. One is not preferred over the other based on the downstream speed zone.

**The architectural and decorative name signing in the lower gateway speed zones is achieved with the overhead sign. It is not shown in the 70 km/h downstream speed zone because it would likely be located outside the clear zone

Rural - Urban Transition on a Divided Highway

In Alberta, most primary highways that are divided and on relatively level terrain are posted at 110 km/h. At many cities and towns in the province, the posted speed limit is often reduced to anywhere from 90 to 70 km/h. The following table presents three packages that may be considered for these types of transitions.

TABLE 3.6 GATEWAY TREATMENTS FOR TRANSITIONS ON DIVIDED HIGHWAYS

Gateway Treatment Categories	Gateway Speed Zone		
	70 km/h	**80 km/h**	**90 km/h**
Horizontal Gateway Elements	Pavement Hatching	Pavement Hatching	Pavement Hatching
Vertical Gateway Elements	Speed Limit Signs* Architectural or Decorative Name Signing Trees, Flag Poles and Other Vertical Features**	Speed Limit Signs* Architectural or Decorative Name Signing Trees, Flag Poles and Other Vertical Features**	Speed Limit Signs* Architectural or Decorative Name Signing Trees, Flag Poles and Other Vertical Features**
Pavement Surface	Pavement Colour	Pavement Colour	Pavement Colour
Other Gateway Treatments	Advanced Countdown Signs	Advanced Countdown Signs	Advanced Countdown Signs
Examples			

*Note that the different speed limit sign configurations are shown as an example. One is not preferred over the other based on the downstream speed zone.
*Note that the different vertical elements are shown as an example. One is not preferred over the other based on the downstream speed zone.

Urban - Suburban Transition

Within most Alberta jurisdictions, the speed limit on roads within residential areas ranges from 30 to 50 km/h. The following table presents a package that may be considered for transitions between urban and suburban areas.

TABLE 3.7 GATEWAY TREATMENTS FOR URBAN - SUBURBAN TRANSITIONS

Gateway Treatment Categories	**Gateway Speed Zone**
	<50 km/h
Horizontal Gateway Elements	Curb Build-Outs Raised Median Island
Vertical Gateway Elements	Speed Limit Signs Architectural or Decorative Name Signing* Illumination** Trees, Flag Poles and Other Vertical Features Walls, Rails and Fences
Pavement Surface	Pavement Colour
Example	

* In the example, the community name is mounted on the wall to create the decorative effect.
** Illumination would likely already be present in urban and suburban areas. If illumination is not already present it should be considered.

3.1.7 Recommended Procedure

A four-step procedure has been developed to systematically determine the need for gateway treatments in Alberta, taking into consideration the criteria described above.

Step 1: Determine if gateway treatments are needed.			
A.	Is there a transition of land use and speed context with a reduction in the posted speed limit as determined by legislation or engineering analysis of at least 20 km/h?		
	Yes		*Continue to 1.B.*
	No	*Gateway treatments are not needed.*	.

B.	Are the vehicle speeds at the edges of the community or through the urban area excessively high? Are the reported injury collision rates higher than average or is an overall reduction desired? Are there many collisions involving vulnerable road users?		
	Yes to any of the above		*Continue to Step 2.*
	No to all of the above	*Gateway treatments are not needed.*	
Step 2: Determine the gateway speed zone.			
A.	Is there a transition zone between the upstream speed zone and the downstream speed zone?		
	Yes		*Continue to 2.B.*
	No	*The gateway should be located at the threshold of the upstream speed zone and the local speed zone.*	*Continue to 2.C.*
B.	Refer to historical collision data and travel speed data and assess the risks to vulnerable road users. Are there more challenges due to excessive speeds in the transition speed zone or in the downstream speed zone?		
	Downstream Speed Zone	*The gateway speed zone should be located at the threshold of the transition speed zone and the downstream speed zone.*	*Continue to 2.C.*
	Transition Speed Zone	*The gateway should be located at the threshold of the upstream speed zone and the transition speed zone.*	*Continue to 2.C.*
	Equal in Both Zones	*The gateway should be located at the threshold of the upstream speed zone and the transition speed zone.*	*Continue to 2.C.*
C.	Will a gateway at this location block sightlines to nearby intersections or driveways?		
	Yes	*Consider sight lines when choosing gateway treatments, use Hidden Driveway and/or Hidden Intersection signs as required.*	*Continue to 2.D.*
	No		*Continue to 2.D.*
D.	Does this location allow the gateway to be visible from the Stopping Sight Distance as determined using the 85th percentile approach speed?		
	Yes		*Continue to Step 3.*
	No	*Consider removing obstacles and using very conspicuous treatments as necessary to increase the visibility of the gateway.*	*Continue to Step 3.*

Step 3: Choose Gateway Treatments that are suitable for the land use and speed context. Refer to Implementation Section for implementation considerations for each treatment.	
A.	Refer to TABLE 3.4 to determine which treatments should be used. Note that the *Gateway Speed Zone* refers to the downstream speed zone or transition speed zone, as determined in Step 2.B.
B.	Alternatively, choose one of the treatment combinations shown in TABLE 3.5 to TABLE 3.7.
Step 4: Once the treatments are chosen, the benefit-cost can be computed and the potential layout verified.	

3.1.8 Implementation Considerations

These application guidelines are intended to assist practitioners in determining when gateway treatments are warranted. The design and implementation of the treatments are not covered in this document. Additional general guidance regarding the implementation of these treatments are available in various provincial and national documents such as the Alberta Highway Geometric Design Guide, the Alberta Roadside Design Guide and the Manual of Uniform Traffic Control Devices for Canada. More specific installation guidance may be provided in municipal guidelines.

General implementation considerations are as follows:

- It is imperative that all roadside features (posts, trees, etc.) be located outside the clear zone, be of a breakaway construction or be protected.
- Pavement markings are not favoured for use in Alberta due to the climate. Pavement markings would likely be covered by snow for several months of the year. If they are necessary, it is recommended that high visibility/durability markings are selected.
- Generally, the more measures that are used, the greater the speed reduction. However there has been some argument that too many treatments constitute a visual intrusion and may be counterproductive to road safety[30].
- Vehicle travel speeds should be measured at various locations (before, at, and past the threshold) before and after the implementation of the gateway treatments to determine if the desired speed reduction has been achieved. If not, additional treatments may be considered.

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

More specific considerations for different types of treatments are outlined below.

Placement

Speed Limit Sign Location

The posted speed limit signs must be located within 20 m of the start of the warranted speed reduction.

Transition Zones

At the approaches to some towns there exist progressive speed limits. This includes a transition zone speed limit that is in place for a short distance before the lower speed limit. In this case, an analysis of the historical collision trends, current travel speeds and the risks to vulnerable road users must be performed to assess the location of the problem. If the problem is within the transition zone, or within both the transition zone and the local speed zone, then the gateway must be located in the transition zone. If the problems occur primarily in the local speed zone, then the gateway should be located there.

Property Accesses, Intersections and Traffic Control Devices

When a gateway is located near an intersection or access to properties, it is imperative that the visibility of the intersection or access and associated traffic control devices not be impeded. Every effort should be made that any conspicuous vertical roadside elements do not obstruct sight distances to intersections and driveways, including traffic signals, pedestrian crossings and other traffic control devices.

Gateway Visibility

Gateways are most effective when they can be seen in advance by drivers, and drivers can adjust their speeds accordingly. Gateways should be visible from at least the stopping sight distance (as determined by Section B.2.3 of the *Alberta Highway Geometric Design Guide* (1998), Section 1.2.5.2 of the *TAC Geometric Design Guide for Canadian Roads* (1999), or municipal equivalent) of a vehicle travelling at the 85th percentile approach speed at that location.

Care should be taken to ensure that gateways located on large-radius curves are not outside of a driver's cone of vision.

Horizontal Gateway Elements

Creating a "pinch point" is one of the essential characteristics of a gateway. The feeling of a reduced roadway width encourages drivers to slow down. As previously mentioned, this can be done with physical or visual road narrowing measures. Painted visual narrowing measures are less appealing in Alberta, due to the fact that the hatching would likely be obscured my snow for several months of the year. In addition, the wear from ploughs and de-icing agents will require a rigorous maintenance schedule.
The road narrowing should be done over a length of approximately 10 to 20 metres. The minimum roadway width to allow for the passage of oversized vehicles should be considered if the roadway is along a truck route. Parking should be prohibited within the pinch point.

Curb Build-Outs

It is recommended that wherever the roadway width permits, built-out curbs should be considered. Curb build-outs are not appropriate for higher speed roads as they have the potential to launch vehicles that hit them at high speeds into the air. Curbs shall be built to the standards as outlined in the *Alberta Highway Geometric Design Guide* (1998), *Alberta Roadside Design Guide (2007),* TAC *Canadian Guide to Neighbourhood Traffic Calming* (1998) or local standards such as the *City of Calgary Traffic Calming Policy* (Revised 2007).

Pavement Hatching

In the case where the roadway width does not permit built-out curbs, longitudinal hatching along the side of the roadway may be used to visually narrow the roadway. Optical speed bars are also shown to be effective at creating an illusion of higher speeds and reducing vehicle speeds. Highly visible and durable pavement markings are recommended due to Alberta's climate.

Raised Median Islands

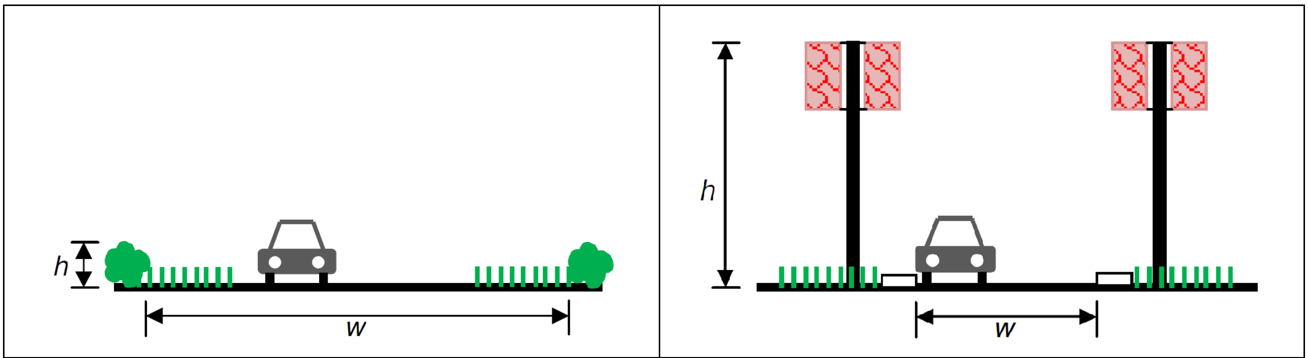
Raised median islands can be considered to reduce the width of the roadway. However, they should only be used at gateways where the reduced speed limit is 60 km/h or lower, and must be properly marked. A minimum island width will ensure motorists can see the median.

Painted Median Islands

In the case where the roadway width does not permit a raised median island, one may be painted to visually narrow the roadway. As with pavement hatching, highly visible and durable pavement markings are recommended due to Alberta's climate.

Vertical Gateway Elements

It is recommended that vertical elements (including speed limit signs mounted on both sides of the roadway) always be used whenever the gateway effect is desired. Vertical elements identify and improve the visibility of the gateway to approaching drivers. It has also been shown that drivers will travel at slower speeds when the height of the vertical elements is greater than the width of the roadway[31] as shown below in FIGURE 3.10.



h<w Optical width that encourages speed | ***h>w*** Optical width that discourages speed

FIGURE 3.10 OPTICAL WIDTH TO DISCOURAGE SPEED

The minimum width to allow for the passage of oversized vehicles through the gateway should be considered if the roadway is along a truck route. In the case where vertical elements restrict the width of the gateway, they should either be mounted on pivoting bases to allow them to swivel out and increase the available width between them, or be easily removable.

[31] LTSA

As with any roadside appurtenances, **crashworthiness must be maintained within the clear zone** as stated in Section C.5.2 of the *Alberta Highway Geometric Design Guide* (1998), Sections 3.1.3 and 3.1.4 of the *TAC Geometric Design Guide for Canadian Roads* (1999) or local municipal standards.

Speed Limit Signs

It is recommended that speed limit signs be installed on both sides of the roadway as a treatment whenever the gateway effect is desired. Common practice in other parts of the world is to combine a speed limit sign with a place name sign. This should be considered if a speed limit sign within another sign is enforceable (the Alberta Traffic Safety Act does not appear to contradict such a practice, but this should be verified). Another issue may be the possible interpretation of the sign to imply that the speed limit shown applies to all roads within the named jurisdiction (i.e. the cross streets).

The appropriate sign colour for the larger sign also needs to be determined; in other countries a single colour has been reserved for gateway application (e.g. green in New Zealand).
FIGURE **3.11** below presents a generic schematic. An alternative to the "sign within a sign" approach is providing oversize speed limit signs and a tab beneath to identify the town.

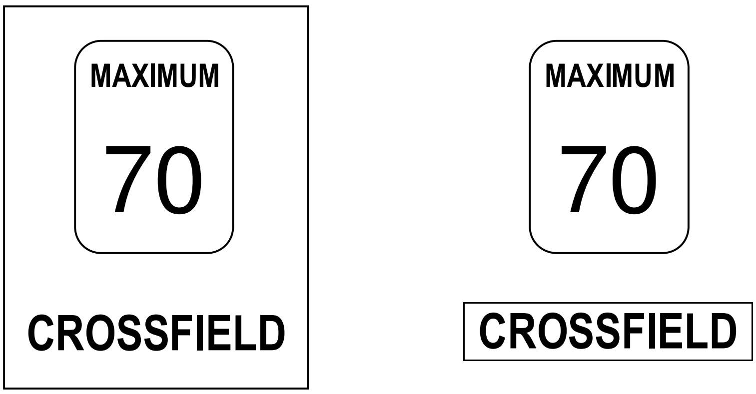


FIGURE 3.11 SPEED LIMIT SIGN DISPLAY OPTIONS

As previously mentioned, the speed limit signs must be within 20 m of the start of the warranted speed zone.

Architectural or Decorative Welcome Signing

It is recommended that an architectural or decorative place name sign be installed on the right or both sides of the roadway whenever the gateway effect is desired. This will alert motorists that they are entering a community and therefore a low-speed environment in which vulnerable road users might be present. In addition, a decorative welcome sign provides an opportunity to advertise community identity. Additional guidance on architectural and decorative place name signs can be found in Alberta Transportation's *Welcome Sign Recommended Practice* (2006).

Illumination

It is recommended that illumination be provided at all gateways where raised medians and curb build-outs are used. This will not only improve the conspicuity of these features at night, but the light standards themselves will also serve as vertical features during the day, and will contribute to the optical height of the gateway.

Walls, Rails and Fences

The benefits of walls, rails and fences as gateway treatments are uncertain; however, they have been briefly mentioned as possible supplementary treatments in existing guidelines. They may be added to increase the conspicuity of the gateway. They may create the "closing-in" effect that is known to cause drivers to slow down. However, walls, rails and fences are considered fixed objects and must be included with caution.

Walls, rails and fences located outside of the clear zone may not serve to provide the desired "closing-in" effect due to their distance from the roadway. In these cases, they are less effective. Walls, rails and fences are likely more effective at lower speed gateways, where the clear zone requirements are less, and they can be positioned more closely to the roadway.

Trees, Flag Poles and Other Vertical Features

It is recommended that vertical features of a height greater than the width of the travelled roadway be used whenever the gateway effect is desired. Trees that provide vertical height may be supplemented with smaller shrubs to provide a "closing-in" effect, where the driver feels as though the pinch point is quite narrow. Coniferous trees and shrubs are preferable as the seasonal loss of leaves on deciduous trees can reduce the conspicuity of the gateway.

Layered landscaping (shown in FIGURE 3.12) may be effective at creating a gateway feeling with the advantage of having smaller, breakaway shrubbery in the clear zone and keeping larger trees outside of the clear zone[32]. Additional guidance on landscaping can be found in Alberta Transportation's *Highway Beautification – Landscape Projects in the Highway Right-Of-Way Recommended Practice* (2006).

FIGURE 3.12 LAYERED LANDSCAPING

Trees, flags and other features shall be positioned so as to avoid creating sight obstructions or excessive shading of the road surface (which may cause ice build up during the winter). Consideration should also be given to maintenance requirements of the feature chosen, and the ease of accessibility to these features. Trees and shrubs need to be pruned regularly to ensure that they do not obstruct sightlines. Additional guidance on decorative elements on poles can be found in Alberta Transportation's *Decorative Features on Street Lights and Signal Poles Recommended Practice* (2007).

Overhead Gateway Elements

Overhead elements (sometimes referred to as "banners") represent perhaps the most emphatic gateway treatment. The benefits of overhead elements as gateway treatments are moderate, although they have not been rigorously evaluated. They have been briefly mentioned as possible supplementary treatments in existing guidelines. Overhead elements increase the conspicuity of a gateway tremendously; however, those safety benefits may be outweighed by the significant cost of these treatments. To ensure that they are of a height and width to properly allow access of all vehicle types is impractical on multilane highways, especially those with large medians.

[32] Determining Effective Roadway Design Treatments for Transitioning From Rural Areas to Urban Areas on State Highways, Final Report, FHWA Report No. FHWA-OR-RD-09-02, September 2008.

These features can be considered for low speed applications on roadways with a narrower right of way, for example, at the entrance of a residential neighbourhood, where heavy vehicles are prohibited. In this context, the clear zone requirements are less stringent (due to the lower speeds and/or the presence of curbs) which increases the feasibility of this feature.

Pavement Surface

A change in the pavement surface adds to the conspicuity of a gateway by making it stand out from its surroundings. Changes to pavement colour or surface type can be considered.

Pavement Colour

A change to the pavement colour through the length of the gateway can be considered to increase the conspicuity of the threshold. The pavement colour cannot be white or yellow and must be selected in accordance with the MUTCD Section 3G.

Additionally, the speed limit can be painted onto the roadway surface in the direction of the decreasing speed limit. This should be done in accordance with the MUTCDC Section 3.

Pavement Surface Change

Bricks or other decorative cobblestones can be used to achieve the same result as coloured pavement. However, care should be taken to ensure that the skid resistance of the pavement is not compromised. In addition, these types of treatments have been found to cause an increase in noise level. In cases where a gateway is near to residences within a city or town, this may pose a problem to residents.

Other Gateway Treatments

Roundabouts

Roundabouts are not specifically mentioned in existing guidelines since they are intersection traffic control devices. However, they can be adapted to function more as a gateway treatment by adding vertical elements and other community identifying features in the centre of the roundabout. Other roadside gateway treatments may be used on the leg that approaches the community, provided that they do not interfere with the sightlines and the operation of the roundabout.

Although roundabouts have a much higher capital cost than many of the other features presented, they also serve a traffic control purpose. This multifunctional solution to traffic control and speed reduction may be quite cost-effective in some situations. Separate guidelines are currently being prepared by the Province to encourage the application of roundabouts at current stop controlled intersections along highways.

Advance Signage

It is recommended that advance warning signs be installed prior to all gateway locations, particularly if sight distances are an issue or if the reduction in speed is greater than 20 km/h. Standard advance speed limit signs (RB-5) can be used on both sides of the road in advance of the required speed reduction to inform drivers that it is approaching. The exact locations of these signs should be determined as per Section A3.6.9 of the Manual of Uniform Traffic Control Devices for Canada (MUTCDC).

In addition, standard Destination Distance guide signs (IA-4) can be used on both sides of the road in advance to remind drivers that they will soon be entering a local community. Multiple signs at various distances may be used to indicate to drivers that they are approaching a community. Signs should be implemented as per Section A4.2.2 of the MUTCDC and using Alberta Transportation's *Calculation of Distances to Communities Recommended Practice* (2007).

Provisions for Vulnerable Road Users

There exist locations where there is a demand for pedestrian and cyclist facilities. In these locations, the preferred course of action is to construct a path around the "pinch point". This allows vulnerable road users to bypass the location where there would be an increased likelihood of collisions due to the narrower right-of-way. An example of such a path can be seen below.

FIGURE 3.13 PEDESTRIAN AND CYCLIST PATH TO BYPASS PINCH POINT

3.1.9 Human Factors

Gateway treatments have highly positive human factors implications in terms of all of the key principles: expectancy, clarity/simplicity, conspicuity, and sensory influence.

If designed properly, the sight distances to gateways should make them visible from a distance. Although there are many features used in one place, they are all features that should be familiar to drivers, and thus are unlikely to catch most drivers off guard.

There has been some argument that too many treatments constitute a visual intrusion and may be counterproductive to road safety[33]. The presence of multiple treatments may appear to have negative impacts for simplicity. However, the only driver action that is required is a reduction in speed; therefore, the message to the driver is simple and clear. Nonetheless, care should be taken that the combination of treatments chosen does not cause distractions to drivers.

Gateway treatments are designed to be conspicuous and highly visible to drivers. The contrast of the features from the surroundings in size, shape, colour, texture and position all serve to make the gateway perceptible to drivers.

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

The sensory influence of gateway treatments is provided by the “closing-in” effect caused by the narrow road and high vertical elements. The “feel” of the roadway environment changes drastically as it appears much narrower than before. This effect causes drivers to subconsciously slow down.

3.1.10 Maintenance Considerations

Certain gateway treatments can be high-maintenance. Trees and other vegetation must be tended and pruned regularly to ensure that they do not obstruct sight distances. Community signs, light standards, flag poles and any other elements must be maintained in working order. As discussed above, due to Alberta’s winter climate, pavement markings will likely require regular maintenance to keep them visible and effective.

Generally, the maintenance of these treatments is fairly simple. However, consideration must be given to the access of these elements, and the ease with which they can be repaired and replaced. Additionally, in the case where a municipality is seeking gateway treatments on a highway entering their jurisdiction, an agreement must be reached between them and the responsible road agency outlining the maintenance responsibilities of each party.

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ALBERTA TRANSPORTATION

METHODS OF REDUCING COLLISIONS ON ALBERTA ROADS

APPLICATION GUIDELINES FOR VARIABLE SPEED LIMITS

FINAL

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3.2 Variable Speed Limits

3.2.1 Background and Definition

A "Variable Speed Limit" (VSL) is a variation on posted speed limit traffic control in which regulatory posted speed limits can be changed. Typically, the speed limits are changed to reflect a safer driving speed along a particular road section, based on the expected or real time conditions, such as traffic, road surface and weather conditions.

Speed limits are considered safest and most appropriate when they reflect the roadway environment. Because static speed limits are set according to ideal conditions (i.e. clear weather and free-flow traffic), they become less effective during variable conditions. Variable speed limits can provide a more real-time and accurate reflection of the prevailing conditions, and hence can improve speed limit compliance, traffic flow and traffic safety.

Variable Speed limits are applied in many parts of the developed world, and most widely in Europe. They are also applied in the United States, and on a very limited basis in Canada. They are proven in leading to safety and operational benefits, which has raised the question of applicability in Canada. The Manual of Uniform Traffic Control Devices for Canada (MUTCDC) makes no reference to Variable Speed Limits as a traffic control measure. While their application in Canada has been limited primarily by the lack of guidance and enabling legislation, this has not been properly investigated for Alberta or Canada.

The Alberta Traffic Safety Plan (2006) identifies Variable Speed Limits as one of the Intelligent Transportation Systems measures to investigate as part of the objective to reduce fatal and injury collisions on rural roads in Alberta.

The purpose of this document is to identify and summarize:

- the proven benefits of Variable Speed Limits in other jurisdictions;
- the situations in which VSL can provide the greatest safety benefits in Alberta; and
- the key legislative and infrastructure requirements for implementing VSL in Alberta.

Although speed limits are typically lowered in construction zones, this application of lower speed limits is excluded from the VSL applications discussed in this document.

3.2.2 Current Status of VSL Systems

International

VSL systems are currently in use throughout the world, with the earliest implementations in Germany and France, and more recent installations in the United Kingdom, Sweden, Finland, the Netherlands, and Austria. Other international locations with VSL include New Zealand and Hong Kong. Most of the systems were installed to slow vehicles in advance of traffic congestion.

Variable speed limits are used to a much lesser extent in the United States. On Interstate 90 at Snoqualmie Pass, Washington, (near Seattle) variable speed limits are used to slow traffic in severe winter weather. This is also done on other mountain passes in Washington. Variable speed limit signs, in combination with variable message signs, have been in use since the 1960s on the New Jersey Turnpike, where officials can adjust the speed limit according to weather, traffic conditions, and construction. Other roadways with variable speed limits include the Pulaski Skyway in New Jersey, I-495 in Delaware and I-270 and I-255 in Missouri.

Canada

The Transport Canada Report *International Road Engineering Safety Countermeasures And Their Applications In The Canadian Context (2009)* states that VSLs have been installed in some parts of Canada. However, no specific locations were identified, and discussions with various municipalities and agencies failed to identify any locations. The MUTCDC neither discusses nor specifically discourages the use of Variable Speed Limits.

Alberta

The Alberta Traffic Safety Act, which sets out the law regarding speed limits in Alberta, states in Section 108 that a road authority may prescribe speed limits that are different from the speed limits stated in Sections 106 and 107 of the Act. For highways, a Ministerial order is required. While the Act doesn't specifically mention Variable Speed Limits, it is assumed that this applies to static speed limits. Secondly, the Act implies that signs are to be provided in accordance with prescribed guidance. The MUTCDC is the recognized national guidance, but doesn't recognize VSL. Therefore, while nothing in the Act prohibits the use of VSL, the interpretation of the existing references to speed limits need to be reviewed by lawyers, and recommendations made to TRANS to expand the definition as required to include VSL.

In Alberta, a reduction in posted speed limit from 90 km/h to 70 km/h is put into operation each year along a section of the Trans Canada Highway between approximately 5 - 6 km west of Lake Louise and 1 km east of Lake Louise. This reduction is initiated by Parks Canada during the summer and fall months (approximately from the May long weekend through to Thanksgiving) to protect the grizzly bear population in the area. Parks Canada reviewed the potential for providing VSL in conjunction with the twinning of the Trans Canada highway through Banff National Park. This objective of this installation would be to address high speeds during poor weather and/or road conditions. However, the study failed to conclusively identify the potential safety benefits of providing VSL, and it is understood that to date VSL has not been implemented on Trans Canada Highway.

A study was recently conducted by the City of Edmonton of the feasibility of applying VSL on the Whitemud Freeway. However, this did not include an evaluation that identified the Whitemud as an appropriate candidate, nor an analysis of the potential safety benefits.

3.2.3 Example Applications

Most VSL systems use electronic displays depicting either the entire sign or just the posted speed limit value. As shown in
FIGURE 3.14, there is a wide variety in the appearance of VSL. The signs may look similar in colour text to regulatory signs as shown in the United States example. Other signs may have a different background colour but are consistent with the standard speed limit sign, as shown in the United Kingdom example where the signs are shown with the standard number inside a red circle. The signs are sometimes supplemented with devices such as flashing lights, flags and message boards. In some cases, information signs in advance of road sections with VSL notify motorists that the speed limits are variable. The change in speed limits can be made with human control (typically based on information provided to a manned control centre) or automatically using sensors (such as loop detectors or temperature gauges).

Interstate 90, Washington

Motorway M25, United Kingdom

Aberdeenshire, Scotland

FIGURE 3.14 EXAMPLES OF VARIABLE SPEED LIMIT SIGNS

3.2.4 Benefits and Costs

Benefits

The two main benefits are collision reductions and speed reductions, both of which are described below. With these two benefits, a third benefit also arises. Fewer collisions and a more uniform traffic speed results in improved mobility.

Collision Reduction

The safety benefits of VSL systems have been widely researched, with the majority of the safety studies referring to applications focused on for traffic congestion. Lind and Lindkvist found that Swedish roads with VSL reduced the rate of injury crashes by 20 percent.[34] Siegener et al found that in Germany, VSL reduced collisions by 15 percent, with greater reductions in sections with higher traffic volumes.[35] The Government of the United Kingdom has documented injury collision reductions of 15 percent along the M25 Motorway.[36]

[34] Lind, G., and Linkvist, A. Traffic Controlled Variable Speed Limits, Sweden. TEMPO Evaluation Expert Group, European Commission, 2009.
[35] Siegener, W., Trager, K., Martin, K., and Beck, T. Accident occurrence in the area of route information and management systems, allowing particularly for traffic load. IVT Ingenieurburo fur Verkehrstechnik GmbH. BAST, 2000
[36] United Kingdom Department for Transport. M25 Controlled Motorway - Results of the first Two Years. 1998.

There are fewer studies documenting collision reductions for lower-volume roads. A study for VSL-related lane control during wet weather along the Kolner Ring Road in Germany found wet weather crash reductions of 10 percent, of which injury crashes were reduced by 20 percent.[37]

There have been other studies that rely on models and simulations. Abdel-Aty et al found that VSL can reduce rear-end and lane-change crash risks[38]. The study also showed that safety benefits are more likely in congested conditions as opposed to low-volume conditions.

Vehicle Speed Reduction

The effects of VSL on vehicle speeds have been studied at various levels. Studies have shown that effectiveness appears to be higher when VSL is in the context of poor road or weather conditions, with speed reductions from 8 to 10 km/h during fog conditions[39], 13 to 14 km/h during severe surface conditions[40], and 7.5 mph during wet and dark conditions.[41] In contrast, the speed reductions related to congestion areas is lower along areas that are not congested, unless there is visible enforcement or messages stating that congestion is ahead.

Since drivers tend to drive at what they feel is the appropriate safe speed, regardless of the posted speed limit, it appears that unless there are visible reasons to drive more slowly (such as inclement weather or poor visibility), other supplementing measures such as enforcement or messages are needed to achieve significant speed reductions. Although not all studies reviewing vehicle speed impacts explicitly note the safety benefits, it is implied that slower travel speeds will have a positive safety effect.

Costs

The cost of VSL depends on the sign structure type used. If roadside signs are used, they are estimated (based on TRANS 2010 *Unit Price Averages Report*) to cost $1000 per new sign, plus an additional $200 per sign to be removed. For overhead signs, the cost was estimated to be $300,000 per sign. Annual M&O costs were assumed to be $2500.

[37] United Kingdom Department for Transport. Overhead Dynamic Lane Control on the A3 Kolner Ring (Leverkusen to Heumar), Germany, 1998.
[38] Abdel-Aty, M., Cunningham, R.J., Gayah, V.V., and Hsia L. Considering Dynamic Variable Speed Limit Strategies for Real-Time Crash Risk Reduction on Freeways, Transportation Research Board (TRB) Annual Meetings, Washington DC, 2008.
[39] Netherlands Urban - A16 near Breda
[40] Lind, G. Effects of traffic and weather controlled variable speed limits in Sweden. Proceedings of the 6th European Congress and Exhibition on Intelligent Transport Systems and Services, 18-20 June 2007, Aalborg, Denmark.
[41] Examples of Variable Speed Limit Applications, Speed Management Workshop, 2000 TRB Annual Meeting

In addition to VSL, there will be other complementing devices such as message boards, detectors, and/or cameras for real-time monitoring. Information signs advising motorists of the approaching VSL system should also be considered. Note that the costs of these extra devices were not included in the cost estimate.

3.2.5 Existing Guidance

Regulatory Guidance

Hines and McDaniel examined the legal issues in the United States that may arise from implementation and enforcement of variable speed limits. Their study found that in general the legal issues that will arise should be no different from the legal issues that have been considered by courts in adjudicating alleged violations of prima facie speed limits and other fixed maximum speed limits. Although their study was specific to the United States, the legal issues discussed may potentially be pertinent in Alberta. That said, Division 1, Section 108 of the Alberta Traffic Safety Act indicates that a road authority may set speed limits that are different from "standard speed limits" set in Section 106 and 107 given certain situations. It is expected that VSL would not only be enforceable but would sustain any legal challenges if the Alberta Traffic Safety Act is edited to include the governance and application of VSL similar to Division 1.

Application Guidance

Based on the literature review, VSL can be implemented along any location (rural or urban), road classification, prevailing posted speed limit, or terrain.

There are no clearly documented engineering guidelines for the application of VSL. However, most existing applications are provided in the following circumstances:

- Recurring congestion
- Variable road or weather conditions
- Variable surface conditions
- Incidents
- Long-term construction zones

There are no references in the literature to collision thresholds above which VSL should be considered.

3.2.6 Recommended Guidance

Based on the findings to date, the following procedures are recommended to be addressed in Alberta to effectively implement Variable Speed Limits:

Enabling Legislation

All matters addressing the legality of VSL should be addressed to ensure that not only are VSL considered to be regulatory, but also enforceable. Consultation with legal professionals will be required. Statutes written into the Alberta Traffic Safety Act should be addressed first, such as explicitly stating that VSL signs are considered to be legal posted speed limit signs, and that the signs may display different speed limits. These clauses would be required so a Ministerial Order isn't required to change a speed limit on VSL signs. Alternatively, a pilot study with VSL could be undertaken to test its effectiveness, with the understanding that police cannot enforce the posted VSL. To ease enforcement of VSL as well as gain motorists' respect of the signs, the appearance of the VSL sign should be close to existing posted speed signs.

3.2.7 Application Guidance

Land Use and Speed Context

The recommended land use and speed environments for the application of VSL are summarized in TABLE 3.8. VSL are typically provided on freeways, where movement is free-flow outside of peak traffic periods and not influenced by traffic control devices such as traffic signals. Based on current worldwide applications, they would be most commonly provided for congestion relief in more urbanized areas, and for weather/road conditions in more rural areas.

TABLE 3.8 ACCEPTABLE LAND USE AND SPEED RANGES FOR VARIABLE SPEED LIMITS

LAND USE	POSTED SPEED LIMIT (km/h)			
	50 or less	60 - 70	80 - 90	100 or more
Rural	-	-	✓	✓
Urban**	-	-	✓	✓
Semi-Urban / Suburban	-	-	✓	✓

***appropriate along freeways, but not arterial roads*

Application Criteria

VSL are best suited at locations where the existing posted speed limit frequently becomes unsafe due to vehicle congestion or inclement weather. Further review of the location would need to be undertaken to determine the safe and appropriate speed to display, as well as the length of the applicable section.

- *Congestion Management*: along roadways where recurring congestion occurs and that there is a safety issue due to unexpected lower speeds. In Alberta, this would include freeways such as Deerfoot Trail in Calgary and Whitemud Trail in Edmonton.
- *Variable Road or Weather Conditions*: along sections of road that have a history of encountering road or weather conditions where the safe driving speed is different than under normal circumstance. This can include locations that are prone to fog, or locations where the formation of ice significantly reduces the roadway friction factor. This can include valleys, sag curves, bridge decks and locations near bodies of water.
- *Incidents*: at locations where incidents such as stopped vehicles or crashes requiring vehicles to stop along the road may result in the need for slower speeds. VSL would be particularly helpful where there are minimal shoulder facilities for the safe refuge of vehicles involved in incidents, or where rubbernecking is more likely to cause further incidents.

3.2.8 Implementation Considerations

For locations where it is deemed appropriate to provide VSL, review of the following implementation considerations is expected to maximize its effectiveness.

Appearance and Visibility

Based on the literature findings, the following practices are suggested:

- To gain respect of the VSL signs from motorists, as well as make it easier to legally enforce, the signs should be close in appearance to typical regulatory posted speed limits.
- For better driver compliance, complimentary supplemental signs and/or messages describing any road conditions should be provided. This includes circumstances such as queues, congestion, incidents, or poor road/weather conditions.
- Information signs in advance of sections with VSL should be provided to inform motorists that the speed limits can change.
- To maximize sign visibility, especially for multi-lane roads, the signs should be provided on both sides of the road or overhead.

FIGURE 3.15 EXAMPLE OF SIGN INFORMING MOTORISTS OF VSL

Other Installation Considerations

Other more specific installation considerations are as follows:

- Policies as to when and for how long the posted speeds displayed in the VSL systems change is typically determined to the road agency.
- In general, the minimum speed zone length is approximately 1 kilometre. Therefore any VSL system should be enforceable for at least that distance.

- Studies indicate that differences in posted speed limit zones should not be greater than 20km/h. Therefore unless there are unusual or severe circumstances, it is suggested that the lower speed in a VSL system not be greater than 20km/h difference from the previous posted speed. Conversely, the VSL system could be set up to include step-down speed zones if the section is long enough.
- Whether the posted speeds displayed in the VSL system is manually controlled or not will depend on the road agency. However, it is understood that various other devices such as cameras (if monitoring real-time congestion or incidents), road sensors (if monitoring temperature or queues) will likely need to be installed.
- Studies have documented that some type of visible enforcement will be required from time to time.

Issues Limiting Safety Effectiveness

While VSL have proven and potential safety benefits, they also bring a set of issues that may increase the liability of the road authority and possibly limit their effectiveness:

- Drivers come to rely on variable speed limits to warn of dangers. Should the speed limits fail to operate, the driver will proceed unaware of the danger or expect that no danger lies ahead.
- Potential liability issues as the system places a greater amount of responsibility for proper selection of speed under prevailing conditions on the engineers and less on the drivers.
- The benefits of variable speed limits, like static speed limits, will be limited by the ability of the police to enforce them. As well, issues such as conflicting documentation of the posted speed limit displayed at the time of the infraction will further hinder enforcement.
- Situations where there are advisory speed limits (such as along a sharp curve) within a section where VSL may be implemented may make the posted VSL at those locations unsafe. These issues would need to be reviewed on a site-specific case, and may potentially exclude the use of VSL at that location.
- Public education will need to be provided to clarify to the driving population that variable speeds limits are regulatory, not advisory. Drivers will still need to drive to the conditions.

3.2.9 Human Factors Considerations

A well designed and managed VSL is based on good human factors design, since it reflects the speed that drivers typically consider reasonable. As well, they provide warning of upcoming change in conditions, which supports expectancy and reduced surprises, as well as provides legitimacy to the reduced speed limit. As long as the information provided on the VSL is reliable and reasonable, it can substantially reduce driver stress, which in turn can improve safety. As well, the appearance of VSL should be of signs that are legitimate and enforceable; therefore the signs displaying the posted speed limit should be close in appearance to typical posted speed limit signs.

3.2.10 Maintenance Considerations

As motorists rely on VSL systems to notify them of the appropriate speed limit, the maintenance of VSL systems is important. Any need to repair or service the system should be made promptly. Scheduled inspection of such systems, continual monitoring when operating, and testing is also generally suggested.

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ALBERTA TRANSPORTATION

METHODS OF REDUCING COLLISIONS ON ALBERTA ROADS

APPLICATION GUIDELINES FOR CONVERSION OF STOP-CONTROLLED INTERSECTIONS TO ROUNDABOUTS

FINAL

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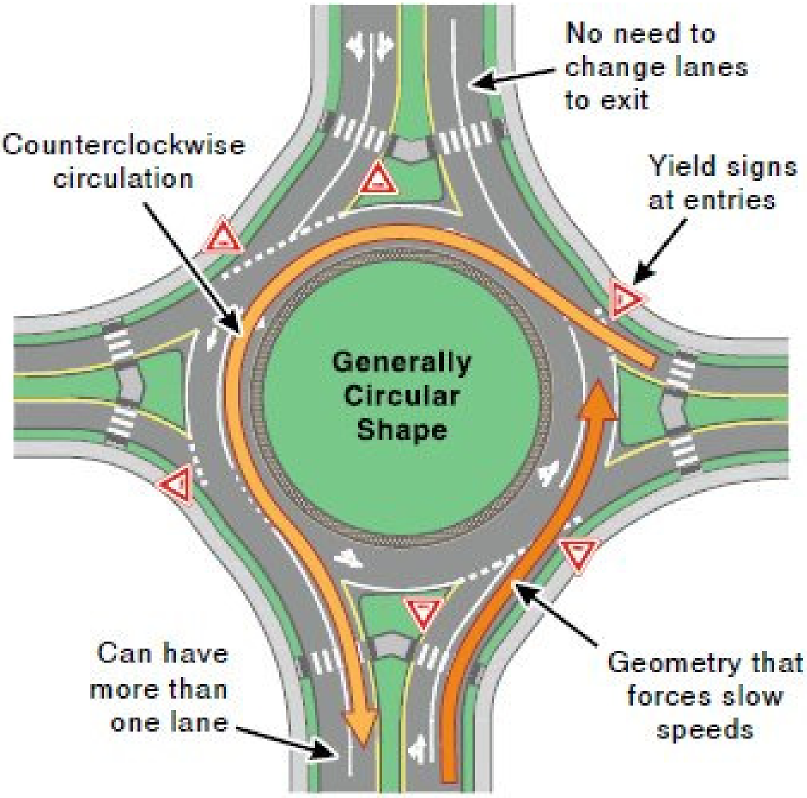
3.3 Conversion of Stop-controlled Intersections to Roundabouts

3.3.1 Background

A high proportion of the major injuries and fatalities in Alberta occur at stop-controlled intersections. The results of treatments to enhance the stop control (such as oversize signs and flashing beacons) have been mixed, but the benefits are generally limited. Therefore, modern roundabouts, although historically more commonly applied in lower-speed or urbanized situations in Alberta, have recently been more seriously considered at two-way stop-controlled highway intersections. However, no clear guidance was provided in industry documents for this specific application until Design Bulletin 68 was issued in May 2010.



Source: Federal Highway Administration Roundabouts Technical Summary (2010)

Roundabouts have been successfully implemented in numerous countries, providing benefits to both road agencies and road users. Benefits include reductions in collision severity, improved traffic operations, reduced vehicle speeds, reductions in vehicular delays and reduced greenhouse gas emissions.

Roundabouts have been proven to significantly reduce high severity collisions at intersections by reducing the number of conflict points and the risk of high speed right-angle and left-turn across path collisions.

While it is recognized that the effective application of roundabouts is highly context sensitive and therefore difficult and potentially unwise to construct roundabouts without further analysis in, the purpose of this document is to encourage their more widespread but systematic consideration where safety problems persist. It also promotes the consideration of roundabouts at all new intersections, but provides examples of exceptions. This document supplements Alberta Transportation's Roundabout Guideline.

3.3.2 Definitions

Modern Roundabout: A modern roundabout (hereafter referred to as a roundabout) is a circular intersection designed for improved traffic flow and reduced collision risks. Traffic circulates in a counter-clockwise direction around a centre island. Motorists entering the roundabout must yield to traffic already in the roundabout. Once in the roundabout, motorists must yield the right of way to vehicles on their left.

Traffic Circle: Roundabouts are often confused with older traffic circles or rotaries that have suffered from poor safety and operational performance. Traffic circles do not have specific uniform rules for driving in them. They operate differently from a roundabout as traffic in the circle is sometimes required to yield to traffic entering the circle, which can result in high entry speeds and large diameter circles. Roundabouts have been proven to have a better safety performance than traffic circles and conventional intersections.

3.3.3 Current Status in Alberta

Roundabouts have started to be implemented in Alberta over the past decade. Numerous low speed urban roundabouts have been implemented in the province and a few roundabouts have been constructed at provincial highway intersections such as:

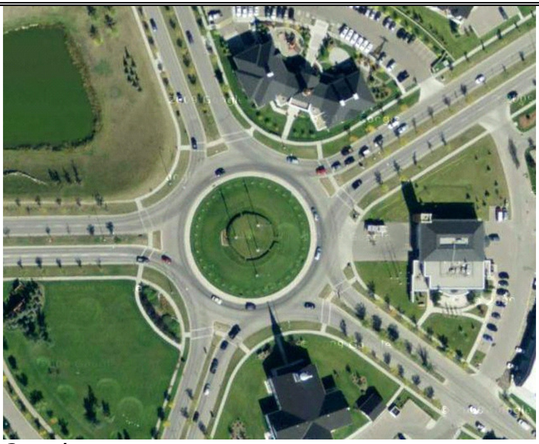
- Highway 8 and Highway 22 near Bragg Creek;
- Highway 11A and Highway 20 near Sylvan Lake;
- Highway 63 and King Street Interchange in Fort McMurray; and,
- Highway 744, 96 Avenue and 100 Street in Peace River.

Roundabouts are more common outside of Alberta: in other parts of Canada (such as British Columbia), the United States and abroad.

3.3.4 Example Applications

Roundabouts can be an appropriate and effective traffic control device for a wide variety of applications. Although roundabouts are more common on low speed urban roadways, they can also be applied on high speed roads and in rural contexts. TABLE 3.9 illustrates examples of roundabouts in Alberta with different road classifications and land uses.

TABLE 3.9 ROUNDABOUT EXAMPLE APPLICATIONS IN ALBERTA

Roundabout Location McKenzie Towne Blvd., Inverness Gate, McKenzie Towne Gate and Prestwick Blvd. Intersection Calgary, Alberta Roundabout Description Multilane roundabout located at the intersection of five low-speed local arterial roads. Roundabout is located in an urban area and provides provisions for pedestrians.	 *Source: Googlemaps.com*
Roundabout Location Highway 8 and Highway 22 Intersection Bragg Creek, Alberta Roundabout Description Roundabout located at the intersection of two high speed (100 km/h) rural highways. Posted speed limits are reduced in the vicinity of the roundabout.	 *Source: Alberta Transportation*

Roundabout Location Highway 63 and King Street Interchange Fort McMurray, Alberta Roundabout Description Roundabout located at the intersection of King Street (local arterial) and the exit and entrance ramps of Highway 63 (high speed highway).	 *Source: Alberta Transportation*

3.3.5 Benefits and Costs

Collision Reduction Benefits

A well designed modern roundabout can improve the safety of intersections by eliminating or altering conflict types, by reducing speed differentials at intersections, and by decreasing speeds through the intersection. The safety benefits of roundabouts include:

- traffic moves at slower speeds;
- fewer conflict points for pedestrians and motorists;
- reduced potential for right angle (t-bone) collisions; and,
- elimination of head-on and high speed collisions.

Roundabouts have a well documented history of reducing the frequency of higher severity collisions. **TABLE 3.10** provides a summary of the collision reduction factors identified in the National Cooperative Highway Research Program's (NCHRP) *Report 572: Roundabouts in the United States* (2007). The expected collision reduction varies depending on the characteristics of the roundabout, such as the previous traffic control, land use, number of legs and number of circulatory lanes. The results indicate that even in the rural context, where roundabouts are less common, 72% to 87% of collisions are eliminated following the installation of modern roundabouts.

TABLE 3.10 RESULTS OF BEFORE-AND-AFTER ANALYSIS OF ROUNDABOUTS

Previous Traffic Control	Collision Severity	Land Use	Number of Circulatory Lanes (if known)	Collision Reduction
2-Way Stop Control	All	All	-	44%
2-Way Stop Control	All	Rural	1 lane	72%
2-Way Stop Control	All	Urban	-	31%
2-Way Stop Control	All	Urban	1 lane	56%
2-Way Stop Control	All	Urban	2 lane	18%
2-Way Stop Control	Fatal / Injury	All	-	82%
2-Way Stop Control	Fatal / Injury	Rural	1 lane	87%
2-Way Stop Control	Fatal / Injury	Urban	-	74%
2-Way Stop Control	Fatal / Injury	Urban	1 lane	78%
2-Way Stop Control	Fatal / Injury	Urban	2 lane	72%

The average collision reduction for converting urban and rural intersections to roundabouts is summarized in TABLE 3.11.

TABLE 3.11 AVERAGE COLLISION REDUCTION FACTORS

Land Use	Previous Traffic Control	Reduction of All Collisions	Reduction of Injury and Fatal Collisions
Urban	2-Way Stop Control	35%	75%
Rural	2-Way Stop Control	72%	87%

Operational / Maintenance Benefits

In addition to the safety benefits of roundabouts, there are some additional benefits such as:

- Vehicles using a roundabout are not always forced to stop, which reduces delays, congestion, noise, fuel consumption and emissions.
- Roundabouts have lower operation and maintenance costs than traffic signals.
- Roundabouts can effectively and safely slow traffic while still improving traffic flow.
- Roundabouts are generally accepted as being more aesthetically pleasing than signals.
- Roundabouts can emphasize the transition from a rural to an urban environment.
- U-turn movements can be safely accommodated at roundabouts.

Costs

The cost of constructing a roundabout at an existing stop-controlled intersection was estimated to be approximately $250,000. This does not take into account any property acquisition or service relocation costs. Annual M&O costs were assumed to be $3000.

3.3.6 Existing Application Guidance

National Guidance

The Transportation Association of Canada's (TAC) *Synthesis of North American Roundabout Practice* (2008), provides a summary of best practices related to the application and implementation of roundabouts. The report is a reference document and is not intended to be a national guidance document.

The TAC *Geometric Design Guide for Canadian Roads* (2007) provides guidance for the design of roundabouts but limited application guidance.

Provincial Guidance

Guidance for the application of roundabouts on Alberta highways is documented in a recent design bulletin issued by Alberta Transportation entitled *Design Bulletin #68: Roundabout Design Guidelines on Provincial Highways* (2010).

http://www.transportation.alberta.ca/Content/docType233/Production/DesignBulletin68.pdf

The design bulletins supplement Alberta Transportation's *Highway Geometric Design Guide* (1999).

The design bulletin supersedes a previous bulletin (#31) concerning the policy and guidelines for the use of roundabouts on roadways under Alberta Transportation's direction and control.

Municipal Guidance

No municipal guidelines or policies for the application of roundabouts were identified in Alberta. A roundabout policy for the City of Calgary is currently under development.

International Guidance

One of the most commonly used roundabout documents is the United States Federal Highway Administration's (FHWA) *Roundabouts: An Informational Guide* (2000).

http://www.tfhrc.gov/safety/00-067.pdf

This comprehensive document provides information on roundabout policies, planning, operations, safety and design. However, detailed application guidance is not provided. A second edition of this document is planned to be published in 2010.

Other relevant resources for the application of roundabouts include:

- National Cooperative Highway Research Program's (NCHRP) *Report 572: Roundabouts in the United States* (2007), http://trb.org/publications/nchrp/nchrp_rpt_572.pdf ;
- Ourston Roundabout Engineering's *Roundabout Design Guidelines* (2001);
- Austroads' *Guide to Traffic Engineering Practice Part 6: Roundabouts* (1993); and,
- NCHRP's *Synthesis 264, "Modern Roundabout Practice in the United States"* (1998). http://trb.org/publications/nchrp/nchrp_syn_264.pdf

Although the focus of the above documents is the design and implementation of roundabouts, there is some application guidance provided, such as discussing appropriate and inappropriate locations for roundabouts. The key application guidance from these documents has been incorporated into these guidelines. The references are provided in case further information is required.

3.3.7 Recommended Application Guidance

The focus of these guidelines is the reduction of high severity collisions at stop controlled intersections. As such, the focus is on higher speed roads (70 km/h or greater) where the risk of high severity collisions prevails. Although roundabouts provide similar safety and operational benefits for lower speed roads, the focus of this section will be on the high speed context.
In addition to safety, roundabouts can be implemented to improve traffic operations and/or for traffic calming (i.e. to reduce traffic volumes and/or shortcutting on lower class roads). These guidelines focus on the application of roundabouts to improve traffic safety, specifically the reduction of high severity collisions.

Guidance for the application of roundabouts to address traffic operations and/or traffic calming can be found in the following documents (note, this list is not comprehensive):

Traffic Operations

- Alberta Transportation's Roundabout Technical Guidelines (2010);
- National Cooperative Highway Research Program's *Report 572: Roundabouts in the United States* (2007); and,
- Transportation Research Board's *Highway Capacity Manual* (2010).

Traffic Calming

- City of Calgary *Traffic Calming Policy* (2007); and,
- Transportation Association of Canada's *Canadian Guide to Neighbourhood Traffic Calming* (1998).

Guidance for the application of roundabouts with the objective of reducing high severity collisions is provided in the following subsections.

3.3.8 Land Use and Speed Context

Land Use

Roundabouts are appropriate for both urban and rural areas in the appropriate application. Their design may vary depending on the land use; this is discussed among the implementation considerations.

Speed Ranges

Roundabouts are designed to operate at low operating speeds. Therefore, the posted speed limit in the vicinity of the roundabout should be low (typically 40 km/h to 50 km/h, depending on the inscribed diameter). This does not preclude the use of roundabouts on higher speed roads, but they would require a reduced speed zone in the vicinity of the roundabout.
The land use and speed environments where the installation of a roundabout is acceptable is summarized in TABLE 3.12. All land use and speed contexts can potentially be appropriate; their use may be limited by other factors, described in subsequent sections.

TABLE 3.12 ACCEPTABLE LAND USE AND SPEED RANGES FOR ROUNDABOUTS

LAND USE	POSTED SPEED LIMIT (km/h)			
	50 or less	60 – 70*	80 – 90*	100 or more*
Rural	✓	✓	✓	✓
Urban	✓	✓	✓	✓
Semi-Urban / Suburban	✓	✓	✓	✓

*Roundabouts can be implemented on higher speed roads. However, a reduced speed zone in the vicinity of the roundabout is required.

Locations Where Roundabouts are Discouraged

Roundabouts are generally among the preferred options for most intersections. However; there are some locations where the implementation of a roundabout is undesirable. A summary of these locations is provided below and is intended to save unnecessary analysis and debate:

- Locations where the major road carries a very high through volume, with a minimum volume of left-turn traffic, and intersecting roads have a low volume;
- Existing Freeways;
- Roads which are identified as "future freeways" (unless the use of a roundabout for an interim stage is compatible with the staging plan);
- National highway routes where the posted speed is expected to be at least 90 km/h unless the roundabout with lower speed is considered compatible with a staged plan (for example, in a low speed urban environment where the ultimate plan is to by-pass the urban centre); and,
- Where the preservation of a high speed road is both highly desirable and feasible (using options other than a roundabout).

Locations Where Roundabouts are Encouraged

Due to the safety and operational benefits associated with them, roundabouts should be considered as the first option for intersection designs where a greater degree of traffic control than a two-way stop is required (e.g. a traffic signal or a four-way stop).

If a different intersection treatment is recommended, the project documentation should clearly explain why a roundabout was not selected for that location (e.g. a geometric constraint or a capacity problem).

Locations where roundabouts are favoured include:

- Where there is a need for traffic calming such as at the boundary between urban and rural environments (gateway treatment), between high speed and lower speed roadways and/or between divided highways and undivided highway (such as interchange ramp terminals).
- Where there is a desire to provide a corridor with a series of consistent intersection layouts (all roundabouts) such as at all interchange terminals along a route or at all at-grade intersections along an arterial roadway.
- Locations where the intersecting road traffic volumes are similar and/or there is a large volume of left turns from the major road.
- Locations where the geometrics are not favourable for a conventional intersection, such as skewed intersections and intersections with five or more legs.
- Intersections with a high rate of high severity right-angle and/or left-turn across path collisions.

Further application guidance is provided in the following subsections.

3.3.9 Application Criteria

The application guidance has been separated into two categories; Existing Intersections and New or Upgraded Intersections (Design).

Criteria for the applicability of a roundabout have been considered separately for each category and are presented below.

It should be noted that there are lower cost improvements that can be implemented to reduce the risk of high severity collisions at stop controlled intersections. These improvements include, but are not limited to stop control enhancements, such as oversized stop signs, stop ahead warning signs and transverse rumble strips. Although these improvements can reduce the risk of collisions at stop controlled intersections, they are not nearly as effective as the implementation of a roundabout.

Existing Intersections

A. Application Criteria

Based on Alberta Transportation's Design Bulletin #68, the conversion of an existing stop controlled intersection to a roundabout should be triggered by any of the following:

1. the need to provide a higher degree of traffic control than a "two-way stop control";
2. a clear economic benefit based on safety and other considerations under current traffic conditions; or,
3. implementation of a traffic calming measure based on sound engineering judgment.

The capacity analysis and traffic calming triggers are not discussed in this document (references for these triggers are provided in the Recommended Application Guidance section). The safety criterion for the application of roundabouts (criterion #2 above) is further defined in Section B.

B. Safety Criterion

Due to the variation in existing site conditions and construction costs, it is difficult to assign a quantitative safety trigger that works in all situations. In general, the evaluation of a stop control to roundabout conversion should be considered (from a safety perspective) if:

- The intersection is stop controlled;
- The posted speed limit on the uncontrolled road is 70 km/h or greater (due to the high severity of collisions); and,
- There is a history of high severity right-angle or left-turn across path collisions.

An economic evaluation should be conducted to determine the benefits and costs associated with the implementation of a roundabout. The safety benefits of roundabouts are defined as the societal cost savings due to the reduction in the number of, and severity of vehicle collisions. The safety benefits can be determined as follows:

- Determine the existing fatal, injury and property damage only collision rates for the intersection.
- Estimate the expected collision reduction, for each severity, expected due to the implementation of a roundabout. The expected collision reductions are provided in TABLE 3.11
- Multiply the existing collision rate by the expected reduction in collisions to determine the collision rates expected after the implementation of a roundabout.
- Calculate the frequency of collisions expected over the life of the project by multiplying the "after" collision rate by the expected number of vehicles entering the intersection over the life of the project.
- Determine the cost of collisions after implementation of a roundabout by multiplying the number of collisions for each level of severity by the societal cost of collisions. The societal collision costs for collisions in Alberta are provided in TABLE 3.13.

TABLE 3.13 SOCIETAL COLLISION COSTS IN ALBERTA

SEVERITY	SOCIETAL COLLISION COST*
Fatal	$1,345,068
Injury	$100,000
Property Damage Only	$12,000

**The societal collision costs are based on Alberta Transportation's 2009 values.*

The benefits (safety, operational and environmental) and costs (construction, operation and maintenance) should be quantified on an annualized basis such that it is readily usable in a benefit-cost analysis.

Information on how the operational and environmental benefits and construction and maintenance costs can be determined is available in FHWA's *Roundabouts: An Informational Guide*, Sections 3.7.2.2 through 3.7.3.2.

If it is determined that a roundabout is favourable from a safety perspective, an analysis of traffic operations should be reviewed to determine if a roundabout is feasible from an operations perspective.

Application at New or Upgraded Intersections (Design Stage)

A. Application Criteria

If it is determined through capacity analysis during the design stage that a two-way stop controlled intersection warrants a signal or a four-way stop control within 10 years of the proposed project, a roundabout should be considered as the first option for intersection design.

B. Safety Criterion

The safety trigger to evaluate the need for a roundabout when upgrading an intersection treatment is the same as evaluating existing intersections as collision data should be available.

In the case of new intersections, the collision history is non-existent. If local stop controlled intersection collision prediction models are available, the expected frequency of collisions could be estimated and a benefit/cost analysis conducted to determine if a roundabout is economically favourable.

The design AADT's can also be reviewed to identify potential safety issues. If the proportion of major and minor road traffic volumes are similar or there is inadequate capacity for left-turn movements from the major road, a roundabout may improve traffic operations while at the same time reducing the risk of right-angle and left-turn across path collisions.

Potential Application Constraints

These guidelines are intended to help practitioners identify when a roundabout should be considered for implementation; they do not cover feasibility or constructability issues. However, some general implementation considerations have been identified in the Implementation Considerations section, including potential constraints that could make the implementation of a roundabout unfeasible. As roundabouts have high construction costs, design constraints should be identified and evaluated, and mitigation options considered to determine if a roundabout is a feasible traffic control option in the early stages of planning.

3.3.10 Human Factors

There are some positive and negative human factors characteristics associated with roundabouts. Some of the benefits include:

- Motorists don't have to look for and judge gaps in high speed traffic, where an error in judgement could contribute to a collision;
- Reduced driver workload at each leg;
- Visibility of conflicting vehicles is improved; and,
- Lower speeds reduce the decision sight distances required by motorists, and reduce collision severity (to motorists, pedestrians, and cyclists).

Some of the drawbacks include:

- Roundabouts are still a relative new traffic control in Alberta and not all motorists are aware how to negotiate them properly, which can result in conflicts. Education may be required to inform motorists how to drive in a roundabout;
- Roundabouts create challenges for cyclists that may not know how to negotiate a roundabout. Likewise, motorists may be unaware of how cyclists are intended to use the roundabout;
- Motorists in the roundabout may not anticipate pedestrians crossing the exit leg. Likewise, motorists entering the roundabout, looking left for a gap in traffic, may not anticipate or see a conflict (pedestrian) approaching from the right; and,
- Roundabouts can present challenges for visually impaired pedestrians.

Designers should also limit the use of signage at roundabouts to just what is required. This will help to minimize clutter and information over-load.

3.3.11 Implementation Considerations

The actual design and construction of roundabouts is not covered in this document. However, some general implementation considerations are provided below:

- Roundabouts typically have a larger footprint than conventional intersections. Therefore, acquiring the right-of-way required for a roundabout could be difficult or costly.

- Since roundabouts are relatively unfamiliar, there implementation is often resisted by the public. Studies have shown that although acceptance of a roundabout is low prior to construction, it is typically high once the roundabout is in operation.
- Capacity analysis should be conducted to evaluate how the roundabout will function and any implications it might have at other locations, such as neighbouring intersections, driveways or railway crossings.
- The vehicle types that will be using the roundabout will need to be considered. Larger vehicles may require larger roundabouts or aprons to accommodate their turning radius.
- Pedestrian and bicycle operations and safety need to be considered closely to ensure their needs can be accommodated in the design.
- Geometric conditions must be reviewed. Roundabouts are most suitable where gradients on the through alignments or approaches are less than two percent along the travelling direction within a roundabout. Sight lines on approaches should provide adequate decision sight distance in advance of the roundabout.

More detailed implementation guidelines are provided in the following documents:

- Alberta Transportations' *Design Bulletin #68: Roundabout Design Guidelines on Provincial Highways* (2010);
- FHWA's *Roundabouts: An Informational Guide* (2000); and,
- TAC's *Synthesis of North American Roundabout Practice* (2008).

3.3.12 Maintenance Considerations

Maintenance costs of roundabouts are typically higher than stop controlled intersections due to the additional pavement area and signs required at roundabouts. Roundabouts require night time illumination; therefore, the costs to electrify and maintain the illumination are typically higher than stop controlled intersections.

The maintenance costs associated with traffic signals are typically higher than roundabouts.

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ALBERTA TRANSPORTATION

METHODS OF REDUCING COLLISIONS ON ALBERTA ROADS

APPLICATION GUIDELINES FOR POSITIVE OFFSET LEFT-TURN LANES

FINAL

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3.4 Positive Offset Left-turn Lanes

3.4.1 Background

Left-turns are one of the most challenging manoeuvres that exist in the road network, and are among the leading causes of collisions, including fatalities and injuries, at intersections. During a left-turn at a signalized intersection, vehicles in the opposing left-turn lanes can impede the view of conflicting through traffic. All drivers (aging drivers in particular) have difficulty gaining an effective view of opposing traffic and successfully selecting a gap in traffic.

It is possible to remove opposing traffic as an obstruction by offsetting the left-turn lanes laterally. When the two opposite left-turn lanes are directly aligned with each other, the offset is zero. A negative offset is achieved when the left-turn lanes are moved to the right of one another, and a positive offset (FIGURE 3.16) is achieved when they are moved left.

While this practice is encouraged, it is not standard in any Alberta jurisdictions. The purpose of this document is to encourage their more widespread and systematic consideration at *signalized* intersections. The literature on safety benefits of positive offset left turn lanes at *unsignalized* intersections is limited and has not been addressed in this guideline.

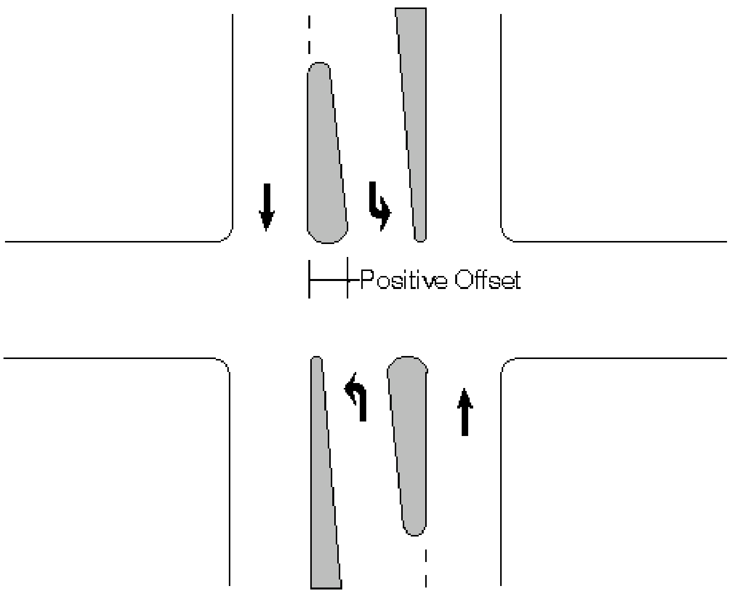


FIGURE 3.16 POSITIVE OFFSET LEFT-TURN LANE CONCEPT

3.4.2 Definitions

Positive Offset: The arrangement of left-turn lanes to the left of one another, i.e.: when positioned in the left-turn lane, the left edge of the opposing left-turn lane is offset to the right.

Negative Offset: The arrangement of left-turn lanes to the right of one another, i.e.: when positioned in the left-turn lane, the left edge of the opposing left-turn lane is offset to the left.

3.4.3 Example Applications

Positive offset left-turn lanes are in place in several Alberta municipalities and along provincial roadways, most commonly at high volume urban and suburban intersections; however, also applied in rural situations. Example applications of positive offset left-turn lanes are shown below. FIGURE 3.17 shows a dual left-turn lane application while FIGURE 3.18 and FIGURE 3.19 show a single left-turn lane application in urban and rural environments.

FIGURE 3.17 DUAL POSITIVE OFFSET LEFT-TURN LANE (SUBURBAN)

FIGURE 3.18 SINGLE POSITIVE OFFSET LEFT-TURN LANE (URBAN)

FIGURE 3.19 SINGLE POSITIVE OFFSET LEFT TURN LANE (RURAL)

3.4.4 Benefits and Costs

Benefits

The benefits of providing positive offset left-turn lanes can be expressed in terms of safety, capacity, and truck operations. The safety benefits are highlighted here.

Positive offset left-turn lanes situate vehicles further to the left on the approach, which enhances safety for permissive left-turn movements by providing additional sight distance to aid in the gap assessment aspect of the decision making process. Moreover, positive offset left-turn lanes have been found to be particularly beneficial for older drivers[42] due to the decrease in the critical gap required by a driver making a left-turn from a left-turn lane at a signalized intersection when the offset is zero or larger, and the fact that older drivers tend to require slightly longer clearance times when making left turns.

Therefore, positive offset left-turn lanes reduce the risk of left-turn across path collisions, which typically result in injury. However, in the presence of a protected-only left-turn phase, the safety benefits may be reduced due to the protected nature of the crossing which does not involve the decision making aspect related to gap acceptance. The relationship between left-turn phasing, laning and relative safety benefits is outlined in TABLE 3.14.

TABLE 3.14 RELATIVE SAFETY BENEFIT OF POSITIVE OFFSET LEFT-TURN LANES WHEN USED WITH PROTECTED/PERMISSIVE LEFT-TURN PHASING

	PROTECTED	PERMISSIVE
1 Left-Turn Lane	Low Safety Benefit	High Safety Benefit
2 or More Left-Turn Lanes	Low Safety Benefit	Not Recommended*

*Permissive phasing should not be provided at locations with 2 or more left-turning lanes. Consult Protected-Only Left-Turn Phasing Guideline" for more information.

Aside from the left-turn across path collisions, positive offset left-turn lanes typically reduce the rear-end and sideswipe collision risk on the approach as a result of:

- Clearly defined turning paths within an expansive median opening; and,
- Elimination of lane changes in the immediate area of the intersection because of the divisional island (from left to through and vice versa).

The positive offset geometry increases the angle between the approach path and exit path to and away from the intersection which results in capacity improvements to the left-turn movement at signalized intersections due to decreased crossing distance and time to make the manoeuvre. This may have a positive impact on congestion related collision upstream of the intersection. The increased angle also improves truck operations and safety, and is particularly

[42] Tarawneh, M.S.; Rifaey, T.; McCoy, P.T. "Effects of Intersection Geometrics on Driver Performance:. *Transportation Research Record*, 1998. p. 30:1-10.

effective where log haul trucks with long rear overhangs routinely turn left. The separation provided from the adjacent through lane assists in preventing the swept path of the rear overhang from conflicting with the adjacent through traffic.

The collision reduction factors associated with the implementation of positive offset left-turn lanes at signalized intersections are shown in TABLE 3.15. No information on the phasing before or after implementation was provided in the sourced material.

TABLE 3.15 COLLISION REDUCTION FACTORS FOR OFFSET LEFT-TURN LANES

COLLISION TYPE	REDUCTION FACTOR	COUNTRY	CONTEXT	SOURCE
All intersection collisions	34%	US (Wisconsin, Nebraska, Florida)	Geometric, traffic and crash data were compared for a total before period of 852 site-years* and a total after period of 474 site-years*.	FHWA TechBrief: "Safety Evaluation of Offset Improvements for Left-Turn Lanes". FHWA Publication No.: FHWA-HRT-09-036.
Urban injury collisions	36%			

*a site year is defined as the number of intersections studied times the number of years the treatment was in place.

Costs

The costs of retrofitting an existing intersection with positive off-set left-turn lanes depends greatly on whether or not the current road width is sufficient or if land will have to be purchased. Assuming the road is sufficiently wide; the cost for installing the lane (median island and remarking) was estimated to be $10,000 to $100,000 (depending on the length and width of the median). Annual M&O costs were assume to be $3000.

3.4.5 Existing Application Guidance

Provincial Guidance

Alberta Transportation *Highway Geometric Design Guide – Urban Supplement* (November 2003) [Section U.D.1.4], provides guidance on the implementation of positive offset left-turn lanes. It promotes the use of offset left-turn lanes should be applied to all new intersections in the initial stages of a freeway/expressway design when the median width is sufficient, due to the safety benefits associated with the improved visibility for left-turning vehicles. In Alberta, the median is typically wide enough in the initial stages to accommodate this design.

Additional guidance pertaining to channelization is provided in Alberta Transportation's *Highway Geometric Design Guide* (1996) [Section D.6.3].

The Recommended Application Guidance is based on that information and other sources.

The City of Calgary favours the use of slotted left turn bays where there is sufficient right of way, with similar standards as TAC.

National Guidance

The Transportation Association of Canada's (TAC) *Geometric Design Guide for Canadian Roads* (1999) has a section on offset left-turn lanes (referred to as slot left-turn lanes). Section 2.3.8.7 of the manual provides warrants for offset left-turn lanes, as well as design considerations and qualitative safety and operational benefits. The four warrants include geometric, volume, safety and systems components.

Recommended Application Guidance

This section provides guidance for the systematic application of positive offset left-turn lanes, for both new installations and upgrades.

General Guidance

Positive offset left-turn lanes should be applied to all new signalized intersections in the initial stages of a freeway/expressway design when the median width is sufficient, due to the safety benefits associated with the improved visibility for left-turning vehicles. In Alberta, the median is typically wide enough in the initial stages to accommodate this design.

Generally, it is not cost-efficient to retrofit an existing parallel left-turn lane with a narrow or no median, to an offset left-turn lane due to the high costs of reconstruction and acquiring right-of-way[43]. Providing a protected-only left-turn lane may be considered instead (see Application Guidelines for Protected-Only Left-Turn Phasing).

[43] TAC 1999

In general, positive offset left turn lanes can be considered at any intersection where an intersection approach exhibits a "high left-turn across path" collision history resulting from parallel left-turn lane having been constructed in a wide median. In addition, opposing truck left-turning volumes of over 10 percent create a significant sightline obstruction and may require the provision of positive offset left-turn lanes.

In Alberta, 12.5 percent of all casualty collisions in 2008 were left-turn across path collisions (TRANS *Alberta Traffic Collision* Statistics 2008). A percentage significantly higher than this average at a particular intersection may be indicative of the need for a positive offset left-turn lane.

Land Use and Speed Context

Positive offset left-turn lanes can be considered at any signalized intersection in urban, sub-urban or rural context. Signalized intersections are more common in urban and suburban environments where through and in particular turning traffic volumes are higher, but are also present in rural areas at intersections where there are intolerable delays for left-turning and crossing side street traffic.

Positive offset left-turn lanes at signalized intersections may be particularly appropriate at higher speeds because the gap required to execute a left-turn is greater, and the consequences of misjudging such a gap are more severe at higher speeds. The applicability for various speed limit ranges is shown in TABLE **3.16**.

Locations where positive offset left-turn lanes might be particularly appropriate are:

- Near seniors complexes or in areas with a large senior demographic: this provides a margin of safety for aging drivers who do not position themselves in the intersection before initiating a left turn[44].
- Near logging sites or other heavy producers of truck traffic[45]: the separation provided from the adjacent through lane assists in preventing the swept path of the rear overhang from conflicting with the adjacent through traffic.

[44] Aging Road Users Guide 2006
[45] TAC 1999

TABLE 3.16 TYPICAL LAND USE AND SPEED RANGES FOR POSITIVE OFFSET LEFT-TURN LANES

LAND USE	SPEED LIMIT (km/h)			
	50 or less	60 – 70	80-90*	100 or greater*
Rural	✓	✓	✓	
Urban	✓	✓	✓	

* This applies to roads posted at 80 km/h. Signalized intersections will not be present along 90 km/h or greater roads.

Roadway Characteristics

Offset left-turn lanes are appropriate on major arterials and expressway with wide medians. The minimum median widths are presented in TABLE 3.17. Offset left-turn lanes may also be considered at the early stages of a major road's ultimate development. The median width available for four-lane divided arterials is often great enough for offset left-turn lanes, and allows for the future expansion.

TABLE 3.17 MINIMUM MEDIAN WIDTH REQUIREMENTS

LANES	MEDIAN WIDTH (Metres)
Single Positive Offset Left-Turn Lane	10.8
Double Positive Offset Left-Turn Lanes	13.0

As mentioned earlier, generally it is not cost-efficient to retrofit an existing parallel left-turn lane with a narrow or no median, to an offset left-turn lane due to the high costs of reconstruction and acquiring right-of-way. Providing a protected-only left-turn lane may be considered instead (see Application Guidelines for Protected-Only Left-Turn Phasing).

Intersection Characteristics

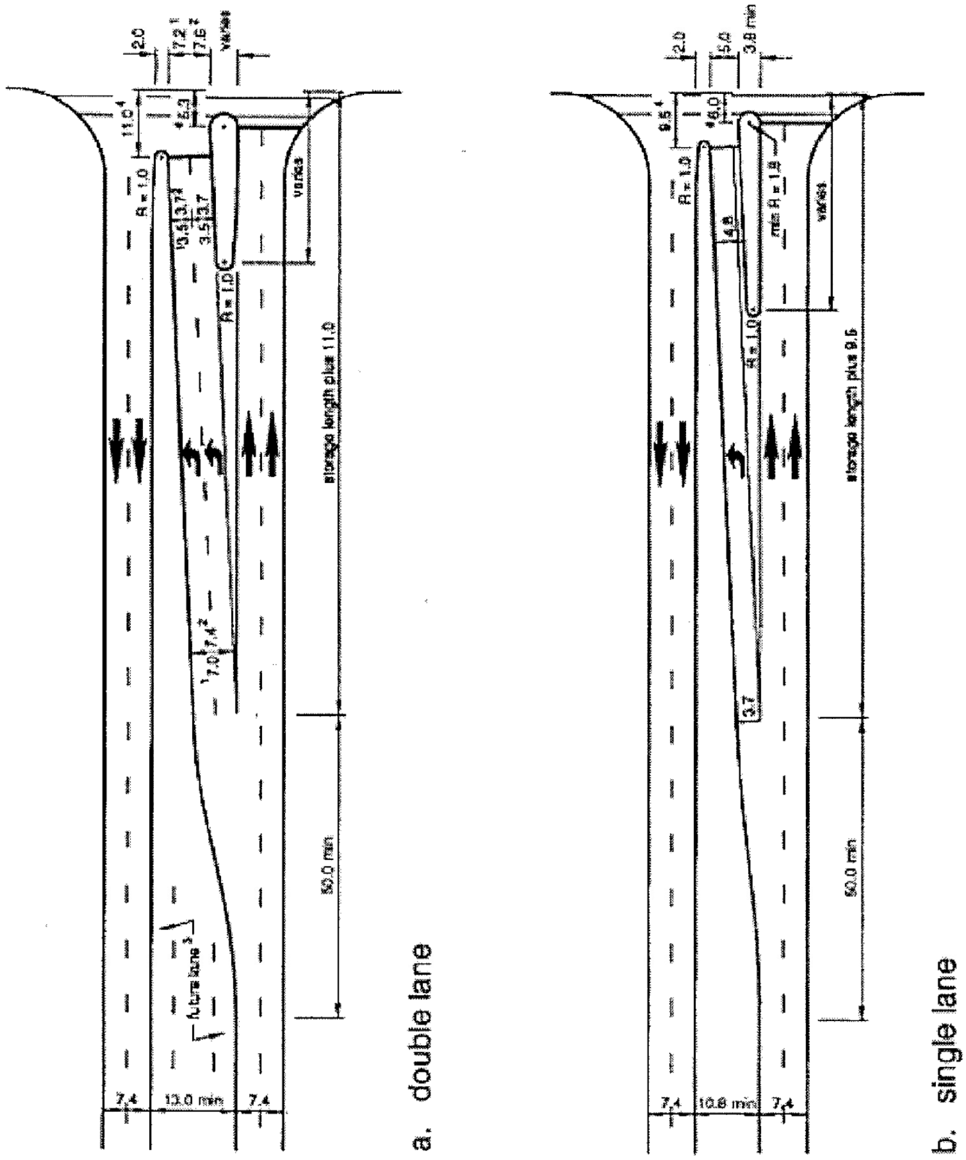
In addition to the land use and speed context and roadway characteristics, the applicability of offset left-turn lanes is a function of multiple intersection and safety-related parameters.

Positive offset left-turn lanes are applicable to all signalized intersections ranging from urban to rural environments. The maximum collision benefit is achieved when a permissive left-turn phase is present. In urban environments the intersections typically feature raised medians and lower speeds.

Positive offset left-turn lanes are strongly recommended at rural signalized intersections. The speeds are typically higher (70-80 km/h) and large crossing distances make it more difficult to successfully assess and accept gaps in traffic. There is also a lower tolerance for left-turn vehicles crossing the path of through vehicles in rural areas. Rural signalized intersections can feature rolled curb medians or depressed medians. Painted medians are also used in some jurisdictions; however, due to the climate in Alberta, pavement markings are less durable and can be covered by sand, snow, or ice during the winter months.

3.4.6 Implementation Considerations

Consistent implementation is important to achieve the maximum safety benefits of positive offset left-turn lanes by meeting driver expectations. FIGURE 3.20 shows the typical design based on the Alberta Transportation guidelines.



Notes: 1. Based on predominately P vehicles with consideration for SU vehicles.
2. *Based on sufficient SU vehicles to govern design.*
3. Slot design eliminated when future lanes added in median area.
4. All nose locations to be checked using design vehicle turning templates.

FIGURE 3.20 POSITIVE OFFSET LEFT-TURN LANE DESIGN

Source: Alberta Transportation Highway Geometric Design Guide – Urban Supplement (November 2003)

There are a number of other items which should be considered prior to the implementation of positive offset left-turn lanes:

1. Channelization should be clearly visible and should not be introduced where sight distance is limited. When an island must be located near a high point in the roadway profile, or near the beginning of a horizontal curve, the approach end of the island must be extended so that it will be obvious to the approaching drivers.

2. Longer walking distance, time and exposure for pedestrians. Ensure medians/islands are wide enough to act as a refuge for pedestrians and that ramps are provided where required.

3. Adequate signage and pavement markings should achieve positive guidance to avoid potential wrong-way movements by opposing direction vehicles entering the left-turn roadway. The implementation of DIVIDED HIGHWAY CROSSING, WRONG WAY, DO NOT ENTER, KEEP RIGHT, and ONE WAY signs (FIGURE 3.21) is recommended at intersections with positive offset left-turn lane applications. Signs should be placed as per MUTCDC specifications or local guidelines in a consistent manner. In addition, oversized signs (sizes larger than MUTCDC specified standard sizes for conventional roadways) are recommended, where practical and where they do not represent sight obstructions.

DIVIDED HIGHWAY CROSSING SIGN(WA-34)

WRONG WAY SIGN (RB-22)

DO NOT ENTER SIGN (RB-23)

KEEP RIGHT SIGN (RB-25)

ONE WAY SIGN (RB-21)

FIGURE 3.21 POSITIVE OFFSET DUAL LEFT-TURN LANE SIGNAGE

4. To reduce the likelihood of wrong-way movements (both main road through movements and minor road left turns), it is suggested that retroreflective pavement marking lane-use arrows be painted at locations where positive offset left-turn lanes are provided (FIGURE 3.22). The pavement markings should be in accordance with the Alberta Highway Pavement Marking Guide.

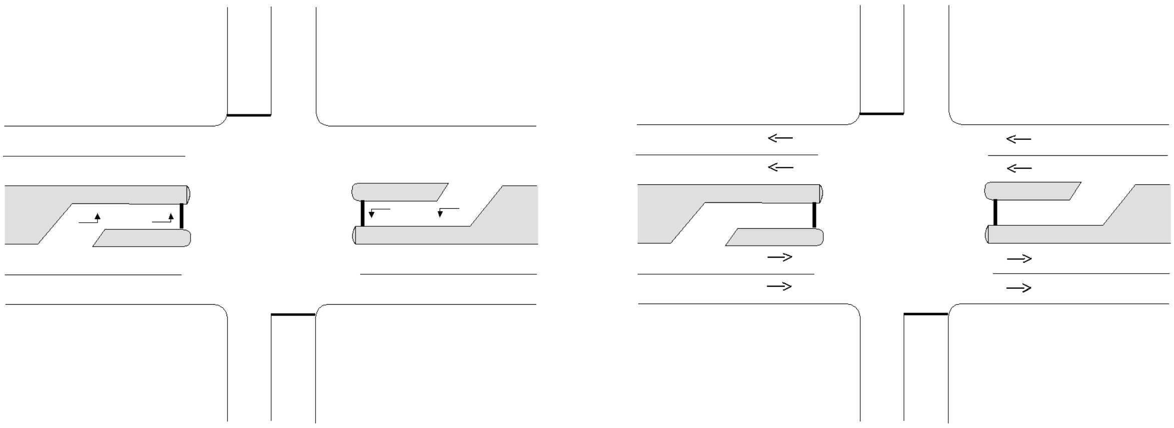
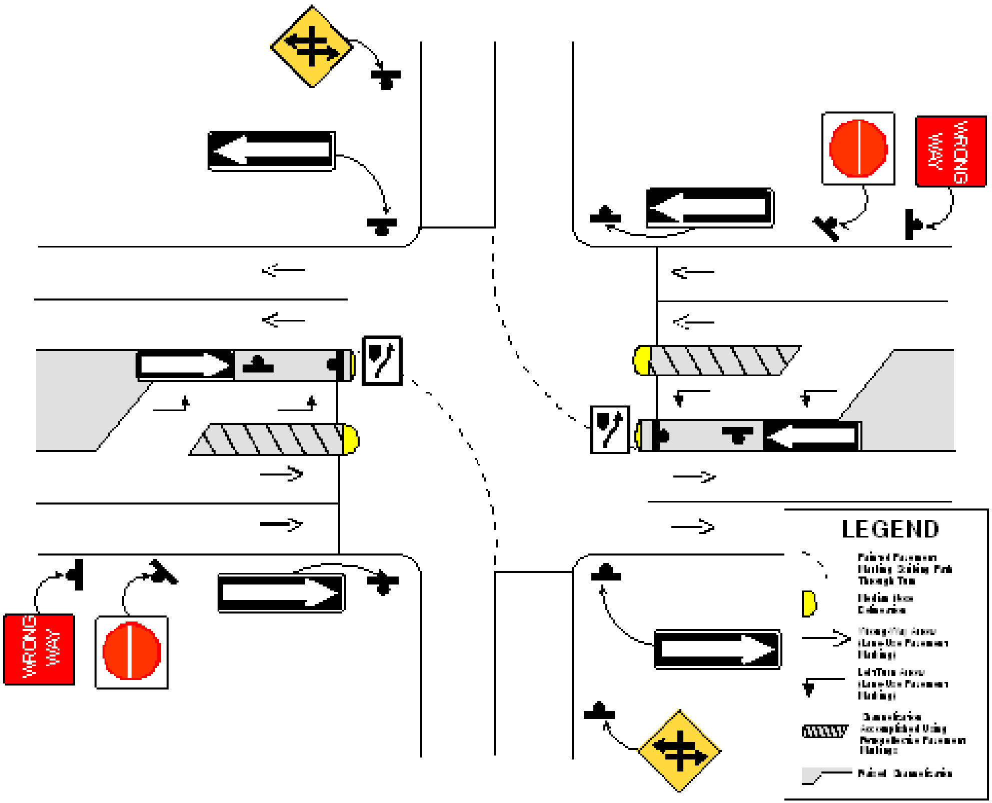


FIGURE 3.22 TURNING LANE PAVEMENT ARROWS

5. Retroreflective guide lines (shown in FIGURE 3.23) which scribe a turning path through the intersection, are recommended. The pavement markings should be in accordance with the Alberta Highway Pavement Marking Guide.

FIGURE 3.23 TURNING LANE GUIDE LINES

FIGURE 3.24 presents the combination of signage and pavement markings that will help to delineate the correct path through the intersection and prevent wrong way manoeuvres.



[Note: Median ONE WAY signs are optional where left-turn lanes result in narrowing of the median, and engineering judgment indicates a potential for motorist confusion.]

FIGURE 3.24 SIGNING AND DELINEATION FOR POSITIVE OFFSET LEFT-TURN LANES

3.4.7 Human Factors

Positive offset left-turn lanes provide a margin of safety for aging drivers (among others) who have difficulties judging the speeds of approaching vehicles and accepting gaps. Some drivers position themselves incorrectly in the intersection before initiating a left turn[46]; positive offset left-turn lanes make this process easier.

[46] Aging Road Users Guide 2006

This provides the opportunity for drivers to focus on the task of accepting gaps since they can already clearly see oncoming traffic. This results in greater comfort, less frustration, and a shorter turning manoeuvre.

3.4.8 Maintenance Considerations

An intersection with positive offset left-turn lanes requires some additional maintenance in terms of salting, sanding and snow removal due to the physical separation of the left-turn lane from the through lanes.

Additional traffic signal maintenance includes routine cleaning and inspections to ensure the units are functioning and to replace any burnt out lights (which is relatively infrequent with the new LED technology).

ALBERTA TRANSPORTATION

METHODS OF REDUCING COLLISIONS ON ALBERTA ROADS

APPLICATION GUIDELINES FOR PROTECTED-ONLY LEFT-TURN PHASING

FINAL

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3.5 Protected-only Left-turn Phasing

3.5.1 Background

Left-turn collisions are among the highest severity collisions that occur at signalized intersections. The left-turn movement at a signalized intersection is typically the most challenging to safely accommodate because it inherently has the highest conflict potential. Protected left-turn phasing is a proven method of reducing left-turn collisions at signalized intersections.

While the use of dedicated left-turn phases is common in most jurisdictions, encouragement of their application is expected to make a significant impact on reducing left-turn collisions. Their application needs to be carefully considered in the context of other engineering objectives, most notably, the intersection capacity. This document is intended to provide systematic guidance for traffic engineers to review the need for protected left-turn phasing, and in particular *protected-only* left-turn phasing, by summarizing and supplementing the existing guidance that is available on this subject.

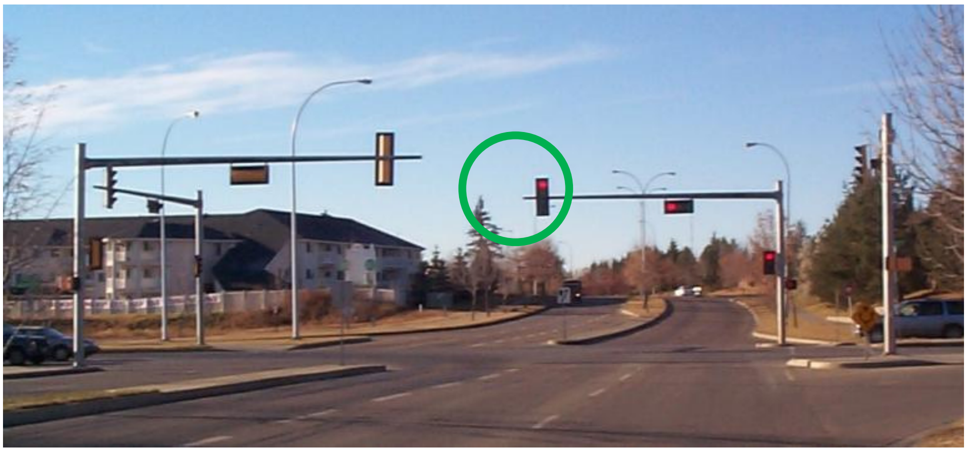

FIGURE 3.25 Protected Left-Turn Phase

3.5.2 Definitions

A protected left-turn phase (FIGURE 3.25) provides a dedicated interval within the signal cycle during which left-turn manoeuvres can be made without encountering conflicting vehicular or pedestrian movements.

The two most common variations of protected left-turn phasing are:

- **Protected-Permissive Left-Turn Phasing** is comprised of two sub-phases: (1) a dedicated left-turn phase without conflicting movements; and (2) a permissive left-turn phase when left-turn traffic must yield to opposing through traffic. The permissive-protected left-turn phase is a variation in which the sequence of sub-phases is reversed.
- **Protected-only Left-Turn Phasing** (sometimes also referred to as "protected-prohibited" or "fully protected" left-turn phasing): left-turns are only permitted during the display of the green arrow and may not be undertaken at any other time. During the protected only left-turn phase, opposing through traffic is not permitted to proceed.

This guideline covers the application of protected-only left-turn phases, which may have the following sequential variations:

- *Leading left-turn phase:* protected left-turn phase starts before the beginning of the through green phase for the opposing direction of travel;
- *Lagging left-turn phase*: protected left-turn phase starts after the end of the through green phase for the opposing direction of travel; and
- *Concurrent left-turn phase*: left-turning vehicles from opposing directions are permitted to turn at the same time.

3.5.3 Current Status in Alberta

Protected-only left-turns are common in Alberta, particularly at high volume urban intersections where the absence of such a phase would result in a poor level of service for the left-turning traffic. Most analysis for the justification of left-turn phasing is therefore based on peak hour conditions. In other cases, less commonly, protected-only phasing has been provided to provide additional safety, particularly at locations with a history of left-turn crashes.

Protected-only left-turn phasing is common at signalized intersections along highways, due to the high approach speeds, but less common in smaller towns, where traffic volumes and the tolerance for signal delays are generally much lower.

3.5.4 Example Applications

Example applications of protected-only left-turn phases are shown in FIGURE 3.26 and FIGURE 3.27.

FIGURE 3.26 DUAL LEFT-TURN LANE WITH A PROTECTED-ONLY LEFT-TURN PHASE

FIGURE 3.27 SINGLE LEFT-TURN LANE WITH PROTECTED-ONLY PHASING

3.5.5 Benefits and Costs

Benefits

Providing protected-only left-turn phasing increases safety by removing the decision making element of the left-turn movement and providing assured gaps in traffic. A motorist might accept an inadequate gap as the result of:

- Misjudgement of opposing vehicle distance, speed or intention;
- Sight obstructions, caused by the road geometry or other vehicles;
- Sun glare, inadequate acceleration or other weather/road/vehicle related factors; or
- Other human factors such as aggression, frustration, distraction or impatience.

Providing a protected-only left-turn phase removes these safety risks from the equation. While these conditions are exacerbated during high traffic conditions, they may be present at any time of the day. A significant proportion of left-turn collisions at signalized intersections are known to occur outside of the conditions where an intersection is at its operational capacity. The collision reduction factors associated with the implementation of protected-only left-turn phases from the most recent, reliable, comprehensive study on the subject are summarized in TABLE 3.18.

TABLE 3.18 SUMMARY OF COLLISION REDUCTION FACTORS FOR THE INSTALLATION OF PROTECTED-ONLY LEFT-TURN PHASING

COLLISION TYPE	REDUCTION FACTOR	SOURCE
Conversion from permissive only to protected-permissive phasing		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).
All intersection collisions	15 - 36%	
Left-turn collisions	35 - 70%	
Urban fatal and injury left-turn across path collisions	16%	
Urban fatal and injury right-angle collisions	19%	
Conversion from protected-permissive to protected-only phasing		
All intersection collisions	10%	
Left-turn collisions	40%	

In many cases, agencies will be looking at converting from protected-permissive to protected only phasing, and can rely on the values in the bottom of TABLE 3.18. However, the conversion from permissive-only to protected-only phasing is expected to provide *higher* collision reduction values than any of those indicated in TABLE 3.18.

Costs

The costs of retrofitting an existing intersection with protected only phasing is minimal when the signals are already in place. In some cases, the existing signals can be reprogrammed to allow for the protected only phase for the labour cost of reprogramming only. Annual M&O costs were assume to be $1000.

3.5.6 Existing Application Guidance

Existing guidance provided on the use of protected-only left-turn phases is summarized in this section.

Transportation Association of Canada

The Transportation Association of Canada (TAC) *Manual of Uniform Traffic Control Devices for Canada* (MUTCDC) (1998), Section B4.4 provides a *Detailed Assessment of the Requirement for a Left-Turn Phase* to determine if a left-turn phase of any kind (protected-only or protected/permissive) should be installed. The analysis involves the evaluation of a specific set of criteria that reflect capacity, safety, geometric and operational characteristics; but the procedure does not provide any specific guidance for the application of *protected-only* left-turn phasing.

Alberta Transportation

Alberta Transportation has jurisdiction over the primary highways in Alberta. Although most primary highway intersections are grade-separated or unsignalized, several provide protected-only phasing. Alberta Transportation follows the MUTCDC in determining the need for left-turn phasing.

Municipalities

Several Alberta municipalities have their own warrants as identified below:

- City of Red Deer: The City's *Warrant for Left-Turn Phasing*, contained in their *Traffic Signal Warrant Standards*, relies on the guidance of the MUTCDC Detailed Assessment to determine the need for a left-turn phase, but provides additional guidance for determining the need for a *protected-only* phase with 24 hour per day operation. The 24-hour method is based on a paper published in the Transportation Research Record entitled "Selection Criteria for Left-Turn Phasing and Indication Sequence"[47].
- City of Edmonton: The City's *Left-Turn Guidelines* outline a number of considerations for determining the need for *protected-only* left-turn phasing which is based on the collision experience, and a high level consideration of speed, laning and sight distance.
- City of Calgary: The City's *Traffic Control Policy Manual* outlines the methodology used in the progression of traffic signals from permissive to protected/permissive to protected only.

3.5.7 Recommended Application Guidance

Recommended guidance for the appropriate application of protected-only left-turn phasing at signalized intersections in Alberta, with the objective of improving safety, is provided here.

It is recommended that before reviewing the operational capacity during the peak hours, that factors other than traffic conditions that have an influence on safety be considered. The key considerations are described here. For the peak hour analysis, the current method prescribed by the MUTCDC (and summarized in the attachment at the end of this section) can be applied.

Land Use and Speed Context

Land Use

Protected-only left-turn phasing can be considered at any signalized intersection. Signalized intersections are more common in urban and suburban environments where through and in particular turning traffic volumes are higher, but are also present in rural areas at intersections where there are intolerable delays for left-turning and crossing side street traffic.

Protected-only left-turn phasing is strongly recommended at rural intersections where signals are warranted. The typically higher speeds and larger crossing distances make it more difficult to successfully assess and accept gaps in traffic. There is also a lower tolerance of left-turn vehicles crossing the path of through vehicles in rural areas.

[47] Asante, S.A.; Ardekani, S.A.; Williams, J.C. Selection Criteria for Left-Turn Phasing and Indication Sequence. Transportation Research Record No. 1421 p. 11-20. Washington DC. 1993.

Posted Speed Limit

Traffic signals are typically only present where the posted speed limit is 80 km/h or less. Therefore, this measure does not pertain to roadways posted at 90 km/h or above. Left-turn collisions in higher-speed locations are typically high impact, and can result in severe injury or fatality. Therefore, protected-only left-turn phases are strongly recommended at locations with posted speeds of 70 km/h or 80 km/h. The need for protected-only phasing on 50 km/h or 60 km/h roads will likely only be present in urban areas, but should be considered together with geometric factors, described below.

In low speed environments (such as on collector roads in urban areas where the posted speed limit may be less than 50 km/h) protected-only left-turn phases are generally not considered, due to the lower left-turn demand and the lower tolerance for long cycle lengths along lower-volume roadways.

The typical land use and speed environments where the installation of protected-only left-turn phasing should be considered are summarized in TABLE 3.19.

TABLE 3.19 TYPICAL LAND USE AND SPEED RANGES FOR PROTECTED-ONLY LEFT-TURN PHASING

LAND USE	POSTED SPEED LIMIT (km/h)			
	50 or less	60 - 70	80-90***	100 or more
Rural		✓**	✓	
Urban	✓*	✓	✓	
Semi-Urban / Suburban	✓*	✓	✓	

*This applies for roads posted at 50 km/h. Roads posted at anything less are likely to be low volume and provide adequate sight distance.
** This applies primarily for roads posted at 70 km/h. 60 km/h roads are likely to be low volume with sufficient gaps.
*** This applies to roads posted at 80 km/h. Signalized intersections will not be present along 90 km/h roads.

The following sections outline other geometric, operational and collision characteristics to be considered in the application of protected-only left-turn phasing.

Geometric Characteristics

Visibility

Visibility can be severely impaired by any of the following conditions:

- *Approach curvature*. Left-turn drivers may be unable to see opposing vehicles around the curve. Appropriate crossing sight distance needs to be provided. This can be determined based on Section D.4.2.2.1 of the TRANS Highway Geometric Design Guide.
- *Offset left-turn lanes*. An adequate view of opposing traffic may not be achieved without encroaching into the oncoming vehicle path, due to the alignment of the opposing left-turn lanes.
- *Large trucks in opposing left-turn lane*. The visibility can be further constrained by large trucks in the opposing left-turn lane, particularly if they are not properly aligned.

Through Lanes

The number of lanes influences both the crossing distance for the left-turn movement and the degree of complexity in assessing gaps in the traffic stream. Generally, as the number of opposing through lanes increases, the collision risk also increases. *Whenever three lanes or more are present, it is recommended that protected-only left-turn phasing be provided.*

Studies have also shown that crossing two lanes of traffic can have an increased risk at higher speeds. *It is recommended that whenever the speed limit is 70 km/h or higher, protected-only left-turn phasing be provided.*

Dual Left-Turn Lane Operation

Where dual left-turn lanes are provided, left-turn vehicles can sometimes restrict the view for drivers in the adjacent lane. In addition, the gap acceptance behaviours of one left-turn vehicle sometimes influences the other, and can lead to sudden or unsafe decisions or collisions with each other. It is recommended that whenever dual left-turn operation is present, that protected-only left-turn phasing is provided.

Collision Characteristics

While the above considerations relate to the left-turn collision risks at an intersection, collision experience itself can indicate the extent of these or other risks that may be present. Therefore, if there is a pattern of permissive left-turn collisions, it is strongly recommended that the permissive phasing be removed.

There are few examples of what constitutes a “pattern” of left-turn collisions under protected-permissive operation. The City of Red Deer has selected 7 left-turn collisions per 3 years as a threshold, based on a TRB report. The City has indicated that very few protected-permissive intersections in the City meet this threshold. It is recommended that this threshold be used for each approach in question.

Recommended Procedure

The application guidelines for protected-only left-turn phases have been divided into the following two steps, which are discussed in detail in the following subsections.

Step 1: Determine the need for a full-time (24 hour) protected-only left-turn phase (considering the factors described in the Recommended Application Guidance section).

Step 2: Determine the need for a part-time protected-only or a protected/permissive left-turn phase

A. Step 1: Determine the Need for a Full-Time Protected-Only Left-Turn Phase

The first step is to determine if a full-time (24 hour) protected-only left-turn phase is required. For locations in the appropriate land use and speed context, the full-time protected-only left-turn phase is warranted if one of the following conditions is met:

i. Visibility for left-turn movements does not allow for adequate gap assessment;
ii. Left-turns cross three (3) or more opposing through lanes where the speed limit for opposing traffic is equal to or greater than 70 km/h or;
iii. Left-turns are permitted from two or more left-turn lanes on one approach; unless there is no opposing through traffic or the opposing through traffic volume is extremely low.

iv. Left-turn across path collisions exceed seven (7) over a three-year period for an approach where protected/permissive phasing is in use.

B. Step 2: Determine the Need for a Part-Time Protected-Only or a Protected/Permissive Left-Turn Phase

The second step is to determine if a part-time protected-only or a protected/permissive left-turn phase is required. This is done using the methodology outlined in Section B4.4 of the MUTCDC and reproduced below. The need for a left-turn phase is evaluated using the procedure in TABLES A through C (in attachment):

- Criteria A1 and A2 indicate special conditions for which a left-turn phase is recommended independent of the results of Parts B and C of the assessment;
- Criteria B1 to B3 describe negative impacts which may indicate that a left-turn phase is undesirable; while,
- If neither Part A nor Part B are satisfied, Criteria C1 to C3 describe conditions under which a left-turn phase is warranted.

The MUTCDC method does not distinguish between protected-permissive and protected-only left-turn phasing. In cases where protected left-turn phasing is warranted, it is recommended that strong consideration be given to providing protected-only left-turn phasing. Analysis can be conducted to confirm that the loss in overall intersection or approach capacity due to protected-only phasing is still within the tolerable level of service limits. If after implementation, operational problems exist and the addition of the permissive phase is expected to resolve these without significantly impacting safety, the permissive phase can then be added.

For new traffic signal installations in particular, the sequence of progressing from protected-only to protected-permissive phasing is expected to provide a safer transition; in the reverse scenario, there may be a risk of vehicles running the amber or red light at the end of the protected-only phase. In such a conversion, the infrastructure needs that support protected-only left-turn phasing, including the provision of a median-mounted left-turn signal, could simply be retained with the protected-permissive phasing, as they provide superior signal visibility than overhead displays during the permissive phase.

3.5.8 Implementation Considerations

These application guidelines are intended to assist practitioners in determining when a protected-only left-turn phase is warranted. The design and implementation of the hardware and signal timings are not covered in this document. Additional general guidance regarding the implementation of protected left-turn phases is provided in Division 3 of the MUTCDC, Section D.4.3 in the Highway Geometric Design Guide. More specific installation guidance may be provided in municipal guidelines.

General implementation considerations are as follows:

- Median-mounted left-turn displays are favoured for protected-only phasing.
- Pedestrian signals should be provided when a left-turn phase operation is in place for any conflicting crosswalk, in order to avoid conflict between pedestrians and the exclusive left-turn phase. Pedestrian phasing must be examined prior to implementation of protected–only left-turn phasing.
- The timing of a protected-only left-turn phase can be determined through vehicle detectors or by time-of-day.
- Care should be taken to ensure that as phase sequencing changes, all clearance requirements are met such that entrapment is not created.
- Fully protected operations should be implemented on a consistent basis throughout the day, as well as widespread implementation throughout the community, except when, based on engineering judgement, an unacceptable reduction in capacity will result.
- Generally, an increase in the number of phases tends to decrease intersection capacity.
- Protected-only left turn phases require a longer storage bay for left-turning vehicles.
- If a protected-only left-turn phase is not warranted, consideration may be given to the applicability of positive offset left-turn lanes to improve sightlines and safety (refer to *Application Guidelines – Positive Offset Left-Turn Lanes* for more details).
- The selection of the type and length of left-turn protection will need to be considered in the context of any signal coordination provided on either or both intersecting roadways.

3.5.9 Maintenance Considerations

Protected-only left-turn phasing is a low-maintenance measure. Any maintenance additional to regular traffic signal maintenance would be negligible, with the exception of routine cleaning and inspections to ensure the units are functioning and to replace any burnt out lights (which is relatively infrequent with the new LED technology).

ATTACHMENT: MUTCDC PROCEDURE FOR DETERMINING THE NEED FOR PROTECTED LEFT-TURN PHASING

TABLE A SPECIAL CONDITIONS CRITERIA

PART A: SPECIAL CONDITIONS CRITERIA	YES	NO
A1: Are railway or public transit vehicles operating in an exclusive right-of-way median which is parallel to the left-turn lane?		
A2: Are double left-turns permitted where there is an opposing through movement?		
Is a left-turn phase recommended? **(If either A1 or A2 are YES, answer YES)**		
If the answers to both A1 and A2 are NO, proceed to PART B - Negative Impact Criteria		

TABLE B NEGATIVE IMPACT CRITERIA

PART B: NEGATIVE IMPACT CRITERIA	YES	NO
B1: Is there insufficient green time within the current cycle length to accommodate the proposed left-turn phase?		
B2: Will the left-turn phase encourage neighbourhood traffic infiltration?		
B3: Does an assessment of the proposed left-turn phase demonstrate that significant undesirable effects in terms of stops, delay or increased fuel consumption will result?		
Is a left-turn phase undesirable? **(If either B1, B2, or B3 are YES, answer YES)**		
If the answers to all three are NO, proceed to PART C - Warrant Criteria		

TABLE C WARRANT CRITERIA

PART C: Warrant Criteria	DATA	CRITERION	YES	NO
(a) What is the average left-turn demand per cycle		≥3 pcu* per cycle		
(b) What percent of the left-turn volume is delayed more than one cycle		>25% Delayed One Cycle		
(c) What is the total number of left-turn collisions that have occurred				
(i) during the two-hour left-turn study period within the past five years?		>6 within past 5 years		
(ii) during the two-hour left-turn study period within the past 12 months		>2 within past year		
(iii) on a daily basis within the past five years		>20 within past 5 years		
(iv) on a daily basis within the past 12 months		>5 within past year		
(d) What is the average volume of left-turns which clear during the intergreen per cycle?		≥2 pcu* per cycle		
(e) Over the course of an hour, what is the percentage of cycles during which the queue from an exclusive left-turn lane spills back and blocks the adjacent through lane:				
(i) Where there is only a single through lane?		>10%		
(ii) Where there are two or more through lanes?		>30%		
(f) What is the left-turn in-service transit demand per hour?		>3 per hour		
Are any of the following criteria satisfied?				
C1: If both (a) and (b) are YES, left-turn phasing is WARRANTED				
C2: If both (a) and (c) are YES, left-turn phasing is WARRANTED				
C3: If both (a) and any two of (d), (e), or (f) are YES, left-turn phasing is WARRANTED				
If the answers to all three are NO, left-turn phasing is ***NOT WARRANTED***				

*pcu = passenger car unit. Convert using factors (1.5 for single unit trucks, 2.5 for multi-unit trucks, and 3.5 for heavily-loaded multi-unit trucks.

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ALBERTA TRANSPORTATION

METHODS OF REDUCING COLLISIONS ON ALBERTA ROADS

APPLICATION GUIDELINES FOR HIGH-TENSION CABLE BARRIER SYSTEMS

FINAL

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3.6 High-tension Cable Barrier Systems

3.6.1 Background

Run-off-road collisions account for a significant proportion of major injury and fatal collisions on Alberta roads. Measures to reduce the severity of run-off-road collisions can therefore have a potentially significant impact on road safety in Alberta.

High Tension Cable Barrier Systems (hereafter referred to as *cable barriers*) have been successfully applied in the United States, Australasia and Europe for a number of years. More recently, the concept has been applied in Alberta – in the median of Highway 2 in Calgary, with preliminary results showing a substantial reduction in median crossover collisions. Vehicle impacts with cable barrier are typically less severe than other barrier types due to the higher energy absorbing properties of cable barriers.

The primary purpose of a barrier is to reduce the collision severity when the vehicle leaves the roadway and encounters hazards that are less forgiving than striking the barrier system. Traffic barriers do not reduce the frequency of collisions because they represent fixed objects themselves. A traffic barrier should only be installed where it is expected to reduce the severity of potential collisions.

Cable barriers are designed to minimize the impact on vehicle occupants when an errant vehicle collides with the cable barrier. The posts of a cable barrier are designed to break-away upon impact, which results in significant deflection of the cable barrier. The break-away posts help absorb the energy of the impact, which reduces the amount of energy absorbed by the vehicle occupants. Reducing the impact on vehicle occupants typically results in fewer injuries and fatalities.

There is the common perception that cable barriers are dangerous for motorcyclists, but recent tests have proven that they are no more dangerous than other barrier types.

Plans to expand the use of cable barriers in median applications are being considered. Guidelines for median applications are well documented. However, the purpose of this document is to encourage the present systematic guidelines for the application of cable barriers for both median and roadside application, and in particular to further investigate the applicability for roadside applications.

3.6.2 Definitions

Cable barriers are longitudinal barrier systems designed to reduce the risk of vehicle collisions with roadside hazards. Hazards may include fixed objects, steep embankments, pedestrian/bicycle facilities, water bodies, ditches, and opposing traffic streams.

Some common terminology related to cable barriers is provided below:

Cable Barrier: For the purpose of this guide, cable barriers refer to high tension cable barriers. High tension cable barriers are crash worthy barriers designed to protect motorists from hazards. Low tension cable barriers (also referred to as “post and cable fence”) are also commonly used at the roadside. However, these are not crash worthy and are intended to discourage undesirable movements rather than provide protection.

Roadside Cable Barrier: A roadside cable barrier is a barrier intended to protect a roadside hazard such as a fixed object, steep embankment or water body. A roadside cable barrier could be located on the right side of the road or on the left side of a divided roadway.

Median Cable Barrier: Median cable barriers are intended to reduce the risk of cross-median collisions.

Note that the same physical cable barrier in the median can meet both the “median” and “roadside” applications as defined above.

3.6.3 Current Status in Alberta

Cable barriers have only recently been applied in Alberta. The first median application was on the north section of Deerfoot Trail (Highway 2 within Calgary), with additional installations between Calgary and Red Deer. Although roadside cable barriers are used within Alberta, they are relatively new so the associated collision reduction is currently unknown.

3.6.4 Example Applications

Cable barriers are typically used on higher speed roadways, due to their effectiveness at reducing the impact absorbed by vehicle occupants. Cable barriers can be implemented along the roadside (FIGURE 3.28) or within the median (FIGURE 3.29).

FIGURE 3.28 EXAMPLE OF ROADSIDE CABLE BARRIER IN NEW ZEALAND

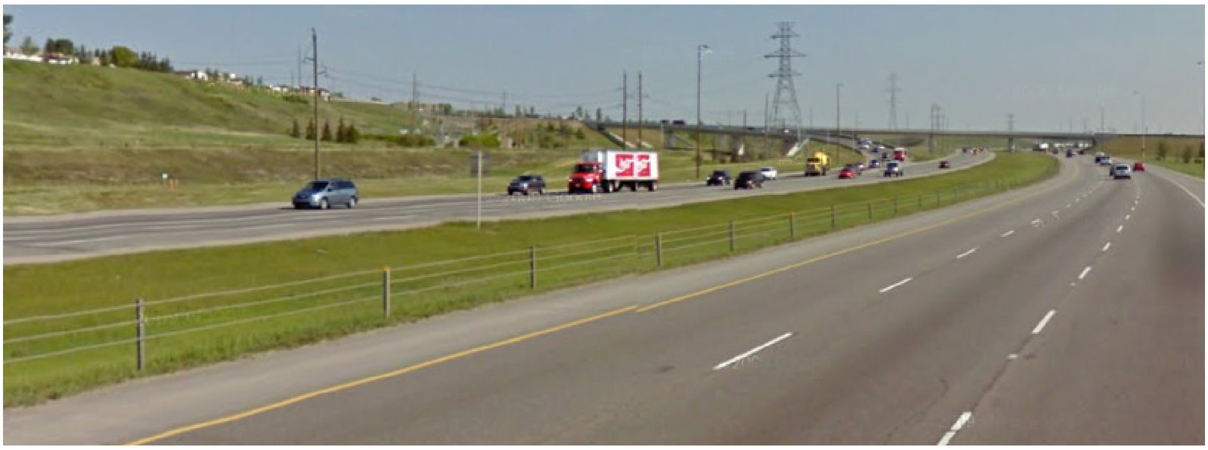

FIGURE 3.29 MEDIAN CABLE BARRIER: DEERFOOT TRAIL, CALGARY

Some cable barriers may be installed primarily as a physical obstruction to prevent undesirable movements. FIGURE 3.30 shows an example of a cable barrier that was installed to prevent dangerous lane changes between a highway exit ramp and a left-turn lane. The cable barrier physically restricts lane changes while posing less of a collision risk to through traffic compared to other barrier types.

**FIGURE 3.30 CABLE BARRIER USED TO DISCOURAGE UNSAFE LANE CHANGES
16 AVENUE N.E., CALGARY**

3.6.5 Benefits and Costs

Collision Reduction Benefits

Cable barriers like other barriers types, are likely to increase collision frequency (collisions with the barrier), but can significantly reduce collision severity of run-off-road movements by absorbing the impact and preventing collisions with other hazards.

As stated in Alberta Transportation's Roadside Design Guide, "*Longitudinal traffic barrier systems that are more forgiving are preferred because they may reduce injuries and fatalities when crashes occur, provided that suitable operating space is, or can be made, available*". The cable barrier is identified in the guide as the most forgiving of the acceptable barrier systems used in Alberta.

Since roadside cable barriers are relatively new, there is limited documentation of their effectiveness. However, an indication of the potential benefits is provided by looking at the benefits of 1) roadside barriers of all types and 2) median cable barriers.

Roadside Barriers

Limited research is available regarding the collision reduction benefits of cable barriers used along the roadside. However, based on experience and on the forgiving characteristics of cable barrier systems, they are expected to provide a benefit equal to or greater than other roadside barrier types when used in the right application. A summary of the crash reduction factors associated with the implementation of roadside barriers (all types), as identified in the Federal Highways Association's (FHWA) *Desktop Reference for Crash Reduction Factors* (2007), is summarized in TABLE 3.20.

TABLE 3.20 DOCUMENTED ROADSIDE BARRIER (ALL TYPES) COLLISION REDUCTIONS

Countermeasure	Collision Type	Collision Severity	Collision Reduction Factor
Install Guardrail (as shield for rocks and posts)	All	All	14%
	All	Injury	31%
Install Guardrail (as shield for trees)	All	Fatal	65%
	All	Injury	51%
Install Guardrail (at culvert)	All	All	27%
	All	All	24%
	All	All	30%
	All	Injury	26%
Install Guardrail (at ditch)	All	Injury	42%
Install Guardrail (at embankment)	Run-off-road	All	7%
	Run-off-road	Fatal	44%
	Run-off-road	Injury	47%
Install Guardrail (inside curves)	All	Fatal/Injury	28%
Install Guardrail (outside curves)	All	Fatal/Injury	63%

The reduction of high severity collisions is expected to be lower for roadside cable barriers compared to median cable barriers, due to the typically high severity of cross-median collisions.

The expected reduction of run-off-road collisions associated with the implementation of roadside cable barriers in Alberta is:

- Property Damage Only Collisions: 10% increase
- Injury Collisions: 40% reduction
- Fatal Collisions: 50% reduction

The expected injury and fatal collision reduction factors in Alberta were estimated as the average of the collision reduction factors identified in TABLE 3.20. The frequency of property damage only collisions is expected to increase by approximately 10 percent based on information found in other literature.

Median Cable Barriers

Median cable barriers have been found to be an effective collision reduction countermeasure in several jurisdictions. Documented collision reduction values are summarized in TABLE 3.21.

TABLE 3.21 DOCUMENTED MEDIAN CABLE BARRIER COLLISION REDUCTIONS

Location	Collision Severity	# of Collisions*		Difference
		Before**	After	
Washington State[1]	All	49	100	+104%
	Disabling Injury	3	0.3	-90%
	Fatal	3.6	1.6	-55%
North Carolina[2]	All	4,685	4,934	+5.3%
	Injury	1,772	1,420	-20%
	Fatal	63	36	-43%
Missouri[3]	Fatal	22	2	-91%

* Before and after time frames are the same for each location. However, the time frames for each location differ.
** All locations had no median barrier prior to the installation of the cable barrier.

1. Washington State Department of Transportation, *Washington State Cable Median Barrier In-Service Study* (2003). http://www.transportation.org/sites/aashtotig/docs/North%20Carolina%20Mediam%20Barrier%20Evaluation.pdf
2. Chandler, Brian: *Eliminating Cross-Median Fatalities: Statewide Installation of Median Cable Barrier in Missouri* (2007).

The results of TABLE 3.21, indicate a reduction in injury and fatal collisions after the implementation of a cable barrier. As discussed earlier, the implementation of a cable barrier did increase the total number of collisions due to the increase in property damage only collisions.

A median cable barrier was recently installed along an 11 kilometre stretch of the Deerfoot Trail in Calgary in 2007. During the 34 months after installation there were 135 incidents of vehicles hitting the cable barrier. No fatal cross-median collisions occurred over the 34 months, compared to seven fatal cross-median collisions in the seven year period prior to the installation of the barrier.

The expected collision reduction of run-off-road collisions associated with the implementation of median cable barriers in Alberta is indicated below. The actual reductions for the recent implementation on the Deerfoot Trail are indicated in brackets (based on a before-after study)[48]:

- Property Damage Only Collisions: 10% increase (48% increase)
- Injury Collisions: 55% reduction (30% decrease)
- Fatal Collisions: 65% reduction (100% decrease)

[48] High Tension Median Cable Barrier Evaluation Study, EBA Engineering Consultants Ltd., Calgary, Alberta, 2010.

The expected injury and fatal collision reduction factors in Alberta were estimated as the average of the collision reduction factors identified in TABLE 3.22. The frequency of property damage only collisions is expected to increase by approximately 10 percent based on information found in other literature.

Operational / Maintenance Benefits

In addition to the reduction in the average collision severity, cable barriers provide additional benefits in terms of operations and maintenance, versus other barrier types. Cable barriers:

- accumulate less snow than other barrier types;
- don't impede overland drainage;
- can improve sight distances along curvilinear sections and reduce view obstructions;
- can be fixed quickly after a collision by replacing the breakaway posts; and
- can be less expensive to implement and maintain compared to other barrier types.

Costs

The cost of a cable barrier was derived from the TRANS *Roadside Design Guide*. The base price ($110 per metre) was used as a low estimate, while the high estimate ($220 per metre) assumed premium pricing due to rocky conditions in a remote area (and short length: $200 metres). Annual M&O costs were assumed to be $2500.

The capital construction cost of the median cable barrier on the Deerfoot Trail was $92,000 per km (2007 dollars), with an annual maintenance cost of $60,500 for a 10.75 kilometre section (2007 dollars).

3.6.6 Existing Application Guidance

National Guidance

The Transportation Association of Canada's *Geometric Design Guide for Canadian Roads* (2007), provides guidance for the application of roadside barriers. However, the guide clearly states that there is no simple "recipe" for determining the appropriate barrier type given the complexity of the road environment.

Provincial Guidance

Guidance for the application of barriers on Alberta Highways is documented in Alberta Transportation's *Roadside Design Guide* (2007).

http://www.transportation.alberta.ca/3451.htm

The guidelines identify when a roadside or median barrier should be used as well as general recommendations on the appropriate barrier type. Detailed design drawings are also provided in the Appendix of the Roadside Design Guide.

Municipal Guidance

No municipal guidelines or policies for the implementation of cable barriers were identified in Alberta. Therefore, the most relevant guideline for both urban and rural applications in Alberta is the Alberta Transportation *Roadside Design Guide*.

International Guidance

An important supplementary document to the Alberta *Roadside Design Guide* is the National Cooperative Highway Research Program's (NCHRP) *Report 350: Recommended Procedures for the Safety Performance Evaluation of Highway Features* (1993).

http://trb.org/publications/nchrp/nchrp_rpt_350-a.pdf

This document outlines the testing criteria for each of the test levels that are referenced in Alberta Transportation's *Roadside Design Guide*.

The NCHRP Report 350 has recently been superseded by the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (MASH) (2009), which contains revised criteria for impact performance evaluation of virtually all highway safety features.

In the United States, the implementation plan for MASH is that all highway safety hardware accepted prior to the adoption of MASH, using criteria contained in NCHRP Report 350, may remain in place and may continue to be manufactured and installed. In addition, highway safety hardware accepted using NCHRP Report 350 criteria is not required to be retested using MASH criteria. However, new highway safety hardware not previously evaluated must utilize MASH for testing and evaluation.

The various publications identified above provide general guidance on the application of roadside barriers. However, due to the importance of site specific characteristics, the guidelines do not provide specific guidance on the application of particular barrier types, including cable barriers.

Other relevant resources for the application of cable barriers include:

- AASHTO *Roadside Design Guide* (2002); and,

- Silvestri, Ph.D., et al., _Experience with Cable Median Barriers in the United States: Design Standards, Policies, and Performance_ (2009).

3.6.7 Recommended Application Guidance

Land Use and Speed Context

Land Use

Cable barriers can be implemented in both urban and rural areas. However, implementing cable barriers in urban areas presents its own design challenges due to the increased presence of design constraints discussed in the Implementation Considerations section.

Speed Ranges

Cable barriers are not commonly used on lower speed roads. The primary benefit of cable barriers is their ability to absorb the impact of high speed collisions. At lower speeds, the benefits of a flexible cable barrier over a more rigid barrier are less pronounced.

However, there still may be some low speed environments where a cable barrier might be beneficial such as locations with a high occurrence of run-off-road collisions involving vehicles exceeding the speed limit or locations where an out of control vehicle may travel faster than the design speed, such as the bottom of a steep incline (particularly during icy conditions).

The land use and speed environments where the installation of a cable barrier is acceptable is summarized in TABLE 3.22.

TABLE 3.22 ACCEPTABLE LAND USE AND SPEED RANGES FOR CABLE BARRIERS

LAND USE	POSTED SPEED LIMIT (km/h)			
	50 or less	60 - 70	80 - 90	100 or more
Rural		✓	✓	✓
Urban		✓	✓	✓
Semi-Urban / Suburban		✓	✓	✓

In general, cable barriers are acceptable for all land uses and speed ranges. However, the need for such a device at lower speeds should be reviewed as the collision reduction benefits are not as pronounced.

Determine the Need for a Cable Barrier

The need for a cable barrier has been separated into two categories:

- Roadside; and,
- Median

A roadside barrier is intended to reduce the risk of vehicle collisions with hazards, such as fixed objects or steep sideslopes, at the roadside. This includes hazards that may be located within the median.

The need for a median barrier can also be evaluated separately based on the risk of cross-median collisions.

The guidelines for cable barriers contained in this document are primarily based on the Alberta Transportation *Roadside Design Guide* (2007), with some modifications to account for all road types, including lower speed urban roads. For easy reference, all figures reproduced from the Roadside Design Guide will maintain the same figure number. The guidelines provided below are intended for cable barriers only. For other barrier types please consult the Roadside Design Guide.

The steps for assessing whether a cable barrier is recommended are outlined in the following subsections. A summary of the steps is provided in FIGURE 3.31 as a flow chart. The general process is to first determine if there is a collision risk that justifies the implementation of a barrier. The next step is to determine if a cable barrier is the most appropriate barrier type. Typically a cable barrier is the most desirable barrier type as it has the lowest potential for injury and fatal collisions. However, there are some road characteristics that may not be appropriate for the implementation of a cable barrier and these factors need to be considered.

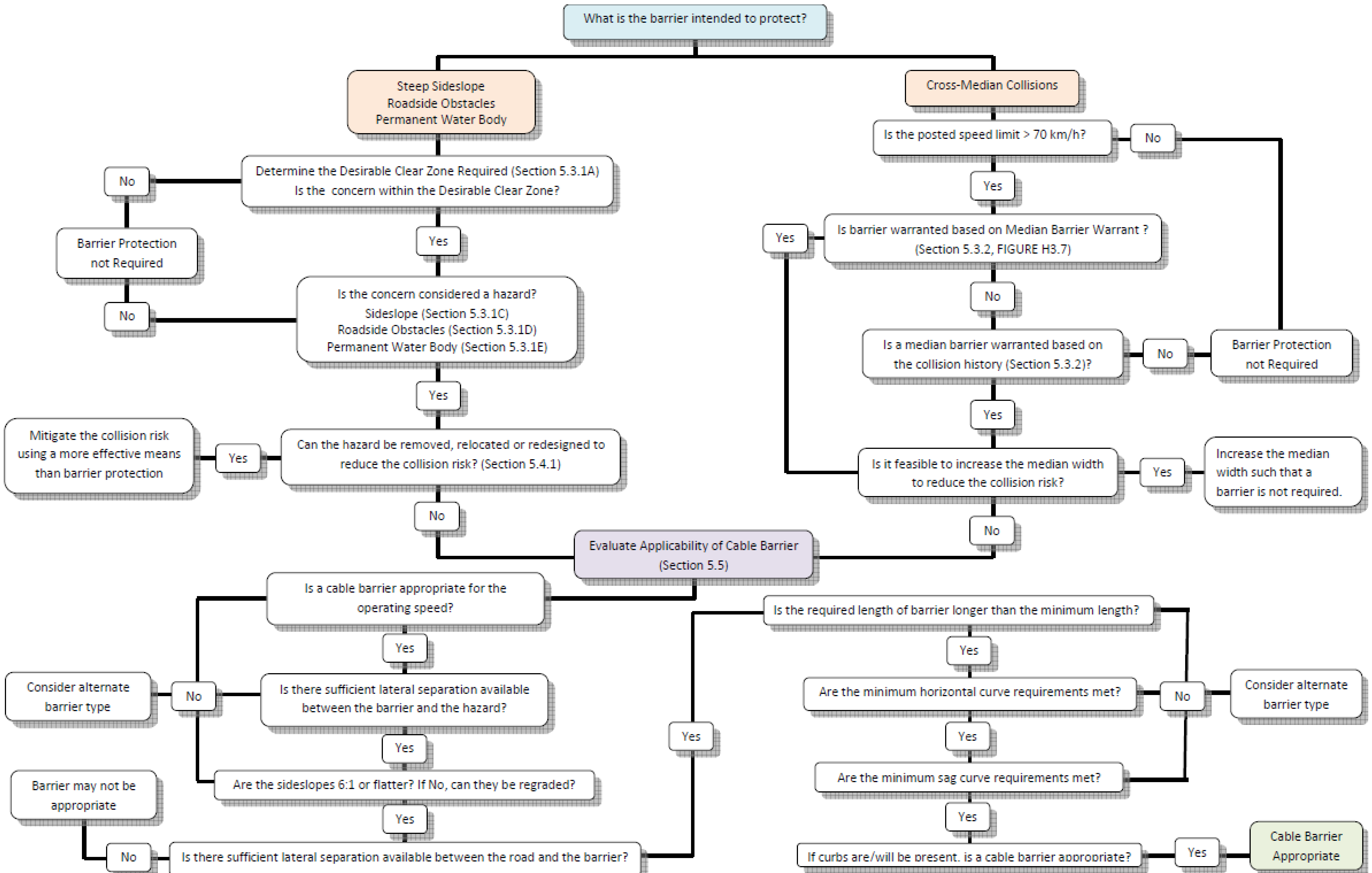

FIGURE 3.31 CABLE BARRIER APPLICATION GUIDELINES FLOW CHART

For guidance on the application of alternate barrier types, see the Alberta Transportation Roadside Design Guide (2007).

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Step 1: Determine if Traffic Barrier Required

The need for a traffic barrier (of any type) is assessed differently for roadside and median barriers as discussed in the following subsections.

Evaluate Need for Roadside Barrier

Ideally, the road designer should strive to provide as wide and as forgiving a roadside as possible, while still considering physical constraints and economics. In this context, a forgiving roadside is considered to be an area adjacent to the driving lane that has a relatively flat, smooth, firm surface, with no hazards, and extends laterally as far as errant vehicles are likely to encroach. This practice has been embodied in a concept which is known as the Clear Zone, and it represents the minimum recovery area which should be provided for a given design situation.

For most projects, there will be isolated locations or longitudinal segments where the Clear Zone cannot be provided in accordance with the preferred design criteria. Factors such as topography, environmental features, drainage requirements, property requirements, and financial commitments will often dictate the shape and area (size) of the space available immediately adjacent to the travelled way.

The Clear Zone concept attempts to establish a balance between the safety benefit of a flat, smooth, firm surface with no hazards, and the economic and social implications related to providing this clear area, adjacent to the travelled way.

The path of an errant vehicle is difficult to predict. It depends largely on the nature of the roadside, the circumstances that first caused the vehicle to depart the roadway, driver action during encroachment, and the characteristics of the vehicle (examples include type, mechanical condition, and height).

The ideal solution is to provide a very wide traversable area adjacent to the roadway to accommodate errant vehicles. However, road authorities can rarely accomplish this because of physical, economic, or fiscal constraints. Tests have shown that approximately 50 percent of errant vehicles leaving the road are able to recover within 3.0m from the edge of the travel lane and 85 percent will recover within 9.0m (assuming moderate sideslopes and a tangent alignment). Consequently, the return on investment to keep the roadside clear decreases as the width of the clear area is increased. This is because the additional cost needed to provide the extended clearance generally increases with Clear Zone width, while the number of vehicles that are predicted to travel to the outer reaches of the Clear Zone area is relatively low.

The Clear Zone concept does not establish an exact area of responsibility for the road authority. It should be viewed as a desirable width for design and maintenance purposes, rather than as an absolute demarcation between safe and unsafe conditions.

Although the Clear Zone width is an attempt to balance the safety benefit against the potential constraints, the wide variety of constraints across the Province may still result in some situations where the full Clear Zone width is simply not achievable. In these cases, an attempt should first be made to address the constraints, whether it be the space available, environmental or property commitments, or funding, such that the Clear Zone can be achieved.

The following sections describe in detail the methods used to determine the Desirable Clear Zone and the roadside mitigation strategies.

A. Desirable Clear Zone

The Desirable Clear Zone (DCZ) is defined as the width of adjacent roadside border area specifically allocated for use by an errant vehicle.

This area, which may consist of paved or unpaved shoulders, shoulder rounding, recoverable or non-recoverable (or traversable) slopes, traversable features, and/or a clear runout area, may be located on the right hand side of the travel lanes of undivided roads or within the median area of divided roadways.

The Desirable Tangent Clear Zone (DTCZ) distance is the value provided for a tangent segment of the roadway. The DCZ may vary along the roadway depending on whether the roadway segment is on a tangent or on a curve. The radius of the curve and the location along the curve also potentially influence the DCZ.

The surface within this portion of the roadside should be relatively firm and free of hazards in order to promote vehicle stability and recovery. The DCZ for a given segment is calculated using the following formula:

$DCZ = DTCZ \times K_{cz}$

where: DCZ = the Desirable Clear Zone
DTCZ = the Clear Zone for a tangent roadway cross section
K_{cz} = curve correction factor

The DTCZ distances for various design speeds and traffic volumes are presented in TABLE H3.1. For divided roadways, traffic volume in one direction is to be used to establish the Clear Zone. For undivided roadways, the full (two-way) AADT is to be used.

TABLE H3.1 Clear Zone Distances (in metres from edge of driving lane)

Design Speed (Km/h)	Design AADT +	Fill Slopes			Cut Slopes		
		6:1 or Flatter	5:1 to 4:1	3:1	3:1	5:1 to 4:1	6:1 or Flatter
60 or less with barrier curb***	All	0.5	0.5	0.5	0.5	0.5	0.5
60 or Less	Under 750	2.0 – 3.0	2.0 – 3.0	**	2.0 – 3.0	2.0 – 3.0	2.0 – 3.0
	750 – 1500	3.0 – 3.5	3.5 – 4.5	**	3.0 – 3.5	3.0 – 3.5	3.0 – 3.5
	1500 – 6000	3.5 – 4.5	4.5 – 5.0	**	3.5 – 4.5	3.5 – 4.5	3.5 – 4.5
	Over 6000	4.5 – 5.0	4.5 – 5.0	**	4.5 – 5.0	4.5 – 5.0	4.5 – 5.0
70 –80	Under 750	3.0 – 3.5	3.5 – 4.5	**	2.5 – 3.0	2.5 – 3.0	3.0 – 3.5
	750 – 1500	4.5 – 5.0	5.0 – 6.0	**	3.0 – 3.5	3.5 – 4.5	4.5 – 5.0
	1500 – 6000	5.0 – 5.5	6.0 – 8.0	**	3.5 – 4.5	4.5 – 5.0	5.0 – 5.5
	Over 6000	6.0 – 6.5	7.5 – 8.5	**	4.5 – 5.0	5.5 – 6.0	6.0 – 6.5
90	Under 750	3.5 – 4.5	4.5 – 5.5	**	2.5 – 3.0	3.0 – 3.5	3.0 - 3.5
	750 – 1500	5.0 – 5.5	6.0 – 7.5	**	3.0 – 3.5	4.5 – 5.0	5.0 – 5.5
	1500 – 6000	6.0 – 6.5	7.5 – 9.0	**	4.5 – 5.0	5.0 – 5.5	6.0 – 6.5
	Over 6000	6.5 – 7.5	8.0 – 10.0 *	**	5.0 – 5.5	6.0 – 6.5	6.5 – 7.5
100	Under 750	5.0 – 5.5	6.0 – 7.5	**	3.0 – 3.5	3.5 – 4.5	4.5 – 5.0
	750 – 1500	6.0 – 7.5	8.0 – 10.0 *	**	3.5 – 4.5	5.0 – 5.5	6.0 – 6.5
	1500 – 6000	8.0 – 9.0	10.0 – 12.0 *	**	4.5 – 5.5	5.5 – 6.5	7.5 – 8.0
	Over 6000	9.0 – 10.0 *	11.0 – 13.5 *	**	6.0 – 6.5	7.5 – 8.0	8.0 – 8.5
110	Under 750	5.5 - 6.0	6.0 – 8.0	**	3.0 – 3.5	4.5 – 5.0	4.5 – 4.9
	750 – 1500	7.5 – 8.0	8.5 – 11.0 *	**	3.5 – 5.0	5.5 – 6.0	6.0 – 6.5
	1500 – 6000	8.5 – 10.0 *	10.0 – 13.0 *	**	5.0 – 6.0	6.5 – 7.5	8.0 – 8.5
	Over 6000	9.0 – 10.5 *	11.0 – 14.0 *	**	6.5 – 7.5	8.0 – 9.0	8.5 – 9.0
120 or More	750 – 1500 +	8.0 – 9.0	9.0 – 12.0	**	3.5 – 5.0	6.0 – 6.5	7.0 – 7.5
	1500 – 6000 +	9.0 – 10.0	10.0 – 14.0	**	5.5 – 6.5	7.0 – 8.0	8.0 – 9.0
	Over 6000 +	10.0 – 11.0 *	11.0 – 15.0	**	7.0 – 8.0	8.5 – 9.5	9.0 – 10.0

* Where a site specific investigation indicates a high probability of continued crashes, or such occurrences are indicated by crash history, the designer may provide Clear Zone distances greater than the suggested range shown. Clear Zones may be limited to 9 m for practicality or to provide a consistent roadway template if previous experience with the subject roadway or similar projects or designs indicates satisfactory performance.

** Since recovery is less likely on the unshielded, traversable 3:1 slopes, fixed objects should not be present in the vicinity of the toe of these slopes. Recovery of high-speed vehicles that encroach beyond the edge of the shoulder may be expected to occur beyond the toe of slope. Determination of the width of the recovery area at the toe of slope should take into consideration right of way availability, environmental concerns, economic factors, safety needs, and accident histories. Also, the distance between the edge of the travel lane and the beginning of the 3:1 slope should influence the recovery area provided at the toe of slope.

***On a curbed roadway, the Clear Zone distance should be measured from the edge of driving lane, e.g. on a 2 lane 10m road width from curb to curb, 3.5 m adjacent to centreline may be considered the driving lane and therefore, the curb is 1.5m from the driving lane. It is still prudent to place obstacles at least 0.5 m behind the curb.

\+ The AADT used for this purpose shall be the daily volume on the roadway i.e. the full AADT on undivided highways and half of the AADT on divided highways.

Source: Alberta Infrastructure and Transportation's Roadside Design Guide (2007)

The curve modification factors, Kcz, for a variety of radii and design speeds are presented in TABLE H3.2. The curve modification factor is applicable only on the outside of a curved segment due to expected increased encroachment on the outside of the curve.

TABLE H3.2 Curve Modification Factors (K_{cz})

<table>
<tr><th rowspan="2">Radius (m)</th><th colspan="6">Design Speed (km/h)</th></tr>
<tr><th>60</th><th>70</th><th>80</th><th>90</th><th>100</th><th>≥110</th></tr>
<tr><td>>1100</td><td rowspan="2">1.0</td><td rowspan="2">1.0</td><td rowspan="2">1.0</td><td rowspan="2">1.0</td><td>1.0</td><td>1.0</td></tr>
<tr><td>1100</td><td>1.1</td><td>1.1</td></tr>
<tr><td>900</td><td rowspan="4">1.1</td><td rowspan="2">1.1</td><td>1.1</td><td rowspan="3">1.2</td><td rowspan="2">1.2</td><td>1.2</td></tr>
<tr><td>700</td><td rowspan="3">1.2</td><td>1.3</td></tr>
<tr><td>600</td><td rowspan="5">1.2</td><td rowspan="2">1.3</td><td rowspan="2">1.4</td></tr>
<tr><td>500</td><td rowspan="3">1.3</td></tr>
<tr><td>450</td><td rowspan="4">1.2</td><td rowspan="3">1.3</td><td rowspan="2">1.4</td><td>1.5</td></tr>
<tr><td>400</td><td rowspan="7"></td></tr>
<tr><td>350</td><td>1.4</td><td rowspan="2">1.5</td></tr>
<tr><td>300</td><td rowspan="2">1.3</td><td rowspan="2">1.4</td><td rowspan="2">1.5</td></tr>
<tr><td>250</td><td rowspan="2">1.3</td><td rowspan="4"></td></tr>
<tr><td>200</td><td>1.4</td><td>1.5</td><td rowspan="3"></td></tr>
<tr><td>150</td><td>1.4</td><td>1.5</td><td rowspan="2"></td></tr>
<tr><td>100</td><td>1.5</td><td></td></tr>
</table>

Notes:
(1) Clear Zone correction factor is applied to outside of curves only.
(2) Curves flatter than 1,100 m do not require an adjusted Clear Zone.

Source: Alberta Infrastructure and Transportation's Roadside Design Guide (2007)

The measurement of the Desirable Clear Zone is only applicable over recoverable surfaces (firm; 4:1 or flatter slopes). The presence of a non-recoverable surface (generally considered to have a slope steeper than 4:1) requires an extension of the Clear Zone distance provided. The extension (called a recovery area), equivalent to the width of the non-recoverable slope located within the Desirable Clear Zone, is provided in recognition that an errant vehicle will likely travel to the bottom of the slope.

FIGURES H3.2 and H3.3 illustrate the measurement of the Desirable Clear Zone over a recoverable surface and a non-recoverable surface, respectively.

FIGURE H3.2 Desirable Clear Zone (DCZ) over Recoverable Surface

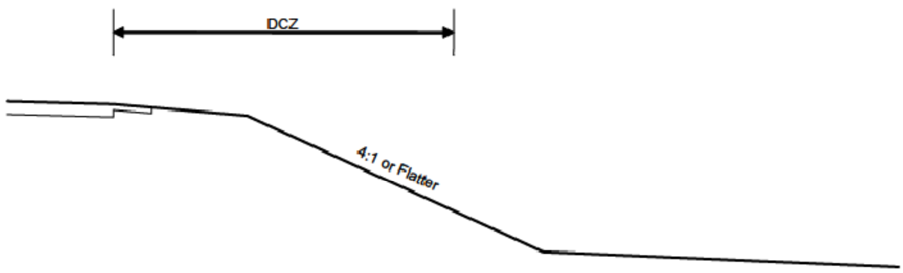
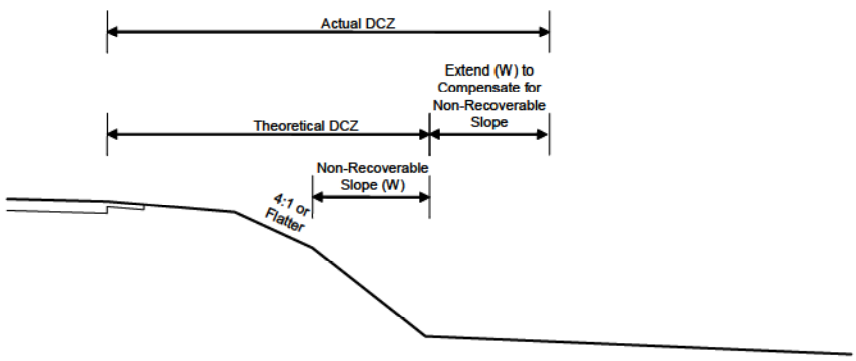


FIGURE H3.3 Desirable Clear Zone (DCZ) over Non-recoverable Surface



Source: Alberta Infrastructure and Transportation's ***Roadside Design Guide*** *(2007)*

The Desirable Clear Zone distance should not be considered as the maximum clear distance that needs to be provided for a facility. Mitigation of hazards beyond the Desirable Clear Zone should be considered where the combination of horizontal curvature, collision experience, and severity of hazard may pose significant concerns if hit by an errant vehicle. If a cost-effective mitigation solution to provide additional width beyond the Desirable Clear Zone is achievable, then increasing the offset to further enhance the safety of the facility should be considered.

The designer should use judgement when applying the Clear Zone offsets. Consider providing some form of hazard mitigation where the cross section or slope of the terrain or horizontal curvature tends to channel errant vehicles towards a hazard outside the Clear Zone. This would also apply for critical isolated hazards, such as bodies of water, cliffs and bridge piers, just beyond the Clear Zone where the consequences of a collision may be extremely severe, even if the probability of a collision are limited. Similarly, if isolated objects such as trees, are found to be just within the Clear Zone while other trees in the immediate vicinity are outside the Clear Zone, removal of the trees inside the Clear Zone may not significantly reduce the risk to drivers. Protection or removal may not be a cost-effective solution.

B. Hazards to be Considered

The hazards must be identified within the Desirable Clear Zone before a mitigation strategy can be formulated. Hazards can be categorized as:

- Sideslopes (see Section C)
- roadside obstacles (see Section D)
- permanent bodies of water (see Section E)

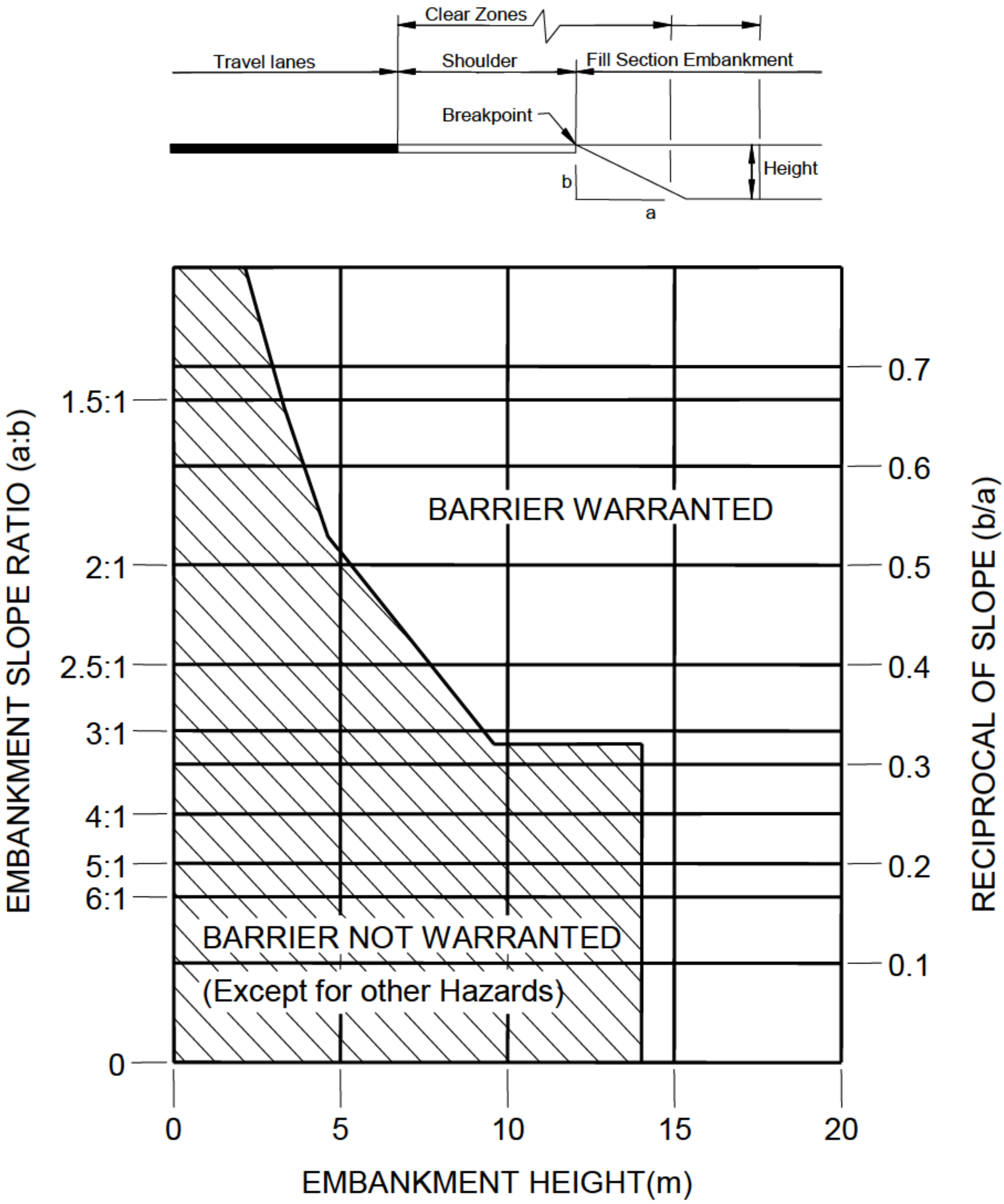
C. Sideslopes

High embankments may be considered as hazards because of the severe consequences related to errant vehicles leaving the roadway and travelling down the slope.

Sideslopes with a slope ratio steeper than 3:1 are considered to be a hazard since the possibility of a vehicle rollover will significantly increase. Similarly, steep backslopes may also be considered as a hazard due to an increased possibility of a vehicle roll-over.

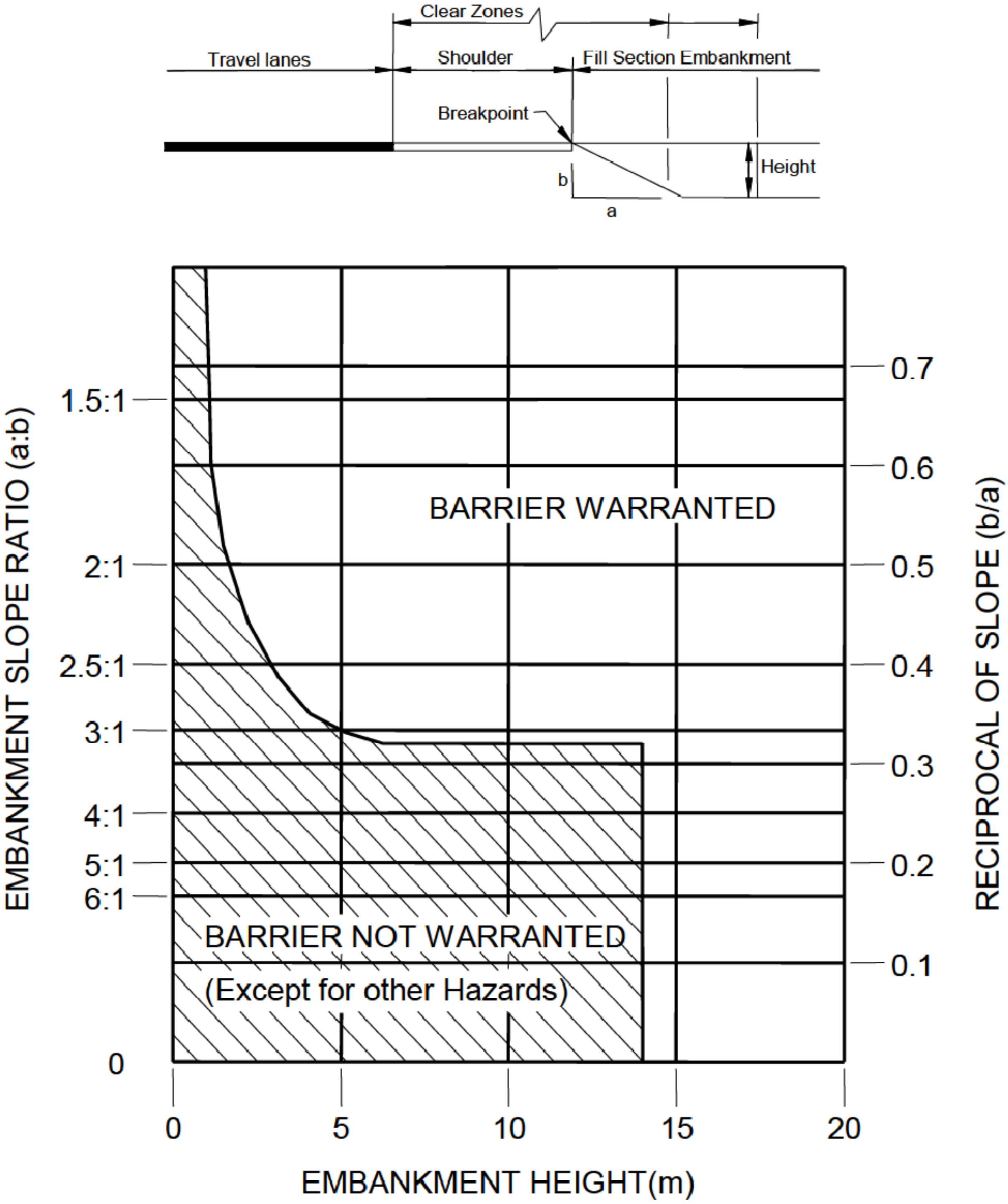
FIGURES H3.4 and H3.5 provide the longitudinal traffic barrier warrants for fill slopes with AADT < 400 vpd and AADT ≥ 400 vpd, respectively.

FIGURE H3.4 Warrants for Sideslopes with AADT < 400 vpd



Source: Alberta Infrastructure and Transportation's Roadside Design Guide (2007)

FIGURE H3.5 Warrants for Sideslopes with AADT ≥ 400 vpd



Source: Alberta Infrastructure and Transportation's Roadside Design Guide (2007)

Slope and height combinations on or below the curve do not warrant shielding unless they include obstacles that are within or immediately outside of the Clear Zone and present a serious hazard to the occupants of errant vehicles. If the sideslope and height of the fill relationship fall within the barrier-warranted zone, the sideslope hazard should be mitigated by either flattening out the slope or shielding it with a barrier. The preferred mitigation is flattening the sideslope versus installing a longitudinal traffic barrier, provided that the slope material is firm and that the overall height of embankment is less than 14 m. However, all slopes that are not shielded by a barrier should be free of obstacles and water hazards based on the Clear Zone criteria.

Where sideslope flattening is used to eliminate the need for a barrier on high embankments, a 4:1 sideslope is typically used. A 4:1 sideslope is generally considered satisfactory for embankment heights up to 14 m provided that the slope itself, and the area at the base of the embankment, are free of obstacles and water hazards and constructed to be firm. If the embankment height is greater than 14 m, barrier protection is suggested regardless of the sideslope ratio.

D. Roadside Obstacles

Roadside obstacles may be non-traversable hazards or fixed objects and may be either man-made or natural features. Hazards that should normally be considered for mitigation include:

- wood poles or posts with a cross sectional area greater than 10,000 mm^2 (100x100 mm) which do not have breakaway features;
- trees having a diameter of 100 mm or more;
- fixed objects extending above the ground surface by more than 100 mm, such as boulders, bridge rail ends, bridge abutments, piers, retaining wall ends, and bridge headwalls;
- intersecting roadways and cross slopes;
- non-breakaway signs or light pole supports;
- non-breakaway utility poles;
- vertical drops greater than 300 mm;
- mailboxes with 100 mm wood posts; or,
- 50 mm steel posts and greater drainage structures, such as culvert and pipe ends without tapered end sections or traversable grates.

The decision on the use of a longitudinal traffic barrier should be based on the size, shape and location of the hazard. These hazards should be mitigated based on the order of preference provided in the Mitigation Strategies section below.

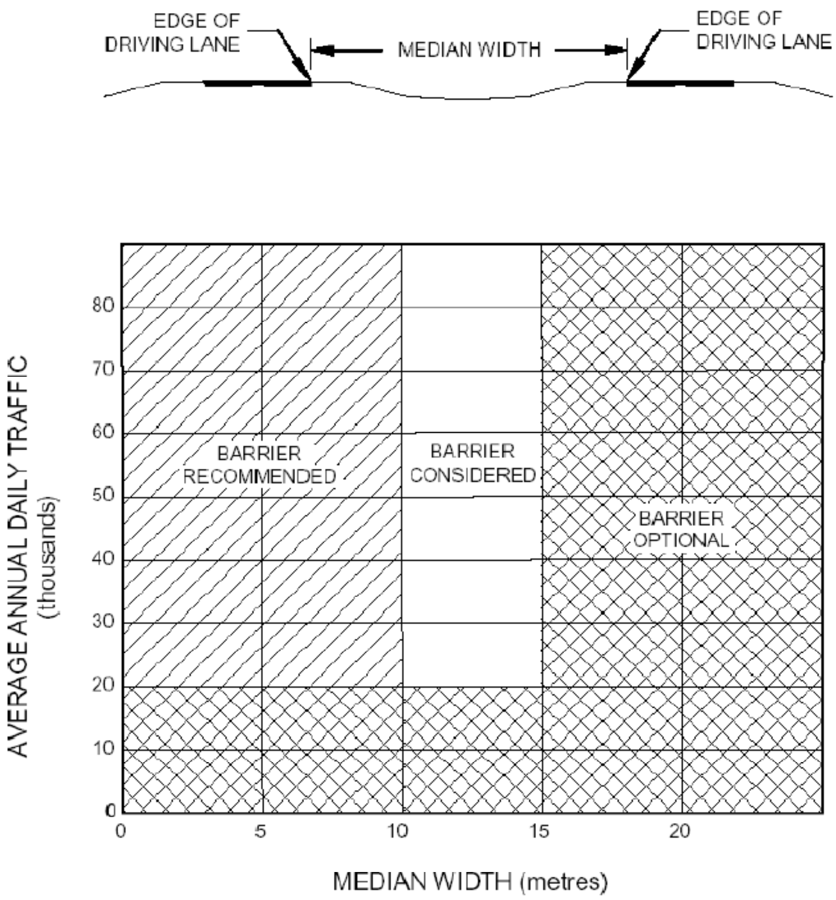
E. Permanent Bodies of Water

Bodies of water with a depth of one metre or more located within the Clear Zone should be considered a hazard. Longitudinal traffic barrier systems are typically used to mitigate this type of hazard. Where the bodies of water are seasonal in nature, or where the depth of water varies based on the season, the designer should use engineering judgement to determine if shielding is warranted based on traffic exposure, offset from roadway, duration of hazard, length of hazard, and severity of the hazard.

Evaluate Need for Median Barrier

The Alberta Transportation *Roadside Design Guide* provides a warrant to determine when a median barrier is required based on traffic volumes and the median width. Although not stated, the median barrier warrant is intended for higher speed roads. It is suggested that median barriers be used on higher speed roads (posted speed limit > 70 km/h) where the potential collision severity is higher. The median barrier warrant is reproduced below in FIGURE H3.7.

FIGURE H3.7 Median Barrier Warrant



Source: Alberta Infrastructure and Transportation's Roadside Design Guide (2007)

In addition to the normal warrant which is used for medians less than 15 m wide, the following warrant, based on collision experience, is used to evaluate wider medians with very high traffic volumes. The collision rate calculation requires a minimum of three crashes within a five-year period. A median barrier is required if one of the following conditions* is met:

- 0.310 cross-median crashes of any severity per kilometre per year
- 0.075 fatal crashes per kilometre per year.

** Criteria based on CalTrans crash study warrant*

Step 2: Review Mitigation Strategies

The mitigation strategies recommended for roadside and cross-median collision vary and are discussed separately in the following subsections.

Roadside Mitigation Strategies

If it is determined in Step 1 that there are roadside (including the median) hazards within the Clear Zone, an appropriate mitigation strategy needs to be identified. For each hazard identified, the following strategies listed in order of priority of preference will be considered to determine the appropriate roadside mitigation:

- Remove the hazard;
- Redesign the hazard so that it can be safely traversed or contacted;
- Relocate the hazard to reduce the probability of it being traversed or contacted;
- Reduce the severity of the hazard;
- Shield the hazard (traffic barrier);
- Delineate and increase the driver's awareness of the hazard, if the other mitigation measures cannot be made to work.

If it is determined that barrier protection is the best mitigation strategy, the next step is to evaluate if a cable barrier is an appropriate barrier type for the application.

Median Mitigation Strategies

In the case of cross-median collisions, there are fewer mitigation strategies available to reduce the collision risk. Other than providing barrier protection, the only other strategy to reduce the risk of cross-median collisions is to increase the median width.

Increasing the median width is preferred over installing a traffic barrier as it is expected to provide a greater reduction in the frequency of collisions (including collisions with the barrier). However, increasing the width of the median may not be feasible due to right-of-way, topographical or financial constraints.

Step 3: Determine if Cable Barrier is Appropriate

Although cable barriers provide some safety benefits over other barrier types, they are not appropriate in all applications. Therefore, it is necessary to determine if a cable barrier is suitable for the intended application. Some potential design constraints to consider prior to implementation are discussed in the following subsections.

A. Operating Speeds

As discussed previously, the collision severity reduction benefits of a cable barrier, compared to a more rigid barrier, are less pronounced at lower speeds. Cable barriers are typically designed to high test levels (TL-4 or greater) that may exceed the requirements for low speed environments. TABLE H3.3 provides the minimum test level requirements based on Alberta Transportation's *Roadside Design Guide*.

TABLE H3.3
Barrier Test Level Requirements

Design Speed (km/h)	Test Level
> 70	TL-3
> 50 to ≤ 70	TL-2
≤ 50	TL-1

The cost effectiveness of installing cable barriers, over other barrier types, on lower speed roads (< 70 km/h) should be reviewed prior to implementation.

B. Distance Between Barrier and Hazards

The design deflection of a barrier system is the distance the barrier will shift laterally when impacted by an errant vehicle. It must be fully considered when selecting the appropriate barrier system. The design deflection of a barrier system defines the minimum offset between the barrier system and the hazard that is being shielded. If the system is placed too close to the hazard, the impacting vehicle may deflect the barrier into the hazard. This may allow the vehicle to interact with the hazard and negate the purpose of the barrier system.

If the hazard cannot be relocated beyond the design deflection of a cable barrier (typically 2.1m – 2.4m), then a different system with a lower design deflection should be selected to ensure that the hazard will not be inadvertently contacted during a collision. The expected deflection of the barrier should be confirmed with the manufacturer based on the design speed and characteristics of the road.

C. Sideslope

Although cable barriers can be installed to protect steep sideslopes, they should not be installed on slopes greater than 6:1. Where existing slopes are steeper than 6:1 and adequate lateral distance cannot be provided, the slope should be regraded to 6:1 or flatter. The sideslope requirements should be confirmed with the manufacturer.

D. Distance Between the Road and the Barrier

The distance between the edge of the travelled way and the barrier should not be less than 1.0m (this applies for all barrier types). The lateral space available adjacent to the road should be reviewed to confirm sufficient space is available between the edge of the travelled way and the barrier and between the barrier and the hazard to be protected.

E. Minimum Length Requirement

Cable barriers may not be appropriate for short sections of barrier protection. The minimum length required for a cable barrier varies up to 35m and should be confirmed with manufacturer.

In addition, short sections of cable barrier are less cost effective as the cost of installing the end anchors is relatively high. End treatments also pose an increased collision risk compared to the rest of the barrier.

F. Horizontal Curves

Cable barrier systems may not be appropriate for small horizontal radii curves. The typical minimum value is 200m. However, this should be confirmed with the manufacturer.

G. Sag Vertical Curves

The posts of some cable barrier systems are free standing and not held down by the system. Therefore, when cables in a sag curve are tightened the cable could lift the posts, resulting in an inadequate barrier height. Sag vertical curves with low K-Values should be avoided and the performance should be confirmed with the manufacturer.

H. Presence of Curbs

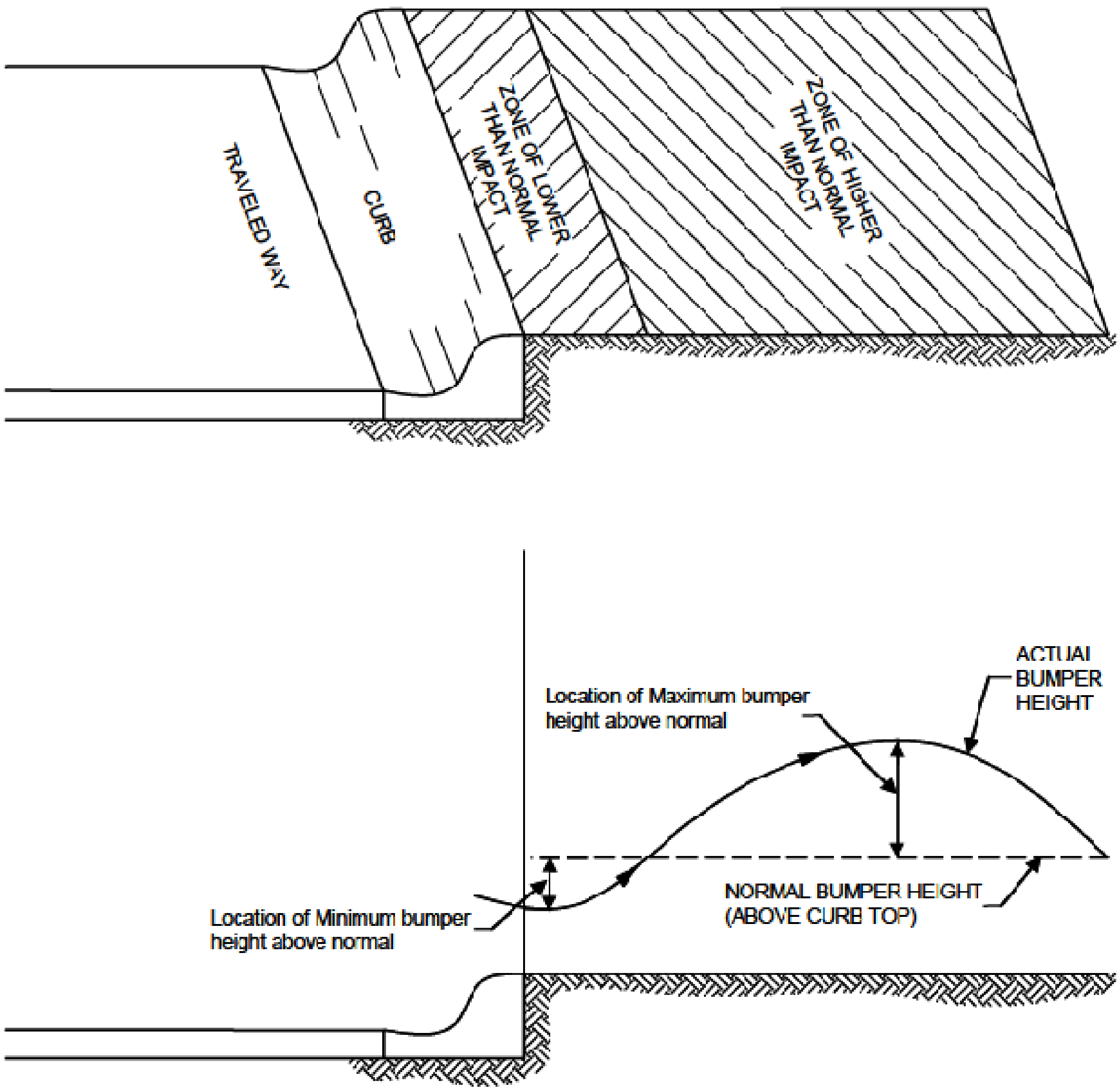
Curbs are often necessary for drainage purposes to collect and/or direct surface flow. Unfortunately, curbs can also adversely affect the trajectory and stability of an errant vehicle when encountered. The combination of curbs and barrier systems presents additional challenges because the vehicle may not effectively interact with the barrier after hitting the curb. The wheels of the vehicle are raised when crossing a curb such that the bumper is elevated to a point where it may be too high to interact properly with the barrier system.

In addition, crossing the curb also causes the vehicle suspension to oscillate and as a result, not only is the bumper height elevated, it is also changing position as the suspension dampens out the effect of crossing the curb.

Striking a barrier system may result in poor impact performance if the bumper and suspension system are out of position when the vehicle begins its interaction with the barrier system. For this reason, the use of curbs in conjunction with barrier systems is generally discouraged. It is often necessary, however, to use a curb for drainage or other reasons at a particular location that also requires a barrier system.

NCHRP *Report 537: Recommended Guidelines for Curb and Curb-Barrier Installations* (2009), documents a recent investigation of the safety implications of combining curbs with adjacent longitudinal W-Beam Strong Post traffic barrier systems. The primary goal of the study was to develop design guidelines for using curbs and curb–barrier combinations on roadways with operating speeds greater than 60 km/h. From this study, the trajectory of the vehicle after contact with the curb was determined. FIGURE H4.1 illustrates the vehicle trajectory based on the bumper height of the vehicle. In general, a barrier curb should not be installed on roadways with posted speeds greater than 60 km/h. For a curb installation in an area with posted speeds greater than 60 km/h, a mountable curb is desirable.

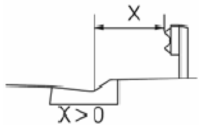
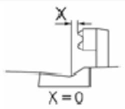
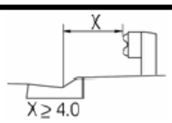
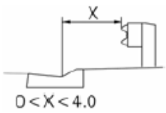
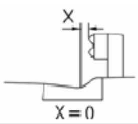
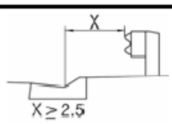
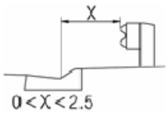
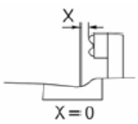
FIGURE H4.1 Vehicle Trajectory after Contact with Curb



Source: Alberta Infrastructure and Transportation's Roadside Design Guide (2007)

Standard drawings for typical curbs used on Alberta highways are provided on the Alberta Transportation website under the Highway Design & Construction subsection of the Technical Resources for Roads, Bridges, & Water section. Acceptable combinations of curb and barrier systems are dependent on the operating speed of the highway, the cross-sectional shape of the curb, and the lateral offset of the curb from the barrier system. The desirable combinations of curb and barrier systems based on operating speed and lateral offset, adapted from NCHRP Report 537, are shown in TABLE H4.1.

TABLE H4.1 Appropriate Curb and Barrier System Combinations (Barrier System Behind Curb)

Operating Speed (km/h) [3]	Allowable Offsets to Barrier Systems (m)	Acceptable Curb Types	Barrier Systems [1]					
			Cable	W-Beam Weak Post	Weak Post Box Beam	W-Beam Strong Post	Modified Thrie Beam	Rigid Concrete Barrier
> 100 [5]	Any Offsets	Mountable, Semi-mountable and Barrier	Installation of curb in conjunction with barrier system not recommended.					
> 85 to 100 [5]		Mountable	Installation of curb in conjunction with barrier system not recommended.					
		Semi-mountable						
		Barrier						
		Mountable	✓	✓	✓	✓	✓	✓
		Semi-mountable	×	×	×	×	×	×
		Barrier	×	×	×	×	×	×
> 70 to 85		Mountable	✓	✓	✓	✓	✓	✓
		Semi-mountable	×	×	×	×	×	×
		Barrier	×	×	×	×	×	×
		Mountable	Installation of curb in conjunction with barrier system not recommended.					
		Semi-mountable						
		Barrier						
		Mountable	✓	✓	✓	✓	✓	✓
		Semi-mountable	✓	✓	✓	✓	✓	✓
		Barrier	×	×	×	×	×	×
> 60 to 70		Mountable	✓	✓	✓	✓	✓	✓
		Semi-mountable	✓	✓	✓	✓	✓	✓
		Barrier	×	×	×	×	×	×
		Mountable	Installation of curb in conjunction with barrier system not recommended.					
		Semi-mountable						
		Barrier						
		Mountable	✓	✓	✓	✓	✓	✓
		Semi-mountable	✓	✓	✓	✓	✓	✓
		Barrier	×	×	×	×	×	×
≤ 60	No Restriction	Mountable, Semi-mountable and Barrier	✓	✓	✓	✓	✓	✓

Note: (1) Excludes application of barrier curbs on structures ✓ Permitted × Not Permitted

(2) Adopted from *NCHRP Report 537*

(3) Operating Speed is defined as the highest speed at which reasonably prudent drivers can be expected to operate vehicles under low traffic densities and good weather. Typically for Alberta highways, the 85th percentile running speed in good conditions is used, provided it does not exceed the design speed. For operating speeds greater than 70 km/h, the suggested minimum offset between the edge of travelled lane and the face of curb is the shy line offset as described in **Section H5.4.1**.

(4) For Alberta standard curb and gutter details, refer to CB6 Standard Plates, such as CB6-4.2M89.

(5) For operating speeds > 85 km/hr, curb and barrier systems combinations are acceptable provided that the curb is installed behind the barrier system at an offset ≥ than the barrier design deflection.

The critical dimensions for the semi-mountable and mountable curbs indicated in NCHRP Report 537 should be provided in order for the combination of barrier and curb to operate effectively. The standard semi-mountable and mountable curbs provided by Alberta Transportation currently meet these requirements.

The critical dimensions for semi-mountable curb are:

- curb height equal to or less than 150 mm from the gutter to the top of curb
- curb slope should be 1:3 (vertical:horizontal) or flatter.

The critical dimensions for mountable curb are:

- curb height equal to or less than 100 mm from the gutter to the top of curb
- curb slope should be 1:3 (vertical:horizontal) or flatter.

3.6.8 Implementation Considerations

These application guidelines are intended to assist practitioners in determining when a cable barrier is warranted. The actual design of the cable barrier systems is not covered in this document. Some general implementation considerations are provided below:

- The feasibility of removing or relocating hazards should be considered prior to considering a cable barrier.
- The characteristics of cable barriers vary depending on the manufacturer. Confirm all characteristics with the manufacturer prior to implementation, including:
    - Deflection distance;
    - Minimum horizontal curve radius;
    - Minimum vertical sag curve radius;
    - Minimum sideslope; and,
    - Minimum length of run

- Ensure adequate separation is provided between the cable barrier and the hazard(s) to accommodate the deflection of the cable barrier.
- Cable barriers should not be attached to a rigid object, including other barriers. Significant differences in the deflection characteristics of the two elements could cause pocketing or snagging, and potentially result in serious injuries.

- Cable barriers can create an impedance to maintenance vehicles. Cable barriers placed too close to the road could also impede emergency vehicles trying to use the shoulder.
- Ground conditions must have sufficient stability to support the posts
- The wake from snow ploughs can damage posts so ensure adequate lateral separation is provided.
- Avoid placing a cable barrier beyond a ditch unless the cable barrier is within 0.3m or beyond 2.4m of the bottom of the ditch. This is to reduce the risk of vehicles under riding the cable barrier.

3.6.9 Maintenance Considerations

Based on the Alberta Transportation *Roadside Design Guide* a cable barrier should typically be inspected at least every two years to confirm the system is in good working order. Manufacturers should be consulted to determine the maintenance requirements for that particular cable barrier system.

After impacts, the cable barrier may remain in tension depending on the severity of the collision and as a result, the system can still provide some protection to motorists. The system should be inspected after every impact to identify any components that were damaged, such as posts, hairpins and lock plates, such that they can be replaced. Re-tensioning of the cable may also be required.

Maintenance staff will require training to learn how to inspect and repair the cable barrier to ensure it remains up to quality standards after implementation. Spare parts, particularly posts, will need to be stored nearby to ensure repairs can be made quickly after an incident.

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ALBERTA TRANSPORTATION

METHODS OF REDUCING COLLISIONS ON ALBERTA ROADS

APPLICATION GUIDELINES FOR REMOVAL OF FIXED OBJECTS

FINAL

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3.7 Removal of Fixed Objects

3.7.1 Background

Drivers who leave the roadway may encounter fixed objects (such as trees, poles, culvert headwalls, bridge abutments, bridge rail ends, piers, retaining wall ends, sign supports, rock faces, fences, fire hydrants, and mailboxes) or other hazards (such as culverts, ditches, steep sideslopes, or water bodies) in the roadside area that generate safety issues resulting from impact, vehicle rollover, or submersion.

The most effective measures to prevent roadside crashes are those that keep road users from encroaching on the roadside area in the first place. These measures could include rumble strips, anti-skid pavement treatments, delineation and signing. However, once drivers leave the roadway and enter the roadside area, mitigation strategies must focus on minimizing injury. The Alberta Transportation *Roadside Design Guide* (2007) advises that mitigation strategies for avoiding injury due to roadside hazards include, in order of preference:

1. removing the hazard;
2. redesigning the hazard to render it less harmful;
3. relocating the hazard;
4. reducing the severity of the hazard;
5. shielding the hazard; and,
6. delineating the hazard.

These guidelines discuss the removal of roadside hazards. There are several existing design guidelines (see below) that discuss what type of fixed objects are considered hazardous and how far from the road these objects should be.

In addition to identifying fixed objects for removal during the design, road agencies should review existing infrastructure to identify pre-existing fixed object collision hazards. The need to remove fixed objects can be identified as part of a roadside safety assessment. This document identifies seven different factors that should trigger a roadside safety assessment.

3.7.2 Definitions

The Alberta *Roadside Design Guide* identifies fixed objects that should be considered for mitigation as:

- wood poles or posts with a cross sectional area greater than 10,000 mm^2 which do not have breakaway features
- trees having a diameter of 100 mm or more
- fixed objects extending above the ground surface by more than 100 mm, such as boulders, bridge rail ends, bridge abutments, piers, retaining wall ends, and bridge headwalls
- intersecting roadways and cross slopes
- non-breakaway signs or light pole supports
- non-breakaway utility poles
- vertical drops greater than 300 mm
- mailboxes with 100 mm wood posts or 50 mm steel posts and greater
- drainage structures, such as culvert and pipe ends without tapered end sections or traversable grates.

For the purpose of this document, the term "fixed object" will refer to items on the above list.

Clear Zone is another common term used when discussing fixed objects at the roadside. The clear zone is the area adjacent to the roadway's traveled lanes that should be free of hazards in case a vehicle runs off road. The minimum clear zone required is based on the traffic volumes, design speed, and roadside geometry. Clear zone requirements are clearly stated in Alberta Transportation's *Roadside Design Guide* (Section H.3.2.1).

3.7.3 Current Status in Alberta

Removing fixed objects at the roadside is a common practice in Alberta, particularly in rural environments. Fixed objects at the roadside are more common in urban areas where space constraints often result in fixed objects being located in close proximity to the road.

Fixed objects are most often identified and mitigated at the design and construction stage. Most road agencies have policies and/or guidelines that discourage the placement of fixed objects near the roadside. Policies and processes to identify and remove fixed objects that are installed after construction is completed are not as common in Alberta.

3.7.4 Example Applications

The removal of fixed objects can provide benefits for all road classifications and land uses. Example applications are illustrated in TABLE 3.23.

TABLE 3.23 EXAMPLE APPLICATIONS

 ***Highway 727:*** *Rural application of wide paved shoulder, roadside delineation, recoverable sideslope, and unobstructed clear zone.*	 ***Pincher Creek:*** *Rural application of wide paved shoulder with shoulder rumble strips.*
 ***Barlow Trail, Calgary:*** *Urban application of wide paved shoulders, recoverable side slopes and an unobstructed clear zone,*	 ***Lougheed Highway, Vancouver:*** *Urban application where fixed objects are frangible (breakaway posts and small caliper trees) and separated from the travel lane by a bicycle lane and sidewalk.*

3.7.5 Benefits and Costs

Collision Reduction Benefits

The removal of fixed objects from the roadside has been proven as an effective countermeasure to reduce both the frequency and severity of collisions. A study conducted by the Lehman Centre for Transportation Research[49] identified the collision reduction factors used by several Departments of Transportation in the United States. A summary of the collision reduction factors used for the removal of fixed objects is provided in TABLE 3.24.

TABLE 3.24 REMOVAL OF FIXED OBJECT COLLISION REDUCTION FACTOR

State Department of Transportation	Collision Type	Collision Severity	Collision Reduction Factor	Average CRF for Collision Type
Arizona	All	All	61%	29%
California	All	All	20%	
Kentucky	All	All	30%	
Missouri	All	All	30%	
Montana	All	All	30%	
New York (AADT > 5,000/lane)	All	All	17%	
New York (AADT < 5,000/lane)	All	All	18%	
Oklahoma	All	All	25%	
Kentucky	All	Fatal	50%	50%
Missouri	All	Fatal	50%	
Kentucky	All	Injury	30%	30%
Missouri	All	Injury	30%	
New York (AADT > 5,000/lane)	Rear-End	-	44%	43%
New York (AADT < 5,000/lane)	Rear-End	-	42%	
Alaska	Fixed-Object	-	100%	88%
Michigan	Fixed-Object	-	75%	
Arizona	Run-off-road	-	71%	71%
New York (AADT > 5,000/lane)	Overturn	-	44%	43%
New York (AADT < 5,000/lane)	Overturn	-	42%	

Operational / Maintenance Benefits

49 Gan, A., Shen, J., and Rodriguez, A., "Update of Florida Crash Reduction Factors and Countermeasures to Improve the Development of District Safety Improvement Projects." Florida Department of Transportation, (2005)

Removing fixed objects from the roadside has a minimal impact on traffic operations. Operational benefits can be achieved in some circumstances by improving intersection and stopping sight distances. Removing fixed objects from the roadside provides maintenance benefits as the fixed objects will not require maintenance from being struck and damaged by a vehicle. Maintenance benefits are also derived from the lack of obstacles to avoid for mowing, paving, etc.

Costs

The cost to remove fixed objects varies greatly depending on the object to be removed. The low end of the cost range (assumed to be $100 - $500) would be to remove an unapproved sign or trim a bush. The higher costs ($1.5 million) would be to demolish a large building. Annual M&O costs were assumed to be $2500. However, depending on the nature of the fixed object, it is unlikely to return (especially to the extent that it was prior to removal). A tree may grow back, but it should be removed before growing too large.

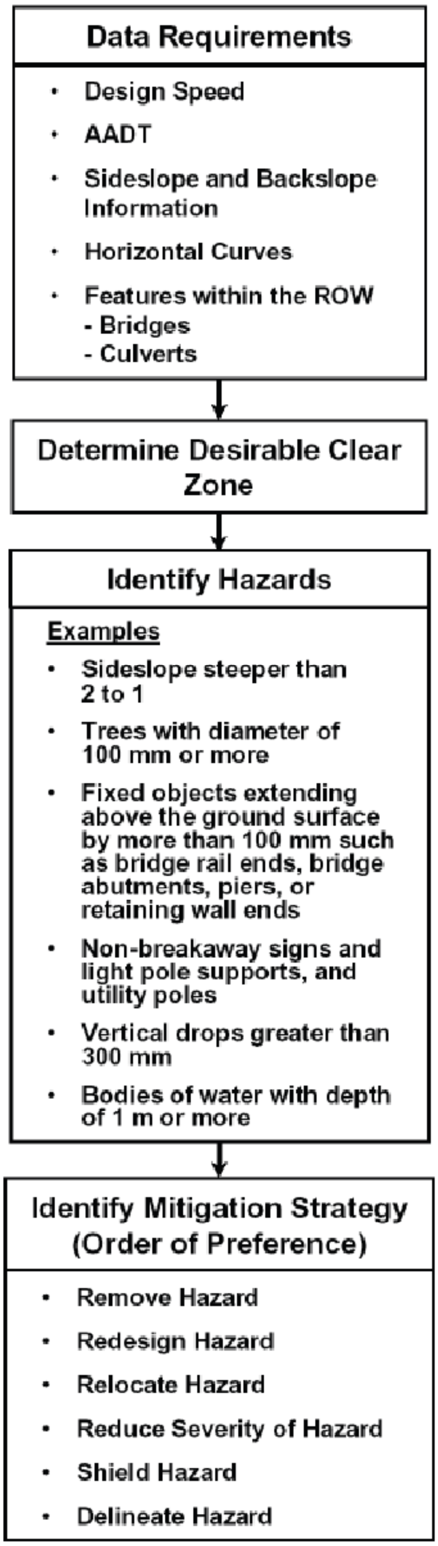
3.7.6 Existing Application Guidance

National Guidance

The Transportation Association of Canada's *Geometric Design Guide for Canadian Roads* (2007), provides guidance on the appropriate clear zone required based on the road characteristics (Section 3.1.3). Sections 3.1.4 and 3.1.5 of the guide identify common fixed object hazards and recommends mitigating measures to reduce the collision risk.

Provincial Guidance

Roadside design in Alberta is governed by the *Alberta Roadside Design Guide*[50] (TRANS, 2007), which guides highway designers in how to develop cost-effective roadside environments that meet the province's safety objectives. The Alberta *Guide* outlines the general philosophy and principles of roadside design, presents TRANS's current practices and guidelines governing roadside design activities, and includes a comprehensive design process for roadside design treatments. Section H3 of the *Guide* summarizes the design process used to determine the most appropriate and cost-effective design strategies for roadside features. Figure H3.1 *(right)* outlines the roadside design process.



Municipal Guidance

No municipal guidelines or policies for the removal of fixed objects were identified in Alberta. Therefore, the most relevant guideline for both urban and rural applications in Alberta is the *Alberta Transportation Roadside Design Guide*.

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[50] http://www.transportation.alberta.ca/3451.htm

International Guidance

In addition to the *Geometric Design Guide for Canadian Roads* and *Alberta Roadside Design Guide*, guidance is available from the following documents and websites:

- *Roadside Design Guide (Third Edition)* (American Association of State Highway and Transportation Officials, 2006)
- *Urban Street Geometric Design Handbook* (Institute of Transportation Engineers, 2008) (Chapter 8, *Roadside Design)*
- *Safe and Aesthetic Treatments in Urban Areas* (National Cooperative Highway Research Program, Report 16-04 (Transportation Research Board, 2008) (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_612.pdf)
- *Highway Safety Manual* (American Association of State Highway and Transportation Officials, 2010)
- FHWA *Roadway Departure Safety* website (http://safety.fhwa.dot.gov/roadway_dept/).

3.7.7 Recommended Application Guidance

Land Use and Speed Context

Land Use

Removing fixed objects within the clear zone can and should be implemented in both urban and rural environments. The AASHTO and Alberta *Roadside Design Guide*s address rural, urban and “restricted” (transition and suburban) environments. While acknowledging that it is difficult for a designer to achieve an acceptable clear zone in an urban environment, the U.S. publication *Safe and Aesthetic Treatments in Urban Areas* (see previous section) provides specific advice regarding:

- minimum lateral offsets to hazardous objects in urban areas;
- positioning hazardous objects near lane merges; and,
- the appropriateness of using sidewalks and auxiliary lanes (including bike and bus lanes) as buffers or as part of the clear zone.

Speed Ranges

Removing fixed objects is beneficial on both low speed and higher speed roads. Removing fixed objects on higher speed roads provides a greater benefit as higher speeds typically result in more severe collisions.

All land use and speed environments are considered acceptable for the removal of a fixed object as summarized in TABLE 3.25.

TABLE 3.25 ACCEPTABLE LAND USE AND SPEED RANGES FOR REMOVAL OF FIXED OBJECTS

LAND USE	POSTED SPEED LIMIT (km/h)			
	50 or less	60 - 70	80 - 90	100 or more
Rural	✓	✓	✓	✓
Urban	✓	✓	✓	✓
Semi-Urban / Suburban	✓	✓	✓	✓

Policy for Removal of Fixed Objects

The following subsections outline a policy for the removal of fixed objects at the roadside.

Design

Designers should make every effort to conform to the requirements and guidelines in the *Alberta Roadside Design Guide* (TRANS, 2007) for:

- clear zones;
- grading and drainage;
- roadside and median barrier systems;
- barrier end treatments and crash cushions;
- bridges;
- signs, supports, and poles; and,
- work zones.

Where constraints render compliance with the *Guide* costly or difficult, an assessment of the risk associated with run-off-road crashes should be conducted. The presence of any risk factors, including geometric, operational, or environmental factors that would increase the probability or severity of a run-off-road crash, will support the designer's requirement to comply with the *Guide*.

A roadside safety assessment should be part of all new road designs, and should also be conducted for all existing roads as discussed in the Policy to Conduct a Roadside Safety Assessment section.

Maintenance

Roadways and clear zones should be maintained to minimize the risks associated with run-off-road crashes.

- An abrupt pavement edge drop-off can increase the risk of a run-off-road crash by preventing drivers from safely re-entering the roadway once they have left the pavement. Abrupt drop-offs can result from repeated pavement lifts or shoulder/roadside erosion. Pavement edges should be correctly designed and maintained to allow drivers to re-enter the pavement in a controlled manner, and should be remediated if they deteriorate.
- Mowing and vegetation control guidelines may be developed and implemented to prevent trees from growing within the clear zone.
- Roadside hardware (such as sign posts, light standards, barriers, utility poles, etc.) that does not conform to existing standards should be identified and prioritized for removal and, if necessary, mitigation and replacement. Roadside hardware may no longer comply with standards for many reasons, including:

    - outdated designs that do not meet updated standards;
    - poor maintenance resulting in deterioration;
    - damage due to snowploughing or vehicle crashes;
    - barrier/guardrail that is too low as a result of repeated pavement lifts (which increases the road height) or settlement of the roadside area (which decreases the barrier/guardrail height); or,
    - erosion, resulting in abrupt pavement edge drop-offs or steep or unstable slopes.

- Fixed objects are commonly removed from within the clear zone during the design and construction stages. However, there is the potential for fixed objects to appear within the clear zone (with or without authorization) once the road is operational. Examples of these objects include mailboxes and advertising signs. Periodic inspections should be conducted to identify and mitigate such objects within the clear zone.

Roadside safety assessments should be conducted periodically on existing infrastructure. The Policy section identifies factors that should trigger a roadside safety assessment and the possible removal of fixed objects.

Prevention

In addition to designing a hazard-free roadside whenever possible, preventive measures may be considered on a corridor-wide or site-specific basis to reduce the risk that road users leave the roadway and enter the roadside area. These preventive measures may include:

- shoulder rumble strips;
- centreline rumble strips;
- curve delineation using post-mounted delineators;
- wide edgelines;
- enhanced pavement skid resistance;
- advance warning of curves;
- wide shoulders;
- adequate shoulder stability to prevent erosion of shoulder area;
- durable high visibility pavement markings;
- hazard marking signage; and,
- improved lighting.

Consider all road users. Adequate clear zones should be considered for multi-use trails and cycling facilities. Cyclists can easily attain speeds of 50 to 60 km/hr on sustained downhill gradients, and have little or no protection in the event of a collision.

Policy to Conduct a Roadside Safety Assessment

Roadside safety should be explicitly considered at all stages of road design and operation. Using the guidance provided in the resources listed above, a roadside safety assessment should be conducted as part of all new design projects and periodically on existing infrastructure.

A roadside safety assessment should:

- identify potential roadside hazards
- assess the degree of risk, based on
  - *probability* of a crash (reflecting the presence of factors that could aggravate the likelihood of a crash, such as frequent slippery road conditions or locating a hazard on the outside of a horizontal curve)
  - *exposure* (reflecting the volume of road users, so exposure is typically higher where user volumes are higher)
  - *consequence* (reflecting the likely severity of a crash, increasing with impact speed and with certain users such as motorcyclists)
- identify mitigation where necessary.

Mitigation can include the following measures, in order of preference:

- Remove the hazardous object: Removal of hazards, including non-crashworthy mailboxes, is preferable. Removal can include placement of utilities underground instead of above ground using poles or other supports that can be a roadside hazard.
- Relocate the hazardous object. Where hazardous objects cannot be removed, they should be relocated to outside the clear zone. Where a hazard is located within the clear zone and in an area of higher risk (such as on the outside of a horizontal curve or near a lane drop) and cannot be removed from within or close to the clear zone, consideration may be given to relocating it to where drivers are less likely to leave the roadway.
- Shield, cushion, or redesign the hazardous object: When a hazard cannot be removed or relocated, it should be shielded (using guardrail or barrier), cushioned, or redesigned so that out-of-control drivers collide with a less hazardous element that either redirects the vehicle or decelerates it in a slower and more controlled way. While these measures cannot reduce the frequency of a run-off-road crash (and may in fact increase the frequency by introducing a barrier that is larger than the protected hazard, or closer to the road than the hazard), they may reduce the severity of a run-off-road crash. It is important to note that curbs do not function as barriers, and are generally not capable of containing or redirecting errant vehicles. They should not be considered a substitute for barriers or guardrails.

- Mark the hazardous object: Where the risk of a run-off-road collision results from drivers' lack of awareness of a roadside hazard, rather than loss of vehicle control, the hazard can be marked (delineated). Marking the object will make drivers aware of it so they can avoid it. Markings should be conspicuous and easily visible at night.

Clear zones and the design of roadside hardware should meet or, if possible within project budgets, exceed the current TRANS design guides. In addition to new designs, a roadside safety assessment on existing infrastructure can be triggered by one or more of the seven factors discussed in the following subsections.

History of Frequent and/or Severe Run-Off-Road Crashes

Sites at which run-off-road crashes are frequent and/or severe (resulting in severe injury or fatality) can be reviewed. If a review of the crash history suggests that the presence of run-off-road hazards are a factor in the frequency and/or severity of crashes, a plan may be implemented to remove the hazards, shield drivers from them, or introduce measures to reduce the risk that drivers will leave the roadway in the first place.

A sample Lane Departure Strategic Action Plan provided by the US Federal Highway Administration (FHWA) gives five-year threshold run-of-road crash values that are likely to warrant low-, medium-, and high-cost countermeasures[51]. These are example values only, and should be reviewed with reference to your agency's crash experience. The threshold values are based on achieving a benefit-cost (B/C) ratio of 2.0, and show threshold crash frequencies over a five-year period.

- Because of low unit costs for *low-cost countermeasures*, it doesn't take many crashes to justify an improvement.
- *Medium- or high-cost countermeasures* may also be considered for system deployment; however, because of the higher costs, they are only considered at high crash locations as shown below.
- Because fewer crashes occur on *local roads*, and they occur over a much larger road system, the level of concentration is typically much less than that found on larger highway systems. The FHWA sample action plan identifies three countermeasures to pursue on local roads, as shown in TABLE 3.26.

[51] See *Lane Departure Strategic Action Plan* (US Federal Highway Administration, 2005), available on-line at (http://safety.fhwa.dot.gov/roadway_dept/strat_approach/lanedeparture/page4.cfm).

TABLE 3.26 FHWA SAMPLE ACTION PLAN

Countermeasure	Target Crash Type	Threshold Target Crashes (over five years)
Highway Low-Cost Countermeasures		
edge/shoulder rumble strips	run-off-road	0.7 crashes
advance curve warning	run-off-road (curve)	1.0 crashes
tree removal	tree	0.5 crashes
guardrail upgrade	guardrail	1.1 crashes
Highway Medium- and High-Cost Countermeasures		
Regrade/flatten hazardous slopes	run-off-road (ditch and/or rollover)	25 crashes in 1,000 ft (300m)
shoulder widening to at least 1.9m (where little or no shoulder) with rumble strips	run-off-road	75 crashes in 3,000 ft (900m)
Local Road Countermeasures		
innovative signing and marking for curves	run-off-road or head-one (curve)	10 crashes per municipality
selective tree removal	tree	6 crashes per local rural road
selective run-off-road treatments	run-off-road	10 crashes per local rural road

Maintenance Records Indicating Frequent Run-Off-Road Crashes

A review of maintenance records, or consultation with maintenance staff, can help identify locations where drivers are entering the off road clear zone, as well as the hazards they may encounter. Indications of run-off-road crashes may include frequent repairs to guardrail or replacement of delineator posts or other roadside hardware. Maintenance staff, who are often driving the roadways under all weather and lighting conditions, may also be able to identify locations that they find potentially hazardous.

Initiation of 3R or 1R Projects

A roadside safety assessment should be included in 3R (resurfacing, restoration, and rehabilitation), 1R (resurfacing) projects, and utility projects. The assessment should identify roadside hazards, assess the degree of risk associated with them (based on exposure, probability, and consequence), and identify opportunities to “piggyback” cost-effective improvements on the 3R/1R project to improve roadside safety. Roadside areas, both within the clear zone and near its boundary, should be as clear as practical. Other improvements that can be considered within 3R, 1R, and utility projects include widening, paving shoulders, regrading drainage ditches, and stabilizing roadside slopes.

Substantial Change in the use of a Roadway

Roadways on the urban/rural fringe may change from a rural route to a commuter route as suburbs or “bedroom communities” develop around an urban core, or may be upgraded to a highway. Where this happens, roadside conditions may not meet the standards expected by commuters and other urban/suburban road users, resulting in an increased risk of high-severity run-off-road crashes.

Substantial Geometric and/or Operational Changes to a Roadway

Agency decisions to substantially change the operating characteristics of a roadway should trigger an assessment of whether these changes will increase the risk or severity of run-off-road collisions, and, if so, an assessment of roadside hazards. Changes may include an increase in the posted speed limit, designation of a road as a hazardous goods route or bicycle route, substantial widening or narrowing of the lanes or shoulders (which may affect lateral distance to roadside hazards), addition of lanes (including auxiliary lanes), changes to the horizontal alignment, or introduction of a bike lane or multi-use trail. Cyclist safety is an important consideration, as cyclists can attain speeds of 50-60 km/hr on sustained downhills, and have little or no protection in the event of a crash.

Changes in Agency Operations or Maintenance

Agency decisions to change the operating or maintenance protocol of a roadway may have implications for roadside safety by increasing the risk of a run-off-road crash. Possible operating and maintenance changes include reduced winter maintenance, removal of night-time lighting, reduced mowing and landscape maintenance (which can allow trees to grow to a hazardous size). When these changes are planned, a roadside safety assessment should be initiated to identify impacts and initiate measures to remove or mitigate roadside hazards.

Other Factors

The removal or protection of roadside objects may also be triggered by other factors, such as:

- identification of a roadside hazard in a road safety audit,
- identification of a roadside hazard by emergency crews or police,
- substantial redevelopment of nearby lands, which may present an opportunity to piggyback safety improvements onto the roadway improvements associated with the redevelopment.

3.7.8 Human Factors

Motorists typically feel safer and more comfortable when there are fewer objects at the roadside as the risk of striking an object is reduced. Although this is a benefit for driver comfort, the down side is it may result in higher operating speeds.

Removing fixed objects reduces the potential that a fixed object will obstruct a driver's view of a potential conflict, such as a vehicle, cyclist, pedestrian or animal approaching the road. Therefore, driver expectancy is increased as there is better visibility of potential hazards. In some cases, fixed objects can create a distraction for motorists. Therefore, their removal is expected to increase motorists' attention to the road.

3.7.9 Implementation Considerations

A major consideration attached to removal/relocation of fixed objects arises in urban, suburban, and transitional environments, where the road agency is faced with long-standing situations that may be difficult to change, where right-of-way is typically constrained, and where hazards such as mailboxes and commercial signing may be located on private land outside the agency's authority. In this case, changes to planning and zoning regulations (with the aim of improving future roadside safety in newly-developed or re-developed areas) may be one of the only routes available.

Where roadside safety measures can be more readily implemented, the considerations in TABLE 3.27 may need to be taken into account.

TABLE 3.27 IMPLEMENTATION CONSIDERATIONS

IMPLEMENTATION CONSIDERATION	SAFETY MEASURE*			
	Guidance	Roadside Hardware	Geometric and Shoulder Improvements	Clear Zone
obstruction of pedal cyclists and/or pedestrians (especially in urban areas)		✓		
potentially hazardous to pedal cyclists and motorcyclists, including loss of cyclist control (shoulder rumble strips)	✓			
interference with maintenance activities such as mowing and snow clearance	✓	✓		
increased maintenance requirement	✓	✓	✓	
interference with parking and stopping (including emergency stopping)		✓		
interference with road drainage (including requirement for upgraded drainage)		✓	✓	
increased road noise (rumble strips only)	✓			
need to carefully target sites for most effective implementation of potentially high-cost measures		✓	✓	✓
potential to lead to increased vehicle speeds (especially at night) resulting from increased driver confidence	✓		✓	✓
negative reaction from the public, conservation groups, or other government departments, especially to removal of roadside trees or other aesthetic features, or introduction of features typical of a high-speed rural environment in an urban or suburban environment	✓	✓	✓	✓
increased potential for low-severity crashes associated with safety equipment close to the travel way	✓	✓		

* Safety Measures include:

- *Guidance:* delineators, edgelines, centrelines, rumble strips, audio/tactile markings, raised reflective pavement markers
- *Roadside Hardware:* barriers, guardrail, attenuators
- *Geometric and Shoulder Improvements:* shoulder installation, shoulder widening, shoulder paving, roadway realignment, improved pavement friction, cross-section reduction, safety edge
- *Clear Zone:* removal, remediation (e.g., slope reduction), or relocation of roadside hazards

ALBERTA TRANSPORTATION

METHODS OF REDUCING COLLISIONS ON ALBERTA ROADS

APPLICATION GUIDELINES FOR PEDESTRIAN COUNTDOWN SIGNALS

FINAL

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3.8 Pedestrian Countdown Signals

3.8.1 Background

A Pedestrian Countdown Signal (PCS) is a device that displays a numerical countdown to indicate to pedestrians the remaining time to cross a roadway at a signalized intersection or signalized midblock pedestrian crossing, often implemented where several pedestrian fatalities and injuries are reported to occur. It is a relatively inexpensive technological solution that provides more specific and meaningful information than conventional pedestrian signal displays.

It has become increasingly common in Canada and the U.S. to install PCS in addition to conventional pedestrian signal displays (i.e. “walk”, “flashing don’t walk” and “don’t walk”). Surveys have generally found a high rate of misinterpretation of the “flashing don’t walk” indication. PCS provide the necessary clarification by displaying the number of seconds remaining in the “flashing don’t walk” interval. Pedestrians of all ages typically find PCS more intuitive than conventional pedestrian signals, and their use has been associated with a positive reduction in pedestrian-vehicle conflicts and collisions at many of the locations where they are installed.[52]

While implementation guidance for PCS currently exists through the Transportation Association of Canada, there are currently no specific guidelines that dictate the application of PCS in Alberta or Canada (i.e. in what situations should PCS be provided). This document attempts to fill some of the gaps in the current guidance. In many jurisdictions, PCS are being considered for all new traffic signal installations; therefore, in more practical terms, this document may provide guidance as to when a PCS should *not* be provided at a signalized crossing.

3.8.2 Definitions

A Pedestrian Countdown Signal (PCS) is a pedestrian signal device that displays a descending numerical countdown to indicate to pedestrians the number of remaining seconds available for their crossing.

[52] Transportation Association of Canada. “An Informational Report on Pedestrian Countdown Signals (PCS).” February 2008.

The PCS is paired with a display that shows the standard Walking Pedestrian (directing pedestrians to cross) and Hand (directing pedestrians not to enter the intersection) overlays standard on pedestrian signals currently in widespread use throughout North America.

3.8.3 Current Status in Canada and Alberta

PCS have been installed in urban municipalities in Alberta for several years, particularly in conjunction with the installation of new traffic signals. Some of the leading municipalities include the City of Edmonton (with currently over 50 PCS) and the Town of Banff since about 2001, but they have been more recently installed in Calgary and Lethbridge. In Edmonton, PCS are being considered for all new traffic signals. In Calgary, the need for PCS is evaluated at all new signals using the Transportation Association of Canada guidance. Practices regarding retrofits are more variable, and often combined with other upgrades. Alberta Transportation's Draft Signal Manual states:

"Countdown indications for pedestrian signals are recommended at locations where there is significant pedestrian activity and one or more of the following criteria is met:

- *The crosswalk is longer than 25 m;*
- *There are significant pedestrian traffic with students and/or seniors ;*
- *Adjacent to schools or along major commuting pathways leading to schools;*
- *The duration of minimum walk is shorter than 7 seconds; or*
- *The amber and red clearance intervals are used, in part or full, to satisfy the walk clearance requirements."*

Outside of Alberta, several large municipalities across Canada either already have PCS in place or are developing policies that encourage their use. PCS are very common in the Lower Mainland of British Columbia. The Province of Quebec and City of Burnaby, British Columbia have adopted PCS for all new traffic signals. The City of Toronto is the leading urban jurisdiction in Canada in the application of PCS's, with over 2,100 installations. The City of Toronto plans to have PCS retrofitted at every signalized intersection by 2011.

3.8.4 Example Applications

FIGURE 3.32 shows PCS's in each of the two common signal configurations, separate countdown housing (left) and side by side (right).


Source: Opus International *Source: safety.fhwa.dot.gov*

FIGURE 3.32 PEDESTRIAN COUNTDOWN SIGNALS

3.8.5 Benefits and Costs

The safety and effectiveness of Pedestrian Countdown Signals in Canada and the United States has been studied as they have gained adoption over the past fifteen years.[1] Studies have focused on a range of issues, including their impact on pedestrian-vehicle collisions, conflicts, degree of pedestrian comprehension, and their influence on pedestrian and driver behaviour.

Benefits

Collision Reduction

In general, due to the relative infrequency of pedestrian-vehicle collisions at intersections, PCS's are typically not implemented in response to pedestrian-vehicle collisions at intersections, but rather as a proactive measure for collision and injury prevention. A review of two recent studies completed in North American cities revealed either no change or a decrease in the number of pedestrian-vehicle conflicts.

A before/after study carried out between 1999 and 2003 on 14 intersections in the City of San Francisco revealed a 25 percent reduction in pedestrian-vehicle collisions when corrected for regression to the mean.[53]

[53] Transportation Association of Canada. "An Informational Report on Pedestrian Countdown Signals (PCS)." February 2008.

Factors attributed to this reduction were a decrease in the number of pedestrians still in the crosswalk when the pedestrian phase ended, and a decrease in pedestrians aborting or running during their crossings. The FHWA *Desktop Reference for Crash Reduction Factors* (FHWA, 2008) uses this finding as the estimated CRF for installing PCS at intersections previously equipped with conventional pedestrian signal heads. Based on its own and others subsequent findings, San Francisco has since installed PCS at 700 of its signalized intersections with plans to convert the remaining 400.

A 2002 study in the Region of York, Ontario found that no pedestrian related collisions were reported at three intersections with PCS's.[54] A study in San Jose, California, the same year revealed little difference between the before and after conflict rates (defined as events where either a pedestrian or a vehicle are delayed as a result of a unlawful action by a pedestrian or vehicle) at PCS outfitted intersections.[55] In a 2003 study in Maryland, pedestrian-vehicle conflicts (defined as an interaction where either a pedestrian or a driver take evasive action to avoid a collision, such as weaving, braking, or running) decreased at each of the four observed intersections.[56]

No scientific studies in Canada measuring collision reductions were found. Less scientific studies have been conducted in Quebec and Toronto. A study by the Quebec Ministry of Transport indicated that there was a reduction in pedestrian-vehicle conflicts with PCS, but no supporting data was provided. The City of Toronto has reported that pedestrian fatalities in the City as a whole have remained constant since PCS were first installed in 2006, in spite of the continuing population increase.

Pedestrian Comprehension

A wide range of studies has consistently shown pedestrians understand PCS displays.[57] Moreover, pedestrians overwhelmingly prefer PCS to its conventional counterpart with the most cited reason being the knowledge of how much time was remaining to cross.

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[54] Regional Municipality of York – Transportation & Works Committee (2002). *Pedestrian Countdown Signals; Report of the Commissioner of Transportation and Works.* Municipality of York, ON.
[55] Botha, J.L., et. al. (2002). "Pedestrian Countdown Signals: An Experimental Evaluation," *Pedestrian Count Signals Study in the City of San Jose; Final Report to the California Traffic Control Devices Committee, Vol. 1, pp. 1-35.*
[56] Eccles, K., et. al. (2003). *Evaluation of Pedestrian Countdown Signals in Montgomery County, Maryland.* Washington D.C. Transportation Research Board.
[57] Rousseau, G. Davis, G. (2003). *A Comparison of Countdown Pedestrian Signal Display Strategies;* Draft Report. McLean Virginia: US Department of Transportation: Federal Highway Administration.

Older pedestrians, who typically have a slower stride and require more time versus most other pedestrians, are especially vulnerable at crossings. Laboratory studies conducted by the FHWA showed older pedestrians properly comprehended the displays as well[58]. The crossing time remaining displayed on PCS eases anxiety of these slower moving vulnerable road users.

Driver Behaviour

Pedestrian countdown signals have not been shown to lead to altered driver behaviour. A number of studies have investigated whether PCS led to increases in vehicle speeds and acceleration in attempts to clear intersections before signal changes. These studies, including one completed in the City of Edmonton, have typically shown no noticeable changes in vehicle behaviour following the installation of PCS at intersections.[59]

It should be noted that drivers may be misled in the case of a pedestrian clearance phase ending before the intergreen display, due to an extended green. This could cause stopped motorists to try to get a head start on traffic (thinking they will get a green at the same time the solid hand is displayed), but end up running a red light. If possible, the pedestrian lights should be positioned so as to not be visible to motorists.

Pedestrian Behaviour

The impact of countdown signals on pedestrian behaviour appears to be minimal but positive. A majority of studies completed in North America that consider PCS impacts on pedestrians running, hesitating, or turning around, found either no change or positive change. Multiple studies in California and one in Alberta showed that the number of pedestrians running during the pedestrian clearance interval actually decreased.[60] These findings are consistent with the studies that show pedestrian comprehension of PCS is high amongst all age groups.

The additional information conveyed by pedestrian countdown signals is particularly useful to vulnerable road users. Seniors and otherwise mobility challenged pedestrians are typically aware of their limitations and more likely to be concerned about their safety.

[58] Green, D. (2002). *Pedestrian Countdown Devices: The City of Edmonton's Pilot Project,* Edmonton, AB: The City of Edmonton.
[59] Leonard, J. et. al. (1999). "Behavioural Evaluation of Pedestrians and Motorists towards Pedestrian Countdown Signals," *Safety and Behaviour; Final Report,* Ref. 4723-100.
[60] DKS Associates (2001). "San Francisco Pedestrian Countdown Signals: Preliminary Evaluation Summary." *San Francisco Department of Parking and Traffic*.

Pedestrian crossings on wide streets with substantial traffic and complex phasing can be intimidating. The presence of countdown signals has been shown to enhance their crossing experience, leading to an increased sense of security.

Costs

The cost of a new PCS was assumed to be $400 per signal head. A minimum of two was assumed to be required for most applications. To retrofit PCS at an intersection with standard pedestrian signals, an additional $100 was assumed for the removal of each existing pedestrian signal. Annual M&O costs were assumed to be $2000.

The cost of installing PCS at new signalized intersections is decreasing rapidly and is approaching the cost of using conventional pedestrian signals.

3.8.6 Existing Application Guidance

National Guidance

In Canada, national guidance for the application of pedestrian countdown signals is limited. The latest update to the Transportation Association of Canada's (TAC) *Manual of Uniform Traffic Control Devices for Canada* (MUTCDC, 2008) does not contain any references to PCS. Guidance for conventional pedestrian signal heads, which are used in PCS, is provided. Section B1.5.4 of the MUTCDC details the *Walking Pedestrian* and *Hand* overlays; Section B3.3.4 gives guidance on signal head location.

TAC's *An Informational Report on Pedestrian Countdown Signals (PCS)* (2008), suggests that PCS be adopted as an optional device for installation at locations where pedestrian signals are installed. The report documents the findings of a wide cross-sectional study of PCS in North America of pedestrian comprehension of the devices. The report suggests the factors most appropriate for the application of PCS:

- High percentage of seniors, children and other mobility challenged pedestrians;
- History of high pedestrian-vehicle conflicts;
- High pedestrian or vehicle traffic volumes; and
- High crossing distance (greater than 4 lanes).

The report also includes recommendations on PCS layout, configuration, timing strategies and educational programs for successful introduction.

Provincial Guidance

No current guidance exists at the provincial level regarding the application of PCS's. The Traffic Safety Act Use of Highway and Rules of the Road Regulation, Section 98 refers to the traditional displays only, and not to PCS; therefore, the PCS does not change any of the relevant laws.

Municipal Guidance

The City of Edmonton was the only Alberta municipality for which well developed application criteria were found. Based on the 2008 TAC Informational Report, the City of Edmonton has used the following application criteria:

- Pedestrian volumes;
- Proximity to traffic generators;
- Presence of school children, seniors and the disabled;
- High Walk to Flashing Don't Walk Ratio (ample time for pedestrians to cross); and
- Low permissive left-turn volumes.

The Cities of Edmonton and Calgary now consider PCS at all new traffic signal installations, and refer to the TAC 2008 Informational Report for retrofit situations.

International Guidance

Manual of Uniform Traffic Control Devices (MUTCD), which documents the standards for traffic control devices in the United States, provides in Section 4E: *Pedestrian Control Features* a comprehensive set of criteria for applying pedestrian signal heads (which includes the countdown option) at signalized intersections. Section 4E.07 specifically covers PCS, and contains a requirement that:

"All pedestrian signal heads used at crosswalks where the pedestrian change interval is more than 7 seconds shall include a pedestrian change interval countdown display."

"Change interval" refers to the "flashing don't walk" phase. For locations with a change interval of 7 seconds or less, the use of PCS is optional.

The MUTCD also includes guidance on the general placement and conspicuity requirements of PCS, prescribes location and height requirements, sequencing of pedestrian intervals and pedestrian change intervals requiring PCS. These details are discussed further in the Implementation Considerations section. Part 4 of the US MUTCD can be found at http://mutcd.fhwa.dot.gov/pdfs/2009/part4.pdf.

3.8.7 Recommended Application Guidance

Land Use and Speed Context

PCS can generally be considered at any signalized intersection where pedestrian displays are provided. This is typically the case in urban and suburban environments. PCS are likely to have the greatest benefits in the most highly urban environments, such as downtown cores, and the least benefits in rural areas.

Traffic signals are provided for roads with speed limits up to 80 km/h in Alberta. However, intersections posted at 80 km/h are likely to have low pedestrian volumes and wide cross sections, and crossing is sometimes discouraged. Therefore, PCS are most appropriate across roadways posted at 70 km/h or less.

The recommended land use and speed environments where the installation of pedestrian countdown signals are summarized in TABLE 3.28.

TABLE 3.28 ACCEPTABLE LAND USE AND SPEED RANGES FOR PEDESTRIAN COUNTDOWN SIGNALS

LAND USE	POSTED SPEED LIMIT (km/h)			
	50 or less	60 - 70	80 - 90	100 or more
Rural	-	-	-	-
Urban	✓	✓	-	-
Semi-Urban / Suburban	✓	✓	-	-

New or Upgraded Traffic Signals

Pedestrian countdown signals can be seen as an evolution of conventional pedestrian signals. As such, pedestrian countdown signals should be provided wherever pedestrian signal heads should be provided, subject to the acceptable land use and speed categories in TABLE 3.28. In some cases these may require an upgrade to controller equipment.

The MUTCDC acknowledges that pedestrian signal heads are typically provided at all signalized pedestrian crossings, but does not specifically require them at all signalized intersections. However, the Transportation Association of Canada (TAC) is currently preparing guidance for the application of pedestrian signal heads. Updated information on this project can be obtained directly from TAC.

The majority of application efforts to date have been focused at fully signalized intersections. While the majority of signalized crossing facilities are provided at intersections, it is recommended that the use of pedestrian signal heads and PCS be considered equally for midblock locations, such as at “Pedestrian Signals” (sometimes referred to as “half-signals”) which are provided in some jurisdictions.

Retrofitted Traffic Signals

It is recognized that some municipalities have hundreds of traffic signals and limited budgets for adding PCS to existing intersections. The following guidance can assist in the prioritization of locations, based on the risk factors (exposure, probability and consequence), and hence where they are expected to provide the greatest safety benefits. This approach is particularly helpful since pedestrian collisions are rare.

- *Exposure* refers to the number of pedestrians facing the risk and the duration of the risk. This includes pedestrian volumes and vulnerable pedestrian volumes, crossing time and crossing distance.
- *Probability* refers to the severity of the risk, including the complexity of the signal operations or intersection geometry, or the ratio of the road width to the crossing time; and other factors that may contribute to making the crossing manoeuvre more difficult.
- *Consequence* refers to the likelihood of injury or fatality should a collision occur. Among other factors, this depends on the vulnerability of the road user, traffic speeds and the presence of larger vehicles.

Based on this risk-based approach and guidance from the TAC Informational Report, the latest edition U.S. MUTCD, and findings from various pilot programs throughout North America, key priorities have been developed, and are listed in TABLE 3.29. It should be noted that although PCS may have some benefits for motorists, they are to be installed primarily to serve the needs of pedestrians.

TABLE 3.29 PRIORITY LOCATIONS FOR PCS RETROFITS

Priority 1: Locations with a History of Pedestrian-Vehicle Collisions or Conflicts If there is a history of pedestrian-vehicle crashes, this should be the number one priority. Given the rarity of pedestrian collisions, the *Traffic Conflict Technique* can also be used to quantify the collision risk.
Priority 2: Locations with High "Vulnerable" Pedestrian Volumes The more vulnerable pedestrians, including children, seniors, and mobility challenged pedestrians, have been shown to both understand and prefer PCS for the increased information they provide. Therefore, the benefits of PCS may be highest at locations with high volumes or proportions of these users. Where pedestrian profiles are unavailable, locations within 200 metres of traffic generators, particular schools, community centres, parks and medical centres are deemed to have a higher risk. PCS have positively associated with a reduction in the number of pedestrians running to complete a crossing, which can be either hazardous or not an option for vulnerable road users.
Priority 3: Locations with Critical "Flashing Do Not Walk" Intervals Longer crossings increase pedestrian exposure to traffic and present a higher risk for pedestrians to fail to complete the crossing movement in a timely manner. In particular locations with more than four lanes will benefit more from countdown indications. Although the "Flashing Do Not Walk" phase should be timed to provide the necessary clearance time, based on normal walking speeds, crossings with shorter "Flashing Do Not Walk" intervals, that may require pedestrians to proceed at higher walking speeds can benefit from PCS. Assuming the "Flashing Do Not Walk" phase has been appropriately timed, the time and distance requirements can be satisfied by considering the ratio of the "Walk" interval to the "Flashing Do Not Walk" interval. The TAC *Informational Report* states PCS should be provided where the ratio of the "Walk" interval to the "Flashing Do Not Walk" interval is 0.4 or less.

Priority 4: Locations with High Pedestrian Volumes Since PCS are expected to assist all pedestrians (not only the groups identified in Priority 2), locations within 200 metres of existing or planned major pedestrian generators such as schools, shopping centres, major transit stops, community centres, and parks and medical centres. Pedestrian signal control is recommended near all existing or planned major pedestrian generators.
Priority 5: Locations with Complex Geometric or Operational Characteristics Besides the longer crossing distance and shorter crossing time factors included in Priority 3, there may be other factors that result in confusion or hesitation before or during crossing manoeuvres or in running to complete the crossing, which if done on wider, more complex crossings, increases the likelihood of pedestrian-vehicle conflicts. These factors may include complex operations, high vehicle volumes, especially high conflicting turning volumes, and obstacles in the median or skewed intersection geometry. PCS have been positively associated with greater pedestrian understanding, which helps minimize risk-taking on more complex crossings.

Based on the above guidance, the locations where PCS (or any pedestrian signal type) should *not* be installed include:

- Rural areas and or roadways with speed limits of above 70 km/h; and
- Where the crossing distance is very short, with a pedestrian change interval (clearance time) of 7 seconds or less (MUTCD guideline).

The TAC project that is currently identifying situations where pedestrian signal heads do not need to be provided may also identify other situations where it is unadvisable to provide PCS. The removal of existing PCS is not expected to be required unless the pedestrian signals are determined to no longer be required (unlikely to replace PCS with standard pedestrian signals). If the PCS is determined to be removed, a needs assessment should be undertaken to determine if the pedestrian signals should be completely removed.

3.8.8 Implementation Considerations

This section discusses practical considerations to be made when implementing PCS at new locations or retrofitting intersections with existing pedestrian signals. Consideration to signal timing, signal display configurations, location, and compatibility to existing equipment is provided. More detailed guidance is provided in Chapter 6 of the *2008 TAC Informational Report* and in Section 4E the *2009 US MUTCD*.

Signal Timing

Several options are available for configuring the timing on the countdown display. Pedestrians intuitively believe the timer to represent the number of seconds available for crossing. Studies and surveys suggest the most unambiguous timing strategy – and safest – for pedestrians is to display the countdown only during the flashing *Hand* symbol period. For these reasons, displaying the countdown only during the flashing *Hand* period is the recommended timing configuration.

In this configuration no countdown is displayed during the walk interval. The countdown starts at the beginning of the flashing *Hand* symbol period and ends when the *Hand* symbol stops flashing, typically at the onset of the yellow change interval, or amber phase of the signal. This provides an additional few seconds for crossing before the pedestrian clearance interval expires. FIGURE 3.33, taken from the 2009 edition of the U.S. MUTCD, shows the countdown displayed during the pedestrian change interval, with a steady *Hand* display during the yellow change interval which starts at the end of the Buffer Interval.

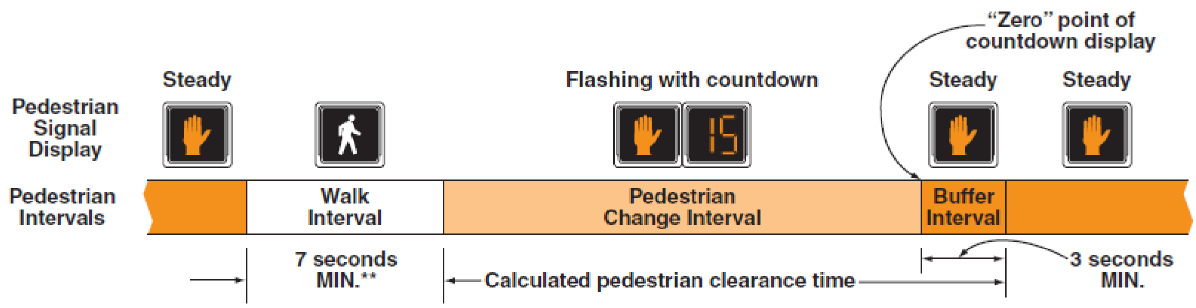

FIGURE 3.33 Pedestrian Countdown Display Timing

Source: U.S. MUTCD 2009 Edition (FHWA)

In line with the U.S. MUTCD, the TAC Informational Report advises that the countdown display only during the flashing Hand interval and stop at the steady Hand interval.

Display Configuration

In North America, PCS are generally installed in one of two configurations:

A. Side by Side: The *Walking Pedestrian* and *Hand* overlay are placed side by side with the numerical countdown in one signal head housing.

B. Separate Countdown Housing: The *Walking Pedestrian* and *Hand* overlay are in one housing or separated in two housings with the numerical countdown in a separate signal head housing

A third configuration, All in One, where the *Walking Pedestrian*, *Hand* and numerical countdown overlays are housed in one signal head, is not commonly used in North America. FIGURE 3.34 shows the two common types of PCS, Side by Side (left) and Separate Countdown Housing (right).

TAC recommends that the Separate Countdown Housing configuration be used in all new locations, and in retrofitting settings wherever possible.

FIGURE 3.34 PEDESTRIAN COUNTDOWN SIGNALS

Source: safeandmobileseniors.com (left); halifax.ca (right)

Compatibility with Controller

PCS are generally compatible with modern signal controller equipment, and can be implemented at most existing intersections with relative ease. Signal controllers twenty to thirty years and older however, may not be able to accurately display crossing time and replacement of controllers at these locations may be required.

Other Implementation Considerations

It is strongly recommended that LED technology be used for all new and retrofit PCS situations, due to its superior performance and energy efficiency.

Some surveys have indicated that motorists may modify their behaviour at intersections with PCS, by accelerating or decelerating. Although no studies conclusively verify this behaviour, it should be monitored following installation. If it is concluded that this risk exists, intersections with PCS may be good candidates for the deployment of intersection safety devices.

When implementing PCS, it is also recommended that consideration be given to implementing accessible features with the pedestrian push-button operation. TAC has prepared separate *Guidelines for the Understanding, Use and Implementation of Accessible Pedestrian Signals (2008)*.

3.8.9 Human Factors Considerations

Pedestrian countdown signals strongly promote good human factors principles. Studies have shown PCS to reduce the ambiguity of pedestrian signals for pedestrians of all ages. This increased clarity and expectancy is accomplished primarily through the provision of additional information via the countdown timer. The timer, in conjunction with the flashing Hand signal, acts to reinforce the notion that pedestrians need to finish their crossing before the signal phase changes.

The increased conspicuity of PCS is also of benefit to pedestrians, especially older road users, whom often suffer from a reduction in visual acuity. PCS typically make use of LED technology, which increases the contrast and reduces the susceptibility to glare, helping to increase the overall readability of the display.

Though not examined in these guidelines, PCS are compatible with audible pedestrian signals, which can help to promote sensory influence.

3.8.10 Maintenance Considerations

Pedestrian countdown signals are very low maintenance countermeasures. No maintenance considerations were identified, with the exception of routine inspections to ensure the units are functioning and replace any burnt out lights (which is relatively infrequent with the new LED technology). LED display technology also has the added benefit of reduced power consumption and a longer life cycle, helping to lower overall operating expenses.

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4.0 EVALUATION OF BENEFITS AND COSTS

The following sub-sections describe how the benefits (collision reduction) and costs (construction, operation and maintenance) of each of the *Highly Effective Measures* were derived, and used towards the development of an implementation strategy (Section 5.0).

4.1 Collision Reduction Estimates

The numerical benefits were estimated as the collision reduction expected with the implementation of the specific countermeasure. Although additional benefits may also result (congestion reduction, reduced travel time, etc.), these were not included in the benefit estimates. The following sub-sections explain how the collision reductions were estimated.

4.1.1 Methodology

The first step was to select an average collision reduction factor or range for the countermeasure from the documented collision reduction factors (CRFs) uncovered during Phase 1. The CRFs based on Alberta collisions were given preference when selecting the best CRF, followed by other Canadian studies. Injury collision reductions were preferred, with greater preference given to severe injuries (as opposed to minor injuries). Fatality collision reductions were generally avoided due to their even greater scarcity and randomness. Where injury reductions were unavailable, fatality reductions were taken to represent injury reductions. It should be noted that although all attempts were made to choose CRFs based on typical applications, several of the references were unclear regarding the specific target group of collisions the CRF referred to (for example, how many legs of an intersection the reduction was applied to). This potential discrepancy was accounted for in the ranges used.

The second step was to adjust the collision reduction based on the Alberta Applicability Rating from Phase 1. The higher this rating, the more likely the collision reduction would be achievable in Alberta. For countermeasures rated as “High” in Alberta (24/33), the collision reduction value from Step 1 was used. For “Moderate” Alberta applicability measures (9/33) a 20 percent reduction was applied. None of the Highly Effective Measures were rated as “Low.”

The third step was to establish a range for the expected collision reductions. CRFs already presented as a range were applied as appropriate. CRFs with no explicitly stated range were taken to represent the high end of the range (in the interest of conservatism), and the low end was taken (typically approximately 50 percent of the high end). This approach is based on the assumption that the measure is applied in the optimal context (with respect to land-use and speed categories), while the low end of the range reflects application in a less than ideal context and variability in locations.

The cost per collision was assumed to be $100,000 (as used by TRANS for injury collisions). This was used in the BCR calculation for all measures. Note that this method allows for comparisons between various treatments assuming the same number of collisions. For implementation at a specific area (i.e. roadway or intersection), the actual collision history of that area should be used to determine the actual expected collision reduction.

4.1.2 Collision Reduction Ranges for Alberta

The injury collision reduction ranges for each of the 33 countermeasures is presented in TABLE 4.2 to TABLE 4.7, below. Details regarding the calculation of the ranges are provided in APPENDIX B.

4.2 Cost Estimates

The following sub-sections describe the methodology of how the construction costs and life-cycle costs for each of the *Highly Effective Measures* were derived.

4.2.1 Methodology

In order to accurately estimate the costs, several sources were used. Where available, information was obtained first from the provincial weighted prices in the TRANS *Unit Price Averages Report* (2010). If information was not available from this source, a range of other sources were used: including municipal unit prices, and estimates previously prepared by Opus. For estimates that were a few years old, factors were applied to account for inflation.

The expected Low and High capital costs of the countermeasures were provided to attain a range of estimated costs. Also, where applicable, costs for retrofitting existing street furniture, as well as providing new items were obtained for each countermeasure.

The cost of implementing the countermeasures was assumed to be over a limited "area of influence". This was to ensure uniformly applied costs for each measure within each objective area (signalized intersections, speed related, etc.). This allows for measures within each objective area to be compared to each other. It should be noted that comparisons between measures in separate objective areas may not be accurate.

4.2.2 Life-cycle Costs

The costs for each countermeasure over its life span was determined based on the expected life span and maintenance and operations (M&O) costs. The assumed life spans for each type of measure are as follows:

- Pavement Markings: 2 years;
- Signs: 5 years;
- Hardware (gateway treatments, PCS, etc.): 10 years;
- Roadways (lanes, roundabouts, etc.): 20 years; and,
- Removals (objects, sight obstructions, etc.): 30 years.

Although 30 years was assumed for "removals", it is expected to effectively have an infinite life span so long as proper maintenance and enforcement are provided to prevent obstructions from returning.

The life-cycle costs for each countermeasure were determined by spreading the capital cost over the life span of the countermeasure, and adding the annual M&O cost. Discounting of the capital cost was not taken into consideration.

The life-cycle costs for each of the countermeasures are illustrated in TABLE 4.1, and further details are provided in APPENDIX B.

TABLE 4.1 LIFE-CYCLE COSTS

Countermeasure	Life Span (yrs)	Construction Costs	Annual M&O Costs	Life Cycle Costs Per Year
Consistent Speed Limits	5	$250 - $500	$1,000	$1,050 - $1,100
Gateway Treatments	10	$2,000 - $500,000	$2,500	$2,700 - $52,500

Countermeasure	Life Span (yrs)	Construction Costs	Annual M&O Costs	Life Cycle Costs Per Year
Transverse Pavement Markings	2	$4,000 - $10,000	$2,000	$4,000 - $7,000
Variable Speed Limits	10	$1,000 - $300,000	$2,500	$2,600 - $32,500
Advance Intersection Warning on Major Road	5	$150 - $800	$1,000	$1,030 - $1,160
Conversion of Stop Controlled Intersections to Roundabouts	20	$250,000 - $500,000	$3,000	$15,500 - $28,000
Dedicated Left Turn Lanes on Major Road Approaches	20	$10,000 - $100,000	$2,500	$3,000 - $7,500
Flashing Beacon on Stop Sign	10	$500 - $2000	$1,500	$1,550 - $1,700
Removal of Obstructions Within Sight Triangle	30	$500 - $500,000	$2,500	$2,516 – 19,166
Transverse Rumble Strips	5	$2,000 - $6,000	$2,500	$2,900 - $3,700
Advance Intersection Warning Flashers	5	$3,000 - $6,000	$2,500	$3,100 - $3,700
Conversion of Signalized Intersections to Roundabouts	20	$275,000 - $500,000	$3,000	$16,750 - $28,000
Dedicated Left-turn Lanes With Phasing	20	$5,000 - $100,000	$3,000	$3,250 - $8,000
Positive Offset Left-turn Lanes	20	$10,000 - $100,000	$3,000	$3,500 - $8,000
Protected Only Left-turn Phase	20	$300 - $1,200	$2,500	$2,515 - $2,560
Removal of Unwarranted Traffic Signals	30	$2,000 - $6,500	$1,000	$1,066 - $1,216

Countermeasure	Life Span (yrs)	Construction Costs	Annual M&O Costs	Life Cycle Costs Per Year
Signal Back Plates	10	$500 - $12,000	$1,500	$1,550 - $2,700
Smart Right-turn Channel	20	$15,000 - $50,000	$2,500	$3,250 - $5,000
Advance Curve Warning Signs	5	$450 - $1,200	$1,000	$1,090 - $1,240
Cable Barrier	10	$22,000 - $50,000	$2,500	$4,700 - $7,500
Horizontal and Vertical Realignments	30	$75,000 - $1,000,000	$1,000	$3,500 - $34,333
Impact Attenuators	10	$30,000 - $60,000	$2,500	$5,500 - $8,500
Removal of Fixed Objects	30	$100 - $1,500,000	$2,000	$2,003 - $52,000
Shoulder Rumble Strips	10	$300 - $600	$2,500	$2,530 - $2,560
Centreline Rumble Strips	To be determined at a later date			
Delineator Posts	5	$750 - $1,000	$1,000	$1,150 - $1,200
Edgelines and Centrelines	2	$169 - $516	$1,500	$1,584 - $1,758
High-visibility Pavement Markings	2	$200 - $600	$1,500	$1,600 - $1,800
Increased Sign Retroreflectivity	5	$500 - $1,600	$1,000	$1,100 - $1,320
Linear Delineation Systems	10	$3,000 - $800,000	$1,500	$1,800 - $81,500
Wider Pavement Markings	2	$200 - $600	$1,500	$1,600 - $1,800
New or Upgraded Intersection Lighting	10	$1,000 - $10,000	$2,500	$2,600 - $3,500
Pedestrian Countdown Signals	10	$800 - $2,000	$2,000	$2,080 - $2,200
Wider Sidewalk or Paved Shoulder	10	$110,000 - $500,000	$2,000	$13,000 - $52,000

4.3 Benefit-Cost Estimates

The highest and lowest BCRs for each of the thirty-three countermeasures were determined as follows:

$$BCR_{Low}=\text{Lowest Expected Benefit / Highest Expected Cost}$$
$$BCR_{High}=\text{Highest Expected Benefit / Lowest Expected Cost}$$

By determining the lowest and highest expected BCR values, a range could be provided. The BCR range for each of the thirty-three countermeasures is provided in TABLE 4.2 to TABLE 4.7. The six objective areas are separated into separate tables. Details on the calculation of the benefits and costs are provided in APPENDIX C.

Although research has shown that the benefits of collision countermeasures can decrease over time[61] as motorists become accustomed to the change (benefit decay), this was not accounted for in these values.

It should be noted that although the benefit of implementing more than one countermeasure within an objective area (at the same location) is expected to be higher than if just one countermeasure is used, it is not the algebraic sum of benefits. This is due to the overlapping benefits gained by installing more than one countermeasure. This was not accounted for in the stated benefits, and the overlap would have to be determined on a case by case basis.

TABLE 4.2 BENEFITS AND COSTS OF SPEED RELATED COUNTERMEASURES

Collision Reduction Measure	Benefit Range	Capital Cost Range	BCR Range
Consistent Speed Limits	10% - 16% of all injury collisions	$250 - $500	9.1 – 15.2
Gateway Treatments	25%-50% of serious injury/fatal collisions	$2,000 - $500,000	0.5 – 18.5
Transverse Pavement Markings	20% - 44% of all fatal and injury collisions	$4,000 - $10,000	2.9 – 11.0
Variable Speed Limits	10% - 16% of all injury collisions	$1,000 - $300,000	0.3 – 6.2

[61] Tarek, S., and P. de Leur. Collision Modification Factors for British Columbia. BC Ministry of Transportation & Infrastructure, 2008.

The most promising speed related countermeasure is the implementation of consistent speed limits. Gateway treatments have the potential to be extremely effective, but there is a wide variety of treatments, which explains the wide range in the BCR. Similarly, variable speeds have a relatively wide range (e.g. lower if high-cost overhead signage is used).

TABLE 4.3 BENEFITS AND COSTS OF UNSIGNALIZED INTERSECTION MEASURES

Collision Reduction Measure	Benefit Range	Capital Cost Range	BCR Range
Advance Intersection Warning on Major Road	15% - 30% of all injury collisions	$150 - $800	12.9 – 29.1
Conversion of Stop Controlled Intersections to Roundabouts	58% - 70% of all fatal and injury collisions	$250,000 - $500,000	2.1 – 4.5
Dedicated Left Turn Lanes on Major Road Approaches	29% - 35% of all fatal and injury collisions	$10,000 - $100,000	3.9 – 11.7
Flashing Beacon on Stop Sign	15% - 30% of all injury collisions	$500 - $2000	8.8 – 19.4
Removal of Obstructions Within Sight Triangle	20% - 37% of all injury collisions	$500 - $500,000	>50
Transverse Rumble Strips	10% - 22% of all injury collisions	$2,000 - $6,000	2.7 – 7.6

The removal of obstructions at an intersection has the highest BCR. Even the low value (highest cost and lowest benefit) exceeded a BCR of 50. Advance warnings on the major road provided the next highest benefit. All six unsignalized intersection measures are expected to be cost effective.

TABLE 4.4 BENEFITS AND COSTS OF SIGNALIZED INTERSECTION MEASURES

Collision Reduction Measure	Benefit Range	Capital Cost Range	BCR Range
Advance Intersection Warning Flashers	20% - 44% of all injury collisions	$3,000 - $6,000	5.4 – 14.2
Conversion of Signalized Intersections to Roundabouts	30% - 62% of all fatal and injury collisions	$275,000 - $500,000	1.1 – 3.7
Dedicated Left-turn Lanes With Phasing	30% - 58% of all injury collisions	$5,000 - $100,000	3.8 – 17.8
Positive Offset Left-turn Lanes	20% - 40% of injury collisions	$10,000 - $100,000	2.5 – 11.4
Protected Only Left-turn Phase	8% - 16% of injury collisions	$300 - $1,200	3.1 – 6.4
Removal of Unwarranted Traffic Signals	25% - 53% of all injury collisions	$2,000 - $6,500	20.5 – 49.7
Signal Back Plates	15% - 32% of all injury collisions	$500 - $12,000	5.6 – 20.6
Smart Right-turn Channel	65% - 80% of all injury collisions	$15,000 - $50,000	13.0 – 24.6

Removing unwarranted traffic signals have the greatest potential for collision reductions among the signalized intersection countermeasures. Although still greater than 1.0, the BCR for conversion of a signalized intersection to a roundabout has the lowest BCR due to the high cost of construction.

TABLE 4.5 BENEFITS AND COSTS OF RUN-OFF-ROAD COLLISION COUNTERMEASURES

Collision Reduction Measure	Benefit Range	Capital Cost Range	BCR Range
Advance Curve Warning Signs	5% - 13% of all injury collisions	$450 - $1,200	4.0 – 11.9
Cable Barriers	15% - 35% reduction of run-off-road injury collisions (roadside) 36% - 72% reduction of head-on injury collisions (median)	$110/m - $250/m (assume 200m length)	2.0 – 7.5 (roadside) 4.8 – 15.3 (median)
Horizontal and Vertical Realignments	50% - 73% of all injury collisions	$75,000 - $1,000,000	1.5 – 20.9
Impact Attenuators	35% - 75% of injury collisions	$15,000 - $30,000	4.1 – 13.6
Removal of Fixed Objects	15% - 30% of all injury collisions	$100 - $1,500,000	0.3 – 15.0
Shoulder Rumble Strips	10% - 18% of all injury collisions	$300 - $600	3.9 – 7.1
Centreline Rumble Strips	BCR calculations to be determined at a later date		

Although potentially highly expensive, the most promising run off road collision countermeasure is horizontal and vertical realignment. The removal of fixed objects may result in a BCR of less than 1.0 depending on the cost of removing the obstruction. All other run off road collision countermeasures have BCRs of at least 2.0.

All of the roadway link countermeasures have promising BCR values. Due to their inexpensive cost, increased sign retroreflectivity has the greatest potential among them. No documented benefits were found for linear delineation systems. However, due to their significantly low cost (when placed on an existing barrier), any injury reductions higher than a 1.8 percent would result in a BCR greater than one.

TABLE 4.6 BENEFITS AND COSTS OF ROADWAY (LINK) MEASURES

Collision Reduction Measure	Benefit Range	Capital Cost Range	BCR Range
Delineator Posts	5% - 11% of all injury collisions	$75 /post - $100 /post	4.2 – 9.6 (assume 10 posts)
Edgelines and Centrelines	10% - 19% of all injury collisions	$850 - $2,600 (assume 200m length)	5.7 – 12.0
High-visibility Pavement Markings	10% - 19% of injury collisions	$1,000 - $3,000 (assume 200m length)	5.6 - 11.9
Increased Sign Retroreflectivity	25% - 42% of all injury collisions	$500 - $1,600	18.9 – 38.2
Linear Delineation Systems	-	$15,000 - $300,000 (assume 200m length)	-
Wider Pavement Markings	10% - 16% of all injury collisions	$1,000 - $3,000 (assume 200m length)	5.6 - 10.0

TABLE 4.7 BENEFITS AND COSTS OF VULNERABLE ROAD USER COLLISION COUNTERMEASURES

Collision Reduction Measure	Benefit Range	Capital Cost Range	BCR Range
New or Upgraded Intersection Lighting	39% - 78% of all injury collisions	$1,000 - $10,000	11.1 – 30.0
Pedestrian Countdown Signals	15% - 25% of all pedestrian collisions	$800 - $2,000	6.8 – 12.0
Wider Sidewalk or Paved Shoulder	65% -89% of all pedestrian collisions	$110 /m - $500 /m	1.3 – 6.8 (assume 1km length)

All three vulnerable road user collision countermeasures have BCRs greater than one. Providing intersection lighting, or upgrading the existing lighting, results in the highest BCR. Although they provide a lower BCR, installing pedestrian countdown signals is a relatively inexpensive countermeasure.

5.0 IMPLEMENTATION STRATEGY

An implementation strategy was developed to facilitate the timely and optimal implementation of the highly effective measures identified in this study. Implementability will depend on numerous factors and is presented as an overall strategy, for the consideration of each agency and for discussion between agencies.

This section first describes the proposed approach to the prioritization of the highly effective measures, and then lists the measures proposed for implementation in each of the three time frames identified at the outset of the study:

- Immediate (“Quick wins”);
- 1-7 years; and
- 7-20 years.

TRANS indicated that these time frames do not correspond to any particular planning or budgeting cycles. Opus’ approach to these three cycles is described in Section 5.1.

Since education, enforcement, and legislation may be required in order for these measures to be effective, guidance is also provided for these in Section 5.5. Finally, since it will be important to measure the performance of the treatments and justify further collision reduction investments, suggestions regarding effective monitoring and evaluation are provided in Section 5.6.

5.1 Approach

Having a clear implementation strategy will help to ensure that funds are properly targeted using evidence-based (proven) countermeasures. The results of the implementations can be monitored and properly evaluated to justify more widespread application, modifications to current application, or diverting funds to other measures.

The approach adopted for the implementation strategy was based on the following principles:

- Implementing early winners (“quick wins”) to gain momentum and start realizing improvements;
- Give higher priority to measures with higher BCRs and lower capital costs;

- Encourage earlier more systematic implementation of traditional proven measures before proceeding to related but novel measures (e.g. provide consistency in static speed limits before exploring variable speed limits);
- To implement as much as possible during the first 7 years;
- Provide options to address each objective area during each of the first two time frames; and,
- Minimize the possible duplication / overlap in benefits of similar measures.

The implementation strategy is no way intended to discourage the application of measures not listed in a particular time frame; rather it is intended to guide road agencies as to where to focus their overall programming efforts since there is research, policy development, education and other resources required for the successful implementation of each measure. Focused implementation can also allow for the more accurate overall evaluation of programs as it is easier to separate treatment effects.

At the micro-level, measures should be implemented such that overlapping benefits are minimized and they can be properly evaluated. For example, if left-turn collisions are a problem at a signalized intersection, the preferred solution may be either dedicated left-turn lanes or phasing - not necessarily both.

Measures that are considered novel may require public education and/or changes to legislation, and therefore may not be able to be implemented effectively right away; these measures have generally been excluded from the "quick wins". For these measures and others for which the application guidance represents a departure from normal practices, the education, pilot and evaluation approach is recommended prior to widespread implementation.

5.2 Quick Wins

"Quick wins" were identified from the list of *highly effective* measures, to assist road agencies to start yielding returns (i.e. reductions in injuries and fatalities) on the ground that can build momentum and justify funding for further initiatives.

For this study, quick wins were defined as measures that:

- Already have good application guidance;
- Can likely be accommodated within regular operating budgets;
- Have a high average BCR (at least 5:1);
- Are already proven in Alberta or Canada (not novelties); and
- Require minimal public education and no changes to legislation to be effective and enforceable.

Up to three quick wins were identified for each objective area, provided they met the above requirements.

The quick wins are as follows, by objective area:

Speed Management:	*Consistent Speed Limits*
Signalized Intersections:	*Removal of Unwarranted Traffic Signals; Smart Right-Turn Channels*
Unsignalized Intersections:	*Removal of Sight Obstructions; Advance Intersection Warning on Major Road; Flashing Beacon on Stop Sign*
Roadways (Links):	*Edgelines and Centrelines*
Run-off-Road:	*Cable Barriers*
Vulnerable Road Users:	*New or Upgraded Intersection Lighting; Pedestrian Countdown Signals*

The following are suggestions and recent developments to assist road agencies to quickly and effectively implement some of these measures:

Consistent Speed Limits: guidelines have been established by the Transportation Association of Canada, and several agencies are adopting them and receiving positive feedback on the results.

Removal of Unwarranted Traffic Signals: This is a relatively inexpensive way to improve both safety, efficiency and reduce cost. There is a prescribed practice for this published by the Institute of Transportation Engineers.

Smart Right-Turn Channels: These have been recently piloted by the City of Edmonton, with increasingly positive results. They are recommended for consideration at any urban intersection with a prevalence of right-turn / rear-end collisions.

Advance Intersection Warning on Major Road: If minor road treatments are proven ineffective, major road treatments can be investigated.

Flashing Beacon on Stop Sign: It is suggested that together with the flashing beacon, the benefits of flashing LED borders be explored.

Cable Barriers: Alberta Transportation has recently prepared a draft design bulletin encouraging the more widespread application of cable barriers. It can be referred to for highway applications, in conjunction with the detailed guidelines prepared as part of this study. There are major projects underway in Alberta involving cable barrier applications on Highway 2, and on Crowchild Trail in Calgary.

Pedestrian Countdown Signals: These are quickly gaining popularity, and should be installed with every new traffic signal. The guidelines prepared in this study provide a method to prioritize retrofit applications.

5.3 1-7 Year Strategies

The measures selected for implementation in the shorter term (1 to 7 year) time frame are those among the remaining measures that:

- are the most effective measures in each objective area;
- may require moderate capital budgets; and
- may require public education or simple changes to legislation.

The 1 – 7 year strategies are as follows, by each objective area:

Speed Management:	*Gateway Treatments, Transverse Pavement Markings; Variable Speed Limits*
Unsignalized Intersections:	*Dedicated Left-Turn Lanes; Transverse Rumble Strips; Conversion to Roundabouts*
Signalized Intersections:	*Signal Back Plates; Advance Warning Flashers; Dedicated Left Turn Lanes and Phasing; Positive Offset Left-Turn Lanes; Protected-only Left-Turn Phasing*
Roadways (Links):	*Increased Sign Retro-reflectivity; High Visibility Pavement Markings; Wider Pavement Markings*
Run-off-Road:	*Impact Attenuators, Curve Warning Signs; Shoulder Rumble Strips (shoulder/centreline)*
Vulnerable Road Users:	*Wider Sidewalks or Paved Shoulders*

Gateway Treatments: Detailed guidelines have been prepared as part of this study. Since there are no municipal, provincial or nationally approved practices for gateway treatments, road agencies will have to endorse a set of guidelines for gateway treatments prior to implementation.

Variable Speed Limits: Since these are not currently enforceable in Alberta (or anywhere in Canada), the laws will have to be revised prior to any implementation. Research is currently being undertaken in Edmonton and considered in Calgary to develop algorithms for applying VSL on freeways. A synthesis of benefits to share with management and legislators was prepared as part of this study. Implementation should be carried out with a single pilot, or handful of pilots, then evaluated prior to modifications or more widespread implementation.
Conversion to Roundabouts: Guidelines were prepared in this study to encourage the consideration of roundabouts for any stop-controlled location where all-way stops are warranted, due to the superior safety benefits. These should be adopted or incorporated into the roundabout policies that Calgary and Edmonton already have in place.

Increased Sign Retro-Reflectivity: A project is currently underway to develop requirements for retro-reflective sheeting in Canada, further to the newer standards adopted in the United States. Road agencies may wish to revise their practices to meet the new requirements.

Wider Pavement Markings: A study will likely be commissioned by the Transportation Association of Canada to look at standard practices for using wider markings for certain applications, after which agencies can revisit their practices.

5.4 7-20 Year Strategies

The measures identified for implementation in the longer term (7 to 20 years) are as follows:

Speed Management:	none
Unsignalized Intersections:	none
Signalized Intersections:	*Conversion to Roundabouts*
Roadways (Links):	*Linear Delineation Systems, Delineator Posts*
Run-off-Road:	*Horizontal and Vertical Realignments; Removal of Fixed Objects*
Vulnerable Road Users:	none

Linear Delineation Systems: This 3M product has been very recently implemented in Alberta. Although no specific studies are available, agency and public feedback has been positive. It is suggested that if a study becomes available proving its effectiveness, this measure be moved up to the 1-7 year program.

Removal of Fixed Objects: Detailed guidelines were prepared as part of this study to trigger the assessment and removal of roadside hazards.

In summary:

- 10 measures are recommended for immediate implementation;
- 18 measures are recommended for implementation in the 1-7 year time frame; and,
- 5 measures are recommended for implementation in the 7-20 year time frame.

5.5 Legislation, Education and Enforcement

The success of several of the measures will depend on the level of public education about them and the extent of enforcement that is conducted. In particular, the following measures should include an education / enforcement component:

Gateway treatments – These treatments are intended to have an effect at the subconscious level, so minimal education is required. However, any combination of the speed limit with the name of the community will need to be vetted for compliance with the MUTCDC and its intent clarified for the public, to avoid the possible misperceptions raised in the detailed guidelines.

Consistent speed limits – Education and enforcement are critical to any speed management initiatives, since there is a heavy reliance on changes in behaviour. While the application of consistent speed limits is intended to result in greater self-regulation, targeted police enforcement is still recommended, and operational speed data should be collected to ensure that they are compatible with the posted speed limits.

Variable speed limits – Variable speed limits would represent a significant change in the way speed limits are determined, displayed and enforced. Therefore, legislation would need to be prepared and passed. An extensive public campaign would be necessary to make the driving public understand that VSLs are as enforceable as static limits. Consultation with legal professionals may be required.

Pedestrian countdown signals – While these have been in place in Alberta for a few years, they are still considered a novelty to some road users, especially outside of Calgary, Edmonton and Banff. There is still a degree of confusion regarding whether the counter displays the amount of time remaining to start to cross or to complete the crossing movement. As the implementation of PCS's continues to expand and they become standard, public education to address this issue will be necessary.

Conversion to roundabout – Roundabouts are also becoming more common in Alberta, but are still new to much of the public. Materials for public education have been developed by Transport Canada, TRANS and several municipalities to assist drivers, pedestrians and cyclists how to successfully negotiate a roundabout, including right-of-way and lane changing rules.

Partnerships and agreements between the Engineering Committee and other committees operating under the Alberta Traffic Safety Plan, such as those responsible for legislation, education and enforcement will be instrumental in maximizing the potential effectiveness of the engineering measures.

TRANS or the municipalities may wish to program the above education and enforcement campaigns as part of a larger campaign, starting with general messages regarding the traffic safety plan and this study, the importance of reducing collisions in Alberta, and the role the public can play in this endeavour.

5.6 Monitoring and Evaluation

The success of any collision reduction initiatives can only be assessed if a clear and effective monitoring and evaluation plan is put into place. This section presents a suggested set of evaluation criteria and methodology, lists the data requirements, and suggests a frequency of evaluation.

5.6.1 Evaluation Criteria

It is suggested that *collisions* be used as the primary source of data, to measure the success of implementing the measures identified in this study. In particular, for consistency with the study objectives, *injury and fatal collision* data should be used. Since fatal collisions are rare, and the difference between a serious injury and a fatality is often based on characteristics that cannot be controlled by road agencies, it is suggested that they not be used alone, but that they be combined with injury collisions for the purpose of analysis.

The collision reduction factors reported in literature and in the current Alberta Traffic Safety Plan are based in large part on collision frequency. The indicators will have to be selected to be consistent with the Alberta Traffic Safety Plan. It is suggested that the Office of Traffic Safety consider moving towards collision rate (and specifically “injury rate”) as the primary indicator of success. Collision rate is defined as the collision frequency per unit traffic volume.

5.6.2 Evaluation Methods

Once safety data is collected via the monitoring program, methods are applied to compare the before and after results. The analytical framework described below represents the state-of-the-practice in evaluation programs:

The evaluation process should note changes in safety performance (collisions, violations) caused by safety improvements instead of other “confounding” factors or causes. Sound conclusions about the effect of the engineering program cannot be made if these other factors contributed to the noted change. The three main factors most relevant to the road safety evaluations are history, maturation, and regression to the mean:

- History refers to the possibility that factors other than the engineering program caused all or part of the observed change in safety.
- Maturation refers to the process by which safety data measures or changes over time, such as the long-term downward trend in collisions due to improved vehicle safety devices.
- Regression artefacts (or regression to the mean) refer to the tendency of extreme events to be followed by less extreme events, even if no change has occurred in the underlying mechanism which generates the process.

A comparison group should be used to account for the effect of history and maturation. In this method, a group of sites that are somewhat similar to the treated sites are otherwise randomly selected and their safety performance is obtained. The treatment effect is then calculated by comparing the safety performance between the treatment sites and the comparison group. To account for the regression to the mean, a technique known as the Empirical Bayes (EB) technique can be used.

5.6.3 Evaluation Schedule

While activities should be monitored on an ongoing basis, it is recommended that the effectiveness of the enhancements be formally evaluated at pre-determined intervals:

Quick wins:

- After one year. While the focus is on injury and fatal collisions, since this short period, the impact on all collisions might also be reviewed. It should be recognized that for some of the measures, there may be a significant initial increase or decrease in the first few weeks or months due to driver caution or behaviour adjustments, prior to a degree of stabilization. The one year evaluation can be a simple before and after analysis, based on frequency.
- Subsequently: every three years. Three years is expected to provide the minimum required statistical significance. These reviews should apply the history, maturation and regression factors described above.

1-7 Year Strategies:

- *Within 3 years*: two full years following the implementation of the quick wins. "Before" data can be collected over a one-period prior to implementation. This is expected to provide a preliminary indication of the effectiveness prior to possible expansion or change in direction. If TRANS adopts new targets for 2015, this evaluation will be aligned with this time frame.
- *Within 7 years*: following the first three years, up to one full year can be taken to make adjustments/expansions; then another formal evaluation be conducted after year 7.

7-20 Year Strategies:

- Formal evaluations should be conducted every three years. The first evaluation would coincide with targets set for 2020.

6.0 NEXT STEP AND POSSIBLE FURTHER WORK

6.1 Next Steps

To maximize the value of this study, TRANS and the Engineering Committee can consider the following follow-up actions:

Circulate study deliverables to road agencies

The benefits of the new knowledge provided by this study will be realized through the sharing of the report deliverables to road agencies and within the industry in general. This would include posting it to Alberta Transportation's website. The electronic database will be a particularly valuable and practical tool. The circulation of deliverables to targeted road agencies may include encouragement to adopt the highly effective measures.

Provide training to industry and stakeholders in Alberta

To properly describe the toolbox measures and highly effective measures and the context sensitive applications, training can be arranged for road agencies and the industry. This would include several examples of how to use the deliverables, depending on the purpose and need.

Incorporate methods into existing processes and budgets

Road agencies may consider incorporating MORCOAR into its current processes. Road networks can be screened to find the most appropriate locations for the highly effective measures. For example, it can be referred to as part of all safety studies, or functional planning studies, or for all retrofit projects. Budgets might be secured for the study or implementation of the highly effective measures. Existing programs of highly effective measures, such as TRANS' cable barrier and rumble strips programs, can be expanded to include other applications.

Adapt guidelines to current policies and standards

TRANS and municipal road agencies will need to review the study findings, and in particular the detailed application guidance, for compatibility with their own practices. Existing policies can refer to the MORCOAR guidelines as supplementary guidance, or they can be adopted in whole or in part into existing practices. "Next steps" are described for each of the Priority 1 measures in the detailed application guidance. For example, lawyers will need to be consulted for further advancement of Variable Speed Limits.

Set up evaluation and monitoring program

As described in Section 5.6, the effectiveness of implemented measures can only be established through active monitoring and scientific evaluation. This may require the collection of "before" data, which should be extracted or collected prior to implementation.

6.2 Possible Further Work

Subsequent to (or in parallel with) the above "next steps", TRANS or the Engineering Committee may consider the following work items, internally or through engaging a qualified consultant:

Conduct another agency survey to prioritize the need for detailed guidance for other 25 Highly Effective Measures

Application guidance is required for several of the highly effective measures other than the 8 for which guidance was developed in this study. The survey that was conducted at the outset of Phase 2 included a relatively small sub-set of road agencies in Alberta. It was focused on agencies that have more guidance (larger municipalities). It is suggested that a wider survey be conducted, particularly with the focus on agencies that need more guidance (smaller municipalities).

Develop application guidance for other HEMs

After the survey establishes where additional guidance is required, this guidance can be developed. For example, if there are 10 more measures that require application guidance, TRANS may decide to develop 5 per year over the next two years.

Initiate the development of national guidance

To encourage effective and consistent use of the concepts and guidelines developed in the study, forums such as the Transportation Association of Canada can be explored, particularly for measures that are relatively new to Canada. In particular, jurisdictions across Canada will benefit from national guidance on the application of Gateway Treatments and Variable Speed Limits.

Provide updates as important new guidance gets released

The information in the MORCOAR report (both CMFs and applications guidance) will only be as good as it is recent. The electronic database can be updated to include new CMFs. New application guidance is always being prepared by TAC, FHWA and other industry leaders. In particular, several new documents are expected in the next several months that relate to the highly effective measures: these include the 2010 update to the FHWA Roundabout informational Guide, and the TAC project on Reflective Sign Sheeting Requirements. Application guidance in the MORCOAR has been dated so that new references and application guidance can be provided as required. TRANS can assign someone to monitor industry developments and lead these updates. Alternatively, an annual focused scan of the industry can be conducted.

Prepare supporting implementation guidance

While implementation considerations were presented in this study, the focus was on application guidance. Implementation guidance can be developed to ensure measures are installed in a way that maximizes their effectiveness. Implementation guidance would include details such as content (e.g. sign content), placement (e.g. cable barrier placement), installation method (e.g. type of rumble strips), dimensions (of pavement markings), display (e.g. countdown signals) and operations (protected-only left-turn phasing).

Incorporate new HSM information and new Canadian CMFs

Although this study included some of the accessible HSM unpublished content, it was essentially complete before the HSM was released. Several but not all of the CMFs in the HSM/Clearinghouse were taken from the FHWA Desktop Reference. It may be worthwhile to review how the content of the new HSM can be incorporated into the MORCOAR deliverables, and in particular the CMFs. Also, more “Canadianized” CMFs are currently being developed at Ryerson University and elsewhere, and should be considered for adoption of modification for Alberta. This will be best conducted when the major portion is complete: expected within one year.

Prepare Alberta-specific collision prediction models

Collision prediction models are developed by some jurisdictions within Alberta. While not directly related to this study, these models help to establish and quantify the problems that MORCOAR attempts to solve. Better problem definition would most certainly lead to more favourable countermeasure development.

Conduct another comprehensive study within 5 years, to capture new national and provincial priorities and 2020 targets

Finally, it is suggested that a study of similar scope to this be conducted every five years. The next iteration would be well timed to reflect new goals established after 2015, depending on the achievement of the 2015 goals, the new priorities, and the 3 year evaluation suggested of the MORCOAR measures recommended for immediate implementation.

APPENDIX A

ROAD AGENCY SURVEY

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Methods of Reducing Collisions on Alberta Roads
Current Agency Status in Alberta for Shortlisted Measures

Agency: City of Edmonton, City of Calgary, Province of Alberta, Strathcona County

#	MEASURE	GUIDELINES YOU ARE USING?	SUFFICIENCY OF EXISTING APPLICATION GUIDELINES	EXTENT OF USE OF MEASURE IN YOUR JURISDICTION	OBSERVED SAFETY EFFECTIVENESS	COMMENTS
1	Road Narrowings – Physical	None (AT) Local (Cal) Provincial TAC (SC) Other: multiple (Ed)	Don't use any (Ed, AT, Cal) Insufficient Sufficient (SC)	Limited but systematic (Ed, AT, SC) Experimental / Piloting Widespread but systematic Ad-hoc / out of control	Highly successful Successful (SC) Moderate Hit and miss (Cal) Mostly unsuccessful (Ed)	• Have had limited to no benefit in application related to speed reduction (Ed) • Generally not used (AT) • Anecdotally effective, some positive feedback, not speed control (Cal) • Snow removal operations are sometimes slow in avoiding them (SC)
2	Road Narrowings – perceptual – e.g. hatching	None (Ed, AT, Cal) Local Provincial TAC Other:________	Don't use any (Ed, AT, Cal) Insufficient Sufficient	Limited but systematic (AT) Experimental / Piloting Widespread but systematic (AT) Ad-hoc / out of control	Highly successful Successful Moderate Hit and miss Mostly unsuccessful	• May have limited benefit especially in winter city conditions (Ed) • Generally not used (AT) • Not used (Cal) • Not generally used (SC)

#	MEASURE	GUIDELINES YOU ARE USING?	SUFFICIENCY OF EXISTING APPLICATION GUIDELINES	EXTENT OF USE OF MEASURE IN YOUR JURISDICTION	OBSERVED SAFETY EFFECTIVENESS	COMMENTS
3	Consistent Application of Speed Limits	None Local (Ed, Cal) Provincial (Ed, AT, SC) TAC (Ed, AT, Cal) Other:_______	Don't use any Insufficient Sufficient (Ed, AT, Cal, SC)	Limited but systematic Experimental / Piloting (Ed) Widespread but systematic (Cal) Ad-hoc / out of control	Highly successful (AT) Successful Moderate (Cal) Hit and miss Mostly unsuccessful	• Testing new TAC guideline along with existing City guidelines as new changes/reviews require. (Ed) • Based on design speed and policy (AT) • Speeds based on design speed and road classification (Cal) • Enforcement tolerance is the real issue (SC)
4	Variable Speed Limits	None Local (Ed, AT) Provincial (SC) TAC Other:_______	Don't use any (Ed, AT) Insufficient Sufficient (SC)	Limited but systematic (Ed) Experimental / Piloting Widespread but systematic (SC) Ad-hoc / out of control	Highly successful Successful Moderate Hit and miss Mostly unsuccessful	• Building this capability in at major river crossings (Quesnell and Capilano); not operation yet (Ed) • Traffic Safety Act does not permit its use (AT) • Not permitted under current legislation (Cal) • High levels of enforcement required (SC)

#	MEASURE	GUIDELINES YOU ARE USING?	SUFFICIENCY OF EXISTING APPLICATION GUIDELINES	EXTENT OF USE OF MEASURE IN YOUR JURISDICTION	OBSERVED SAFETY EFFECTIVENESS	COMMENTS
5	Speed Reader Boards*	None (AT) Local (Ed, Cal) Provincial TAC Other:_______	Don't use any (AT, SC) Insufficient (Ed) Sufficient (Cal)	Limited but systematic (AT) Experimental / Piloting (Ed) Widespread but systematic (Cal) Ad-hoc / out of control	Highly successful Successful (AT) Moderate (Cal) Hit and miss Mostly unsuccessful	• Developing and piloting applicability/technology in a few neighbourhoods for more wide scale application in the future. (Ed) • Mainly for construction zones (AT) • Popular with residents & politicians, effect on speeds is limited, untested. (Cal) • Politically seen as a good thing (SC)
6	Transverse Pavement Markings	None (Ed, AT) Local Provincial TAC (SC) Other:_______	Don't use any (Ed, AT) Insufficient (Cal) Sufficient	Limited but systematic (AT) Experimental / Piloting (AT) Widespread but systematic Ad-hoc / out of control	Highly successful Successful (Ed) Moderate Hit and miss Mostly unsuccessful	• A few sites for stop conditions (AT) • Not currently used but is being contemplated, application guidelines would be helpful, previous use on Deerfoot not successful (1980s) (Cal) • Used as required (SC)
7	Gateway Treatments	None (Ed, AT) Local (Cal) Provincial TAC Other:_______	Don't use any (Ed, AT, Cal) Insufficient Sufficient	Limited but systematic Experimental / Piloting (Ed) Widespread but systematic (Cal) Ad-hoc / out of control	Highly successful Successful Moderate Hit and miss Mostly unsuccessful	• None, mainly due to development, lighting (AT) • Developers use as entry features, untested safety. (Cal) • Not used for collision reduction (SC)

#	MEASURE	GUIDELINES YOU ARE USING?	SUFFICIENCY OF EXISTING APPLICATION GUIDELINES	EXTENT OF USE OF MEASURE IN YOUR JURISDICTION	OBSERVED SAFETY EFFECTIVENESS	COMMENTS
8	Convert Stop control intersection to Roundabout	None (Ed) Local (Cal) Provincial TAC (AT, Cal) Other: AASHTO (AT), FHA (SC)	Don't use any Insufficient (Ed) Sufficient (AT, Cal, SC)	Limited but systematic (AT) Experimental / Piloting (Cal) Widespread but systematic Ad-hoc / out of control	Highly successful Successful (AT, Cal, SC) Moderate Hit and miss Mostly unsuccessful	• Replaced one large intersection 4-way stop with non-compliance to a single lane Roundabout to reduce violations of the stop condition. (Ed) • Soon to be a design practice, being promoted (AT) • Converted one 4-way stop and one 2-way stop, preliminary results show reduction in collision frequency and severity, complaints from pedestrians downstream. (Cal) • Roundabouts were first used in new areas then as a retrofit (SC)
9	Intersection illumination (full or delineation)	None Local (Cal) Provincial TAC (AT, SC) Other: IESNA (Cal)	Don't use any Insufficient Sufficient (AT, Cal, SC)	Limited but systematic Experimental / Piloting Widespread but systematic (AT, Cal) Ad-hoc / out of control	Highly successful (AT) Successful Moderate (SC) Hit and miss Mostly unsuccessful	• Success is undetermined (Cal) • TAC guidelines are used on arterials and collector roads (SC)
10	Warning signs on major approaches	None Local (Ed, Cal) Provincial (Ed, AT) TAC (Ed, Cal, SC) Other:________	Don't use any Insufficient Sufficient (Ed, SC)	Limited but systematic (SC) Experimental / Piloting Widespread but systematic (Ed, AT, Cal) Ad-hoc / out of control	Highly successful Successful (AT, Cal) Moderate (SC) Hit and miss Mostly unsuccessful	• Recent updates to City manual based on recent TAC work (Ed) • Based on department recommended practices (AT) • Used where conditions limit sight distance. (Cal)

#	MEASURE	GUIDELINES YOU ARE USING?	SUFFICIENCY OF EXISTING APPLICATION GUIDELINES	EXTENT OF USE OF MEASURE IN YOUR JURISDICTION	OBSERVED SAFETY EFFECTIVENESS	COMMENTS
11	Remove sight obstructions near intersections	None Local (Ed, AT) Provincial (Ed, AT) TAC (Ed, SC) Other:_______	Don't use any Insufficient Sufficient (Ed, AT, Cal, SC)	Limited but systematic Experimental / Piloting Widespread but systematic (AT, Cal) Ad-hoc / out of control	Highly successful Successful (AT, Cal) Moderate (SC) Hit and miss Mostly unsuccessful	• Completed on an inquiry basis mostly concerns of foliage growth trimming requests. (Ed) • Based on geometric criteria and manual (AT) • Bylaw restrictions, standard practice. (Cal)
12	Convert traffic signal to roundabout	None (Ed, AT) Local Provincial TAC Other:_______	Don't use any (AT) Insufficient (Ed) Sufficient	Limited but systematic (AT) Experimental / Piloting Widespread but systematic Ad-hoc / out of control	Highly successful Successful (AT) Moderate Hit and miss Mostly unsuccessful	• Not applicable to urban environment where signals are primarily triggered by capacity constraints and high volumes. (Ed) • Would recommend a policy or practice (AT) • No conversions yet (Cal) • Not happened to date (SC)

#	MEASURE	GUIDELINES YOU ARE USING?	SUFFICIENCY OF EXISTING APPLICATION GUIDELINES	EXTENT OF USE OF MEASURE IN YOUR JURISDICTION	OBSERVED SAFETY EFFECTIVENESS	COMMENTS
13	"Smart" Right-Turn Channel	None Local (Ed, AT, Cal) Provincial TAC Other: Austroads (Cal)	Don't use any (AT) Insufficient (Ed, Cal) Sufficient (SC)	Limited but systematic (Ed, AT) Experimental / Piloting Widespread but systematic Ad-hoc / out of control	Highly successful Successful (Ed, AT, SC) Moderate Hit and miss Mostly unsuccessful	• Starting to apply Aussie design or "simple" radius to reduce FTC collisions at existing right turn channels City wide. Should start seeing collision change results in the next 1 to 2 years. (Ed) • Would recommend a policy or practice (AT) • Proposed but not yet implemented, guidelines for retrofit applications would be helpful. (Cal) • Applying the new standard (SC)
14	Advance Warning Flashers	None Local (Ed) Provincial (Ed) TAC (Ed, AT, Cal, SC) Other:________	Don't use any Insufficient Sufficient (Ed, AT, Cal, SC)	Limited but systematic (Ed) Experimental / Piloting Widespread but systematic (AT, Cal) Ad-hoc / out of control	Highly successful (AT) Successful (Cal) Moderate (SC) Hit and miss Mostly unsuccessful	• Local guidelines inline with TAC for application in Edmonton. (Ed) • Considered successful but not specifically measured (Cal)

#	MEASURE	GUIDELINES YOU ARE USING?	SUFFICIENCY OF EXISTING APPLICATION GUIDELINES	EXTENT OF USE OF MEASURE IN YOUR JURISDICTION	OBSERVED SAFETY EFFECTIVENESS	COMMENTS
15	Offset Left-Turn Lanes	None Local (Ed) Provincial (Ed, AT) TAC (Ed, AT, SC) Other: Slightly modified TAC (Cal)	Don't use any (Cal) Insufficient (Ed) Sufficient (AT, SC)	Limited but systematic (AT) Experimental / Piloting Widespread but systematic (Cal) Ad-hoc / out of control	Highly successful Successful (AT, Cal, SC) Moderate Hit and miss Mostly unsuccessful	• No set guideline on this application (Ed) • Based on provincial practices (geometric manual) (AT) • Used based on road class and available ROW, Also allows for simultaneous dual left turns (Cal) • Need to include left turns at signals in the Alberta Operators Manual (SC)
16	Protected-only left-turn phases	None Local (Ed) Provincial (Ed, AT) TAC (Ed. Cal, SC) Other: _______	Don't use any Insufficient (Ed) Sufficient (AT, Cal, SC)	Limited but systematic (Ed) Experimental / Piloting Widespread but systematic (AT, Cal) Ad-hoc / out of control	Highly successful (Cal) Successful (Ed, AT, SC) Moderate Hit and miss Mostly unsuccessful	• Follow city established guidelines for this application and will be reviewing updating. (Ed) • Generally considered based on volume (AT) • Considered successful but not specifically measured. (Cal) • Requires more asphalt for vehicle storage (SC)
17	Consistent placement of traffic signal displays	None Local (Ed, SC) Provincial (Ed, AT, SC) TAC (Ed, AT, Cal, SC) Other:________	Don't use any Insufficient (Ed) Sufficient (AT, Cal, SC)	Limited but systematic Experimental / Piloting Widespread but systematic (Ed, AT, Cal) Ad-hoc / out of control	Highly successful (AT) Successful (Cal, SC) Moderate Hit and miss Mostly unsuccessful	• Have general city consistency however would like to see more work on conspicuity from the latest TAC work. (Ed) • Provincial practice (AT) • Considered successful but not specifically measured. (Cal)

#	MEASURE	GUIDELINES YOU ARE USING?	SUFFICIENCY OF EXISTING APPLICATION GUIDELINES	EXTENT OF USE OF MEASURE IN YOUR JURISDICTION	OBSERVED SAFETY EFFECTIVENESS	COMMENTS
18	Vegetation removal	None Local Provincial (AT) TAC Other:________	Don't use any Insufficient Sufficient (Ed, AT, SC)	Limited but systematic Experimental / Piloting Widespread but systematic (AT) Ad-hoc / out of control	Highly successful Successful (AT) Moderate (SC) Hit and miss Mostly unsuccessful	• Complete on an as requested basis (Ed) • Based on maintenance practices (AT) • N/A for wildlife control purpose (Cal)
19	Seasonal wildlife warning signs	None Local (Ed) Provincial (AT) TAC (AT) Other:________	Don't use any Insufficient (SC) Sufficient (AT)	Limited but systematic Experimental / Piloting Widespread but systematic (AT) Ad-hoc / out of control	Highly successful Successful Moderate Hit and miss (AT) Mostly unsuccessful (SC)	• OTS completed recent work in connection with U of A. (Ed) • Not used (Cal) • Try not to install any new wildlife signs as wildlife is everywhere (SC)
20	Wildlife fencing and overpasses	None (Ed) Local Provincial (AT) TAC Other:________	Don't use any (Ed) Insufficient Sufficient (AT)	Limited but systematic (AT) Experimental / Piloting Widespread but systematic Ad-hoc / out of control	Highly successful (AT) Successful Moderate Hit and miss Mostly unsuccessful	• More rural application (Ed) • Based on funding (AT) • Not used (Cal) • Non to date(SC)
21	Advance curve warning	None Local Provincial TAC (AT, Cal, SC) Other:________	Don't use any Insufficient Sufficient (AT, Cal)	Limited but systematic Experimental / Piloting Widespread but systematic (AT, Cal) Ad-hoc / out of control	Highly successful Successful (AT, SC) Moderate Hit and miss (Cal) Mostly unsuccessful	• Tends to form part of the urban sign clutter. (Cal)

#	MEASURE	GUIDELINES YOU ARE USING?	SUFFICIENCY OF EXISTING APPLICATION GUIDELINES	EXTENT OF USE OF MEASURE IN YOUR JURISDICTION	OBSERVED SAFETY EFFECTIVENESS	COMMENTS
22	Chevron signs	None Local (Ed) Provincial (Ed, AT) TAC (Ed, AT, Cal, SC) Other:_______	Don't use any Insufficient (Cal) Sufficient (Ed, AT, SC)	Limited but systematic Experimental / Piloting Widespread but systematic (AT, Cal) Ad-hoc / out of control	Highly successful Successful (SC) Moderate (AT, Cal) Hit and miss Mostly unsuccessful	• Follow current guidelines (Ed) • Based on recommended practices (AT) • Field placement guidelines may be useful e.g. spacing around curves, flexibility to use oversized sign as first sign in series (Cal)
23	Shoulder and centreline rumble strips	None (Ed) Local Provincial (AT) TAC Other:_______	Don't use any (Ed) Insufficient Sufficient (AT, SC)	Limited but systematic Experimental / Piloting Widespread but systematic (AT) Ad-hoc / out of control	Highly successful (AT) Successful Moderate Hit and miss Mostly unsuccessful	• Primarily rural application (Ed) • Based on recommended practices & policy (AT) • Not Used (Cal) • None to date (SC)
24	Cable barrier systems	None (Ed) Local Provincial (AT) TAC (AT) Other:_______	Don't use any (Ed) Insufficient Sufficient (AT, SC)	Limited but systematic (AT) Experimental / Piloting Widespread but systematic Ad-hoc / out of control	Highly successful (AT) Successful Moderate Hit and miss Mostly unsuccessful	• Would like to see more work on this to potential urban application (Ed) • Would recommend a policy and practice (AT) • Not used, would support use Not Used (Cal) • None to date (SC)
25	Linear Delineation Systems	None (Ed, AT) Local Provincial TAC (SC) Other: 3M (Cal)	Don't use any (Ed, AT, Cal) Insufficient (SC) Sufficient	Limited but systematic Experimental / Piloting (Cal) Widespread but systematic Ad-hoc / out of control	Highly successful Successful Moderate (SC) Hit and miss Mostly unsuccessful	• Joint project with AT on Deerfoot at the Calf Robe bridge curves, installation on-going, success to be determined (Cal) • Needs to define what is a line and the legality of a line (SC)

#	MEASURE	GUIDELINES YOU ARE USING?	SUFFICIENCY OF EXISTING APPLICATION GUIDELINES	EXTENT OF USE OF MEASURE IN YOUR JURISDICTION	OBSERVED SAFETY EFFECTIVENESS	COMMENTS
26	Increase Sign Reflectivity	None Local (Ed) Provincial (Ed, AT) TAC (Ed, SC) Other:3M (Cal)	Don't use any (Cal) Insufficient Sufficient (AT, SC)	Limited but systematic Experimental / Piloting Widespread but systematic (AT, Cal) Ad-hoc / out of control	Highly successful Successful (AT, Cal, SC) Moderate Hit and miss Mostly unsuccessful	• Ongoing work/progress on this at TAC etc. should continue (Ed) • Based on policy and practice (AT) • Use of DG[3] is standard practice based on sign type, cost savings where need for lighting is reduced (Cal)
27	Painted Edgelines	None Local Provincial (AT) TAC (Cal, SC) Other:________	Don't use any Insufficient Sufficient (AT, Cal, SC)	Limited but systematic Experimental / Piloting Widespread but systematic (AT, Cal) Ad-hoc / out of control	Highly successful Successful (AT, Cal, SC) Moderate Hit and miss Mostly unsuccessful	• Primarily rural safety application (Ed) • Based on practice (AT) • Considered successful but not specifically measured (Cal)
28	Painted Centrelines	None Local Provincial (AT) TAC (AT, Cal, SC) Other:________	Don't use any Insufficient (SC) Sufficient (AT, Cal)	Limited but systematic Experimental / Piloting Widespread but systematic (AT, Cal) Ad-hoc / out of control	Highly successful (AT) Successful (Cal, SC) Moderate Hit and miss Mostly unsuccessful	• Primarily rural safety application (Ed) • Based on policy and practice (AT) • Used based on road classification, considered successful but not specifically measured (Cal) • Need more information on narrow rural roads (SC)
29	Delineator posts	None Local Provincial (AT) TAC (SC) Other:________	Don't use any Insufficient Sufficient (AT, SC)	Limited but systematic Experimental / Piloting Widespread but systematic (AT) Ad-hoc / out of control	Highly successful Successful (AT, (SC)) Moderate Hit and miss Mostly unsuccessful	• Apply as required (Ed) • Based on recommended practice (AT) • Not used (Cal) • Snow ploughs remove them,(SC).

#	MEASURE	GUIDELINES YOU ARE USING?	SUFFICIENCY OF EXISTING APPLICATION GUIDELINES	EXTENT OF USE OF MEASURE IN YOUR JURISDICTION	OBSERVED SAFETY EFFECTIVENESS	COMMENTS
30	Removal of fixed objects	None Local (Cal) Provincial (AT) TAC (Cal, SC) Other:_______	Don't use any Insufficient (Cal) Sufficient (AT)	Limited but systematic Experimental / Piloting Widespread but systematic (AT) Ad-hoc / out of control (Cal)	Highly successful Successful (AT) Moderate (Cal) Hit and miss Mostly unsuccessful	• Completed as required based on requests. (Ed) • Based on Roadside Design Guide (AT) • Guideline for establishing urban clear zones may be helpful (Cal)
31	Pedestrian countdown signals	None Local (Ed) Provincial (Ed) TAC (Ed, AT, Cal) (SC)) Other:_______	Don't use any Insufficient (AT, SC) Sufficient (Ed, Cal)	Limited but systematic (Ed, AT, Cal) Experimental / Piloting Widespread but systematic Ad-hoc / out of control	Highly successful Successful (Cal) Moderate (AT) Hit and miss Mostly unsuccessful	• Becoming more widely used for all new signal installations and generally follow TAC for retrofit applications. (Ed) • Would recommend a practice be developed (AT) • May become standard on all new installs (Cal) • Unknown (SC)
32	Accessible Pedestrian Signals	None Local (Ed, Cal) Provincial (Ed) TAC (Ed, AT) Other:_______	Don't use any Insufficient Sufficient (Ed, AT, Cal)	Limited but systematic (AT, Cal) Experimental / Piloting Widespread but systematic Ad-hoc / out of control	Highly successful (Cal) Successful Moderate (AT) Hit and miss Mostly unsuccessful	• Have City guideline for consistency in application (Ed) • We use audible not tactile at this time, based on requests from CNIB (Cal)
33	Illumination at pedestrian crossings*	None Local (Cal) Provincial TAC (AT, SC) Other: IESNA (Cal)	Don't use any Insufficient Sufficient (AT, Cal, SC)	Limited but systematic Experimental / Piloting Widespread but systematic (AT, Cal) Ad-hoc / out of control	Highly successful Successful (A, (SC) Moderate Hit and miss Mostly unsuccessful	• Review this as per City / TAC guidelines as part of new designs and retro-fit/rehabs. (Ed) • Based on TAC lighting design guide (AT) • Measure of success not yet quantified, metrics to be established (Cal)

#	MEASURE	GUIDELINES YOU ARE USING?	SUFFICIENCY OF EXISTING APPLICATION GUIDELINES	EXTENT OF USE OF MEASURE IN YOUR JURISDICTION	OBSERVED SAFETY EFFECTIVENESS	COMMENTS
34	Bicycle Lanes*	None (AT) Local (Ed, Cal, SC) Provincial (Ed) TAC (Ed, Cal) Other:________	Don't use any (AT) Insufficient (Ed) Sufficient (SC)	Limited but systematic (Ed) Experimental / Piloting (Cal) Widespread but systematic Ad-hoc / out of control	Highly successful Successful (SC) Moderate Hit and miss Mostly unsuccessful	• Edmonton just beginning to look at city wide application and currently establishing City guidelines based on TAC work etc. (Ed) • Measure of success not yet quantified, metrics to be established (Cal) • On road bike tons are one safe at speeds greater than 50 km/h (SC)

*Measures Added by the Steering Committee at Meeting #6. These will be kept on the list in the final report if we find supporting evidence or strong potential, through this survey or our other sources.

APPENDIX B

BENEFIT AND COST CALCULATIONS

NOTE: countermeasures are grouped within each objective area, and ranked based on their average BCR within each area.

SPEED RELATED (4)

	# of Doc.Ben.	Type	Severity	% Reduction		
Variable Speed Limits	2	All	Injury	20		
Benefits	Benefit Range	Annual Cost Savings per Injury				
Low	0.1	10000		Cost		
High	0.16	16000		Supply and Install Sign Panels - Extruded Aluminum		
				Side		Overhead
Capital Cost		Annual Capital Cost		1000	New	300000
Low	1000	100		1200	Retrofit (assume $200 to remove old)	
High	300000	30000				
		Annual Cost				
Life Span (years)	10	2600				
Annual M&O Costs	2500	32500				
Lowest Benefit/Highest Cost	0.307692308		Average	3.2		
Highest Benefit/Lowest Cost	6.153846154		Rank	4		

Consistant Speed Limits	0		Assume same as Variable Speed Limits (20%)		
Benefits	Benefit Range	Annual Cost Savings per Injury			
Low	0.1	10000			
High	0.16	16000		Retrofit	
				568.36	Supply and Install Sign Panels - Extruded Aluminum
Capital Cost		Annual Capital Cost		0.45	sq.m
Low	250	50		255.762	$/sign
High	500	100			
		Annual Cost			
Life Span (years)	5	1050			
Annual M&O Costs	1000	1100			
Lowest Benefit/Highest Cost	9.090909091		Average	12.2	
Highest Benefit/Lowest Cost	15.23809524		Rank	1	

Gateway Treatments	2	All	Ser. Inj/Fat	50					
Benefits	Benefit Range	Annual Cost Savings per Injury							
Low	0.25	25000							
High	0.5	50000		Lower Cost					
				568.36	Supply and Install Sign Panels - Extruded Aluminum				
Capital Cost		Annual Capital Cost		1.5	sq.m				
Low	2000	200		852.54	$/sign				
High	500000	50000		170.92	Supply and Install Post (100mm X 150mm)				
		Annual Cost		2046.92	2 signs and posts				
Life Span (years)	10	2700							
Annual M&O Costs	2500	52500		High cost assume at least $500,000					
				New/Retrofit assumed to be same costs					
Lowest Benefit/Highest Cost	0.476190476		Average	9.5					
Highest Benefit/Lowest Cost	18.51851852		Rank	2					

Transverse Pavement Markings	2	All	Inj+Fat	55					
Benefits	Benefit Range	Annual Cost Savings per Injury							
Low	0.2	20000							
High	0.44	44000		Lower Cost					
				2	$/m/side				
Capital Cost		Annual Capital Cost		4000	$/km	Assumed treatment is both sides and for 1km,			
Low	4000	2000				but likely less per treatment (high estimate)			
High	10000	5000		Higher Cost					
		Annual Cost		5	$/m/side				
Life Span (years)	2	4000		10000	$/km	Assumed treatment is both sides and for 1km,			
Annual M&O Costs	2000	7000				but likely less per treatment (high estimate)			
				New/Retrofit assumed to be same costs					
Lowest Benefit/Highest Cost	2.857142857		Average	6.9					
Highest Benefit/Lowest Cost	11		Rank	3					

UNSIGNALIZED INTERSECTIONS (6)

	# of Doc.Ben.	Type	Severity	% Reduction				
Advance Intersection Warning on Major Road	1	All	All	30				
Benefits	Benefit Range	Annual Cost Savings per Injury						
Low	0.15	15000						
High	0.3	30000						
				249.68	Supply of Signs, Aluminum - 3M Diamond Grade (VIP)			
Capital Cost		Annual Capital Cost		0.36	sq.m (sign)			
Low	150	30		0.18	sq.m (tab)			
High	800	160		170.92	Supply and Install Post (100mm X 150mm)			
		Annual Cost		64.67	Install Sign - Less than 1 m2			
Life Span (years)	5	1030						
Annual M&O Costs	1000	1160		109.6124	$ Retrofit (assume just tab)			
				435.0872	$ New (assume sign and tab with post)			
Lowest Benefit/Highest Cost	12.93103448		Average	21				
Highest Benefit/Lowest Cost	29.12621359		Rank	2				

Conversion of Stop Controlled Intersection to Roundabout	2	All	Inj+Fat	72% to 87%				
Benefits	Benefit Range	Annual Cost Savings per Injury						
Low	0.576	57600						
High	0.696	69600						
Capital Cost		Annual Capital Cost						
Low	250000	12500		LS Costs				
High	500000	25000		Low	250000			
		Annual Cost		High	500000			
Life Span (years)	20	15500						
Annual M&O Costs	3000	28000						
Lowest Benefit/Highest Cost	2.057142857		Average	3.3				
Highest Benefit/Lowest Cost	4.490322581		Rank	6				

Dedicated Left-turn Lane on Major Road Approaches	2	All	Inj+Fat	35				
Benefits	Benefit Range	Annual Cost Savings per Injury						
Low	0.29	29000						
High	0.35	35000						
				Cost				
Capital Cost		Annual Capital Cost		4.99	Removal of Existing Painted Lines			
Low	10000	500		252.86	Durable Pavement Messages - Turn or Straight Arrows (Single			
High	100000	5000		4.32	Roadway Lines - Supplying Paint and Painting (Lane Dividing L			
		Annual Cost		Total costs				
Life Span (years)	20	3000		Low	High			
Annual M&O Costs	2500	7500		10000	25000	New		
				15000	100000	Retrofit		
Lowest Benefit/Highest Cost	3.866666667		Average	7.8	Low costs assume no island (just painted markings)			
Highest Benefit/Lowest Cost	11.66666667		Rank	4	High costs assume island			

Flashing Beacon on Stop Sign	1	Failure to Stop	All	30	
Benefits	Benefit Range	Annual Cost Savings per Injury			
Low	0.15	15000			
High	0.3	30000		Cost	
				249.68	Supply of Signs, Aluminum - 3M Diamond Grade (VIP)
Capital Cost		Annual Capital Cost		0.67	sq.m (sign)
Low	500	50		170.92	Supply and Install Post (100mm X 150mm)
High	2000	200		64.67	Install Sign - Less than 1 m2
		Annual Cost		500	$/Beacon
Life Span (years)	10	1550			
Annual M&O Costs	1500	1700		500	$ Retrofit (assume just beacon)
				902.8756	$ New (assume beacon & sign with post)
Lowest Benefit/Highest Cost	8.823529412		Average	14.1	
Highest Benefit/Lowest Cost	19.35483871		Rank	3	

Removal of Obstructions Within Sight Triangle	2	All	INJ	37	
Benefits	Benefit Range	Annual Cost Savings per Injury			
Low	20	2000000			
High	37	3700000			
Capital Cost		Annual Capital Cost			
Low	500	16.66666667		Cost	
High	500000	16666.66667		Low (LS)	500
		Annual Cost		High (LS)	500000
Life Span (years)	30	2516.666667		Can range from low cost (tree removal, parking restrictions)	
Annual M&O Costs	2500	19166.66667		to high cost (road realignment).	
Lowest Benefit/Highest Cost	104.3478261		Average	787.3	
Highest Benefit/Lowest Cost	1470.198675		Rank	1	

Transverse Rumble Strips	1	Failure to Stop	All	28	
Benefits	Benefit Range	Annual Cost Savings per Injury			
Low	0.1	10000			
High	0.22	22000			
Capital Cost		Annual Capital Cost		Cost	
Low	2000	400		2234.45	Milled Rumble Strips for Stop Conditions
High	6000	1200			
		Annual Cost			
Life Span (years)	5	2900			
Annual M&O Costs	2500	3700			
Lowest Benefit/Highest Cost	2.702702703		Average	5.1	
Highest Benefit/Lowest Cost	7.586206897		Rank	5	

SIGNALIZED INTERSECTIONS (8)

	# of Doc.Ben.	Type	Severity	% Reduction	
Advance Intersection Warning Flashers	2	All	Inj+Fat	44	
Benefits	Benefit Range	Annual Cost Savings per Injury			
Low	0.2	20000			
High	0.44	44000			
				568.36	Supply and Install Sign Panels - Extruded Aluminum
Capital Cost		Annual Capital Cost		2	sq.m
Low	3000	600		1136.72	$/sign
High	6000	1200		170.92	Supply and Install Post (100mm X 150mm)
		Annual Cost			
Life Span (years)	5	3100		1478.56	Sign and 2 posts
Annual M&O Costs	2500	3700		3000	Assume 2 signs needed
Lowest Benefit/Highest Cost	5.405405405		Average	9.8	
Highest Benefit/Lowest Cost	14.19354839		Rank	5	

Conversion of Signalized Intersection to Roundabout	2	All	Inj+Fat	78	
Benefits	Benefit Range	Annual Cost Savings per Injury			
Low	0.3	30000			
High	0.624	62400			
Capital Cost		Annual Capital Cost			
Low	275000	13750		LS Costs	
High	500000	25000		Low	275000
		Annual Cost		High	500000
Life Span (years)	20	16750		Assume slightly higher than UnSig to RAB due to	
Annual M&O Costs	3000	28000		higher cost of removing signals	
Lowest Benefit/Highest Cost	1.071428571		Average	2.4	
Highest Benefit/Lowest Cost	3.725373134		Rank	8	

Dedicated Left-turn Lanes with Phasing	1	All	All	58			
Benefits	Benefit Range	Annual Cost Savings per Injury					
Low	0.3	30000					
High	0.58	58000					
Capital Cost		Annual Capital Cost					
Low	5000	250		LS Costs	Construction	Widening	Retrofit
High	100000	5000		Low	15000	5000	20000
		Annual Cost		High	30000	70000	100000
Life Span (years)	20	3250					
Annual M&O Costs	3000	8000		Retrofit involves both construction and widening costs			
Lowest Benefit/Highest Cost	3.75		Average	10.8			
Highest Benefit/Lowest Cost	17.84615385		Rank	4			

Positive Offset Left-turn Lanes	1	LT across path	Inj+Fat	20% to 40%		
Benefits	Benefit Range	Annual Cost Savings per Injury				
Low	0.2	20000				
High	0.4	40000				
Capital Cost		Annual Capital Cost		LS Costs	Construction	
Low	10000	500		Low	10000	
High	100000	5000		High	25000	
		Annual Cost		Retrofit assumes lights are in place		
Life Span (years)	20	3500		(new assumes lights are installed as well)		
Annual M&O Costs	3000	8000				
Lowest Benefit/Highest Cost	2.5		Average	7		
Highest Benefit/Lowest Cost	11.42857143		Rank	6		

Protected Only Left-turn Phase	3	LT across path	Inj+Fat	16		
Benefits	Benefit Range	Annual Cost Savings per Injury				
Low	0.08	8000				
High	0.16	16000				
Capital Cost		Annual Capital Cost		LS Costs	New	Retrofit
Low	300	15		Low	300	400
High	1200	60		High	800	1200
		Annual Cost				
Life Span (years)	20	2515		Costs are only cost to change or		
Annual M&O Costs	2500	2560		implement protected only phasing		
Lowest Benefit/Highest Cost	3.125		Average	4.7		
Highest Benefit/Lowest Cost	6.361829026		Rank	7		

Removal of Unwarranted Traffic Signals	2	All	Inj+Fat	53		
Benefits	Benefit Range	Annual Cost Savings per Injury				
Low	0.25	25000				
High	0.53	53000				
				474.65	Removal&Disposal of Existing Light Fixures (assume same)	
Capital Cost		Annual Capital Cost		249.68	Supply of Signs, Aluminum - 3M Diamond Grade (VIP)	
Low	2000	66.66666667		0.67	sq.m (sign)	
High	6500	216.6666667		170.92	Supply and Install Post (100mm X 150mm)	
		Annual Cost		64.67	Install Sign - Less than 1 m2	
Life Span (years)	30	1066.666667		1826.8256	3 way INT with 1 signal each and 1 Stop sign	
Annual M&O Costs	1000	1216.666667		6265.9612	4 way INT with 3 signals each and 2 Stop signs	
Lowest Benefit/Highest Cost	20.54794521		Average	35.1		
Highest Benefit/Lowest Cost	49.6875		Rank	1		

Signal Backboards	1	Right angle	All	32				
Benefits	Benefit Range	Annual Cost Savings per Injury						
Low	0.15	15000						
High	0.32	32000						
				500	Back plate			
Capital Cost		Annual Capital Cost		500	Added cost for installing on existing signals			
Low	500	50						
High	12000	1200			New	Retrofit		
		Annual Cost		MIN 2	500	1000		
Life Span (years)	10	1550		MAX 12	6000	12000		
Annual M&O Costs	1500	2700						
Lowest Benefit/Highest Cost	5.555555556		Average	13.1				
Highest Benefit/Lowest Cost	20.64516129		Rank	3				

Smart Right-turn Channel	0		All	65 to 80	Based on experiences from Edmonton			
Benefits	Benefit Range	Annual Cost Savings per Injury						
Low	0.65	65000						
High	0.8	80000						
Capital Cost		Annual Capital Cost		Per channel				
Low	15000	750		LS Costs	New	Retrofit		
High	50000	2500		Low	15000	15000		
		Annual Cost		High	25000	50000		
Life Span (years)	20	3250						
Annual M&O Costs	2500	5000						
Lowest Benefit/Highest Cost	13		Average	18.8				
Highest Benefit/Lowest Cost	24.61538462		Rank	2				

RUN OFF ROAD COLLISIONS (7)

Note: cable barriers separated into roadside and median

	# of Doc.Ben.	Type	Severity	% Reduction	
Advance Curve Warning Signs	5	All	Injury	13	
Benefits	Benefit Range	Annual Cost Savings per Injury			
Low	0.05	5000		Cost	
High	0.13	13000		249.68	Supply of Signs, Aluminum - 3M Diamond Grade (VIP)
				0.36	Sign and tab buth 600x600
Capital Cost		Annual Capital Cost		64.67	Install Sign - Less than 1 m2
Low	450	90		170.92	Supply and Install Post (100mm X 150mm)
High	1200	240		415.3596	For sign, tab, post
		Annual Cost		830.7192	Assume 1 each direction
Life Span (years)	5	1090			
Annual M&O Costs	1000	1240			
Lowest Benefit/Highest Cost	4.032258065		Average	8	
Highest Benefit/Lowest Cost	11.9266055		Rank	4	

Cable Barriers	3	Run off Road	Fatal	44	roadside barrier
		Head-on	Injury	90	median barrier
ROADSIDE					
Benefits	Benefit Range	Annual Cost Savings per Injury			
Low	0.15	15000			
High	0.352	35200			
Capital Cost		Annual Capital Cost			
Low	22000	2200		Costs (/m)	
High	50000	5000		110	From AT RDG (base rate)
		Annual Cost		220	From AT RDG
Life Span (years)	10	4700		Assume 200m	(base rate+rocky+short+remote)
Annual M&O Costs	2500	7500			
Lowest Benefit/Highest Cost	2		Average	4.7	
Highest Benefit/Lowest Cost	7.489361702		Rank	7	
MEDIAN					
Benefits	Benefit Range	Annual Cost Savings per Injury			
Low	0.36	36000			
High	0.72	72000			
Lowest Benefit/Highest Cost	4.8		Average	10.1	
Highest Benefit/Lowest Cost	15.31914894		Rank	2	

Horizontal and Vertical Realignments	2	All	All	50% to 73%	
Benefits	Benefit Range	Annual Cost Savings per Injury			
Low	0.5	50000			
High	0.73	73000			
Capital Cost		Annual Capital Cost			
Low	75000	2500		LS Costs	
High	1000000	33333.33333		Low	75000
		Annual Cost		High	1000000
Life Span (years)	30	3500			
Annual M&O Costs	1000	34333.33333			
Lowest Benefit/Highest Cost	1.45631068		Average	11.2	
Highest Benefit/Lowest Cost	20.85714286		Rank	1	

Impact Attenuators	1	Fixed objects	Fatal	75	
Benefits	Benefit Range	Annual Cost Savings per Injury			
Low	0.35	35000			
High	0.75	75000			
Capital Cost		Annual Capital Cost			
Low	30000	3000		Costs (each)	
High	60000	6000		Low	15000
		Annual Cost		High	30000
Life Span (years)	10	5500			Assume 2 needed
Annual M&O Costs	2500	8500			
Lowest Benefit/Highest Cost	4.117647059		Average	8.9	
Highest Benefit/Lowest Cost	13.63636364		Rank	3	

Removal of Fixed Objects	3	All	Injury	30	
Benefits	Benefit Range	Annual Cost Savings per Injury			
Low	0.15	15000			
High	0.3	30000			
Capital Cost		Annual Capital Cost			
Low	100	3.333333333		LS Costs	New
High	1500000	50000		Low	100
		Annual Cost		High	1000000
Life Span (years)	30	2003.333333			
Annual M&O Costs	2000	52000			Retrofit
					500
Lowest Benefit/Highest Cost	0.288461538		Average	7.6	1500000
Highest Benefit/Lowest Cost	14.9750416		Rank	5	

Shoulder Rumble Strips	2	All	Injury	18	
Benefits	Benefit Range	Annual Cost Savings per Injury			
Low	0.1	10000			
High	0.18	18000			
Capital Cost		Annual Capital Cost			
Low	300	30		Costs	
High	600	60		701	Milled Rumble Strips (/km)
		Annual Cost		280.4	Assume 200m on each side of road
Life Span (years)	10	2530			
Annual M&O Costs	2500	2560			
Lowest Benefit/Highest Cost	3.90625		Average	5.5	
Highest Benefit/Lowest Cost	7.114624506		Rank	6	

Note: Benefits and Life-Cycle Costs for Centreline Rumble Strips to be determined at a later date

ROADWAY LINKS (6)

	# of Doc.Ben.	Type	Severity	% Reduction		
Delineator Posts	5	All	All	11		
Benefits	Benefit Range	Annual Cost Savings per Injury				
Low	0.05	5000				
High	0.11	11000				
				10	posts	Assume 200m curve with 20m spacing
Capital Cost		Annual Capital Cost				
Low	750	150		71.59	each	Flexible Guide Post/Delineators - Round - Supply and Install
High	1000	200		750	Round to $75/post for low cost	
		Annual Cost		1000	Use $100/post for High cost	
Life Span (years)	5	1150				
Annual M&O Costs	1000	1200				
Lowest Benefit/Highest Cost	4.166666667		Average	6.9		
Highest Benefit/Lowest Cost	9.565217391		Rank	5		

Edgelines and Centrelines	1	All	Injury	24		
Benefits	Benefit Range	Annual Cost Savings per Injury				
Low	0.1	10000				
High	0.19	19000		868.34	/km	Roadway Lines - Supplying Paint and Painting (Lane Dividing a
				843.93	/km	Roadway Lines - Supplying Paint and Painting (Directional Divid
Capital Cost		Annual Capital Cost				
Low	168.79	84.395				
High	516.12	258.06		843.93	/km	Assume 1 centreline for low cost
		Annual Cost		168.786		Assume 200m length
Life Span (years)	2	1584.395		2580.61	/km	Assume 2 edgelines and 1 centreline for high cost
Annual M&O Costs	1500	1758.06		516.122		Assume 200m length
Lowest Benefit/Highest Cost	5.688088006		Average	8.8		
Highest Benefit/Lowest Cost	11.99195908		Rank	2		

High-visibility Pavement Markings	0	All	Injury	24	*	
Benefits	Benefit Range	Annual Cost Savings per Injury				
Low	0.1	10000				
High	0.19	19000		1000	/km per line	
Capital Cost		Annual Capital Cost				
Low	200	100				
High	600	300		1000	/km	Assume 1 centreline for low cost
		Annual Cost		200		Assume 200m length
Life Span (years)	2	1600		3000	/km	Assume 2 edgelines and 1 centreline for high cost
Annual M&O Costs	1500	1800		600		Assume 200m length
Lowest Benefit/Highest Cost	5.555555556		Average	8.7		
Highest Benefit/Lowest Cost	11.875		Rank	3		

Increased Sign Retroreflectivity	1	All	All	25% to 42%		
Benefits	Benefit Range	Annual Cost Savings per Injury				
Low	0.25	25000				
High	0.42	42000				
				249.68	/sq.m	Supply of Signs, Aluminum - 3M Diamond Grade (VIP)
Capital Cost		Annual Capital Cost		0.67	sq.m	
Low	500	100		64.67	each	Install Sign - Less than 1 m2
High	1600	320		231.9556	$/installed sign	
		Annual Cost		170.92	post	Supply and Install Post (100mm X 150mm)
Life Span (years)	5	1100		463.9112	Retrofit (sign only, assume 2 needed)	
Annual M&O Costs	1000	1320		805.7512	New (sign and post, assume 2 each needed)	
Lowest Benefit/Highest Cost	18.93939394		Average	28.6		
Highest Benefit/Lowest Cost	38.18181818		Rank	1		

Linear Delineation Systems	0					
Benefits	Benefit Range	Annual Cost Savings per Injury				
Low	0.81	81000				
High	0.018	1800		Values entered to determine minimum values to get BCR=1		
Capital Cost		Annual Capital Cost				
Low	3000	300		Costs (based on Deerfoot Trail)		
High	800000	80000		Retrofit	15000	/km
		Annual Cost		(LDS only)	3000	/200m
Life Span (years)	10	1800		New	300000	/km
Annual M&O Costs	1500	81500		(LDS+barrier)	60000	/200m
Lowest Benefit/Highest Cost	0.993865031		Average	1		
Highest Benefit/Lowest Cost	1		Rank	n/a		

Wider Pavement Markings	1	All	Inj+Fat	20		
Benefits	Benefit Range	Annual Cost Savings per Injury				
Low	0.1	10000				
High	0.16	16000			1000	/km per line
Capital Cost		Annual Capital Cost				
Low	200	100		LS Costs (/km)		
High	600	300		Low	1000	Assume 1 centreline for low cost
		Annual Cost		High	200	Assume 200m length
Life Span (years)	2	1600			3000	Assume 2 edgelines and 1 centreline for high cost
Annual M&O Costs	1500	1800			600	Assume 200m length
Lowest Benefit/Highest Cost	5.555555556		Average	7.8		
Highest Benefit/Lowest Cost	10		Rank	4		

VUNERABLE ROAD USERS (3)

	# of Doc.Ben.	Type	Severity	% Reduction		
New or Upgraded Intersection Lighting	2	Ped	Inj	78		
Benefits	Benefit Range	Annual Cost Savings per Injury				
Low	0.39	39000				
High	0.78	78000				
Capital Cost		Annual Capital Cost		1962.1	each	Street Light Bases - Supply and Install
Low	1000	100		2856.71	each	Street Light Standard - Supply and Install
High	10000	1000		4818.81	each	Total New Cost
		Annual Cost		Retrofit costs are low for minor adjustments ($1000) to high for remove and replace ($10,000)		
Life Span (years)	10	2600				
Annual M&O Costs	2500	3500		Assume $200/yr for lighting and $300/year other maintenance		
Lowest Benefit/Highest Cost	11.14285714		Average	20.6		
Highest Benefit/Lowest Cost	30		Rank	1		

Pedestrian Countdown Signals	1	Ped	All	25	Assume all Injury	
Benefits	Benefit Range	Annual Cost Savings per Injury				
Low	0.15	15000				
High	0.25	25000				
Capital Cost		Annual Capital Cost			Cost (assume 2 needed)	
Low	800	80			400	/signal head
High	2000	200			100	/signal removal
		Annual Cost				
Life Span (years)	10	2080			800	New
Annual M&O Costs	2000	2200			1000	Retrofit (double for high cost)
Lowest Benefit/Highest Cost	6.818181818		Average	9.4		
Highest Benefit/Lowest Cost	12.01923077		Rank	2		

Wider Sidewalk or Paved Shoulder	1	Ped	All	65% to 89%	*	Assume all Injury
Benefits	Benefit Range	Annual Cost Savings per Injury				
Low	0.65	65000				
High	0.89	89000				
Capital Cost		Annual Capital Cost				Assume 1km long
Low	110000	11000		109.69	/m	Concrete Sidewalk (all widths)
High	500000	50000		16.34	/sq.m	Removing Concrete Surface
		Annual Cost				
Life Span (years)	10	13000			158710	Retrofit (assume 3m wide sidewalk to be replaced with 4m wide)
Annual M&O Costs	2000	52000			109690	New sidewalk
Lowest Benefit/Highest Cost	1.25		Average	4		
Highest Benefit/Lowest Cost	6.846153846		Rank	3		

APPENDIX C

BCR CALCULATIONS

Consistent Speed Limits

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.

Unknown CRF, so assume same as variable speed limits, as both aim to provide consistent speeds.

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

20% of all injuries

Step 2: Adjust average collision reduction factor

a) If “Alberta applicability rating” is *high*, no adjustment is required.
b) If “Alberta applicability rating” is *moderate*, reduce the value by 20%.

16% of all injuries (medium)
Stated as ‘high’ but reduced to ‘medium’ based on method of using VSL CRF.

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

10% - 16% of all injuries

Capital Costs

$250 (Retrofit) - $500 (Retrofit)

BCR

9.1 – 15.2

Gateway Treatments

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
   25% all injury collisions
   50% all serious injury/fatal collisions

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

   50% of all serious injury/fatal collisions

Step 2: Adjust average collision reduction factor

a) If "Alberta applicability rating" is *high*, no adjustment is required.
b) If "Alberta applicability rating" is *moderate*, reduce the value by 20%.

   50% of all serious injury/fatal collisions (high)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

   25% - 50% of all serious injury/fatal collisions

Capital Costs

$2,000 (New/Retrofit) - $500,000 (New/Retrofit)

BCR

0.5 – 18.5

Transverse Pavement Markings

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
   55% of all fatal and injury

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

   55% of all fatal and injury

Step 2: Adjust average collision reduction factor

a) If “Alberta applicability rating” is *high*, no adjustment is required.
b) If “Alberta applicability rating” is *moderate*, reduce the value by 20%.

   44% of all fatal and injury (moderate)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

   20% - 44% of all fatal and injury

Capital Costs

$800 (New) - $300,000 (New/Retrofit)

BCR

2.9 – 11.0

Variable Speed Limits

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
20% of all injuries

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

20% of all injuries

Step 2: Adjust average collision reduction factor

a) If "Alberta applicability rating" is *high*, no adjustment is required.
b) If "Alberta applicability rating" is *moderate*, reduce the value by 20%.

16% of all injuries (moderate*)

*will require legislative change to be enforceable. Unenforceable VSLs expected to be less effective.

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

10% - 16% of all injuries

Capital Costs

$1,000 (New) - $300,000 (New/Retrofit)

BCR

0.3 – 6.2

Advance Intersection Warning on Major Road

Benefits

Step 1: Select average collision reduction factor or range

e) Identify documented CRFs for injury / fatality collisions.
30% all rural intersection collisions

f) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
g) If Alberta-based or Canada-based, select it.
h) Otherwise, select most reliable CRF.

Assume 30% of all injury collisions

Step 2: Adjust average collision reduction factor

c) If “Alberta applicability rating” is *high*, no adjustment is required.
d) If “Alberta applicability rating” is *moderate*, reduce the value by 20%.

30% of all injury collisions (high)

Step 3: Establish collision reduction range

c) If a reasonable range is provided in literature, use it as a starting point.
d) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

15% - 30% of all injury collisions

Capital Costs

$150 (Retrofit) - $800 (New)

BCR

12.9 – 29.1

Conversion of Stop Controlled Intersection to a Roundabout

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
   18% - 72% of all collisions
   72% - 87% of all fatal and injury collisions

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

72% - 87% of all injury collisions

Step 2: Adjust average collision reduction factor

a) If "Alberta applicability rating" is *high*, no adjustment is required.
b) If "Alberta applicability rating" is *moderate*, reduce the value by 20%.

57.6% - 69.6% of all fatal and injury collisions (moderate)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

58% - 70% of all fatal and injury collisions

Capital Costs

$250,000 (Retrofit) - $500,000 (Retrofit)

BCR

2.1 – 4.5

Dedicated Left-turn Lanes on Major Road Approaches

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
   35% of rural fatal and injury intersection collisions
   29% of urban fatal and injury intersection collisions

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

29% - 35% of all fatal and injury

Step 2: Adjust average collision reduction factor

a) If “Alberta applicability rating” is *high*, no adjustment is required.
b) If “Alberta applicability rating” is *moderate*, reduce the value by 20%.

29% - 35% of all fatal and injury (high)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

29% - 35% of all fatal and injury

Capital Costs

$10,000 (New/Rural) - $100,000 (Retrofit/Urban)

BCR

3.9 – 11.7

Flashing Beacon on Stop Sign

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
   30% of failure to stop collisions

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

   Assume 30% of all injury collisions

Step 2: Adjust average collision reduction factor

a) If "Alberta applicability rating" is *high*, no adjustment is required.
b) If "Alberta applicability rating" is *moderate*, reduce the value by 20%.

   30% of all injury collisions (high)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

   15% - 30% of all injury collisions

Capital Costs

$500 (Retrofit) - $2000 (Retrofit)

BCR

8.8 – 19.4

Removal of Obstructions within Sight Triangle

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
   37% of injuries

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

   37% of all injuries

Step 2: Adjust average collision reduction factor

a) If “Alberta applicability rating” is *high*, no adjustment is required.
b) If “Alberta applicability rating” is *moderate*, reduce the value by 20%.

   37% of all injuries (high)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

   20% - 37% of all injuries

Capital Costs

$500 (New) - $500,000 (New/Retrofit)

BCR

>50

Transverse Rumble Strips

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
   28% of failure to stop collisions

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

   Assume 28% of all injury collisions

Step 2: Adjust average collision reduction factor

a) If "Alberta applicability rating" is *high*, no adjustment is required.
b) If "Alberta applicability rating" is *moderate*, reduce the value by 20%.

   22% of all injury collisions (moderate)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

   10% - 22% of all injury collisions

Capital Costs

$2,000 (New/Retrofit) - $6,000 (Retrofit)

BCR

2.7 – 7.6

Advance Intersection Warning Flashers

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
   18% of total collisions
   44% of all fatal and injury collisions

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

   44% of all injuries

Step 2: Adjust average collision reduction factor

a) If "Alberta applicability rating" is *high*, no adjustment is required.
b) If "Alberta applicability rating" is *moderate*, reduce the value by 20%.

   44% of all injuries (high)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

   20% - 44% of all injuries

Capital Costs

$1,500 (New/Retrofit) - $3,000 (New/Retrofit)

BCR

5.4 – 14.2

Conversion of Signalized Intersection to a Roundabout

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
   40% - 48% of all collisions
   78% of all fatal and injury collisions

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

78% injury collisions

Step 2: Adjust average collision reduction factor

a) If “Alberta applicability rating” is *high*, no adjustment is required.
b) If “Alberta applicability rating” is *moderate*, reduce the value by 20%.

62.4% of all injury collisions (moderate)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

30% - 62% of all fatal and injury collisions

Capital Costs

$275,000 (Retrofit) - $500,000 (Retrofit)

BCR

1.1 – 3.7

Dedicated Left-turn Lanes with Phasing

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
   58% all collisions

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

   Assume 58% of all injury collisions

Step 2: Adjust average collision reduction factor

a) If “Alberta applicability rating” is *high*, no adjustment is required.
b) If “Alberta applicability rating” is *moderate*, reduce the value by 20%.

   58% of all injury collisions (high)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

   30% - 58% of all injury collisions

Capital Costs

$15,000 (New) - $100,000 (Retrofit)

BCR

3.8 – 17.8

Positive Offset Left-turn Lanes

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
   20%-40% of left-turn across path injury/fatal collisions

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

20% - 40% of injuries

Step 2: Adjust average collision reduction factor

a) If "Alberta applicability rating" is *high*, no adjustment is required.
b) If "Alberta applicability rating" is *moderate*, reduce the value by 20%.

20% - 40% of injuries (high)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

20% - 40% of injuries

Capital Costs

$10,000 (Retrofit) - $100,000 (New/Retrofit)

BCR

2.5 – 11.4

Protected Only Left-turn Phase

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
 30% - 36% of all collisions
 16% of urban fatal and injury left-turn across path collisions
 19% of urban fatal and injury angle collisions

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

16% of injuries

Step 2: Adjust average collision reduction factor

a) If "Alberta applicability rating" is *high*, no adjustment is required.
b) If "Alberta applicability rating" is *moderate*, reduce the value by 20%.

16% of injuries (high)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

8% - 16% of injuries

Capital Costs

$300 (New) - $1,200 (Retrofit)

BCR

3.1 – 6.4

Removal of Unwarranted Traffic Signals

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
   53% of urban fatal and injury collisions
   25% of all urban collisions

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

53% of all injuries

Step 2: Adjust average collision reduction factor

a) If "Alberta applicability rating" is *high*, no adjustment is required.
b) If "Alberta applicability rating" is *moderate*, reduce the value by 20%.

53% of all injuries (high)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

25% - 53% of all injuries

Capital Costs

$2,000 (Retrofit) - $6,500 (Retrofit)

BCR

20.5 – 49.7

Signal Backboards

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
   32% of right-angle collisions

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

   Assume 32% of all injury collisions

Step 2: Adjust average collision reduction factor

a) If "Alberta applicability rating" is *high*, no adjustment is required.
b) If "Alberta applicability rating" is *moderate*, reduce the value by 20%.

   32% of all injury collisions (high)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

   15% - 32% of all injury collisions

Capital Costs

$500 (New/Retrofit) - $5,000 (Retrofit)

BCR

5.6 – 20.6

Smart Right-turn Channel

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
   65% - 80% of all collisions
   No documented CRF, values based on recent Edmonton experience.

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

65% - 80% of all injury collisions

Step 2: Adjust average collision reduction factor

a) If “Alberta applicability rating” is *high*, no adjustment is required.
b) If “Alberta applicability rating” is *moderate*, reduce the value by 20%.

65% - 80% of all injury collisions (high)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

65% - 80% of all injury collisions

Capital Costs

$15,000 (New/Retrofit) - $50,000 (Retrofit)

BCR

13.0 – 24.6

Advance Curve Warning Signs

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
   10% reduction (all fatal and injury collisions, sign only)
   29% reduction (all head-on collisions, sign only)
   30% (all ROR collisions, sign only)
   13% reduction (all injury collisions, sign with advisory speed tab)
   30% reduction (all collisions, sign with advisory speed tab or flashing beacon)
b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

13% all injuries collisions (sign with advisory speed tab)

Step 2: Adjust average collision reduction factor

a) If "Alberta applicability rating" is *high*, no adjustment is required.
b) If "Alberta applicability rating" is *moderate*, reduce the value by 20%.

13% of all injuries (high)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

5% - 13% of all injuries

Capital Costs

$425 (New/Retrofit) - $600 (New/Retrofit)

BCR

4.0 – 11.9

Cable Barriers

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
44% reduction of run-off-road fatal collisions (roadside guardrail)
90% reduction of head-on injury collisions (median barrier)
91% reduction of head-on fatal collisions (median barrier)
b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.
44% reduction of run-off-road fatal collisions (roadside guardrail)
*assume fatal is injury
90% reduction of head-on injury collisions (median barrier)

Step 2: Adjust average collision reduction factor

a) If "Alberta applicability rating" is *high*, no adjustment is required.
b) If "Alberta applicability rating" is *moderate*, reduce the value by 20%.

35.2% reduction of run-off-road injury collisions (roadside)
72% reduction of head-on injury collisions (median)
(moderate)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.
Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.
The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

15% - 35% reduction of run-off-road injury collisions (roadside)
36% - 72% reduction of head-on injury collisions (median)

Capital Costs

$110/m (New/Retrofit) - $250/m (Retrofit)

BCR

2.0 – 7.5 (roadside) 4.8 – 15.3 (median)

Horizontal and Vertical Realignments

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
   73% all collisions along curve
   50% all collisions along curve

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

Assume 50% - 73% of all collisions

Step 2: Adjust average collision reduction factor

a) If "Alberta applicability rating" is *high*, no adjustment is required.
b) If "Alberta applicability rating" is *moderate*, reduce the value by 20%.

50% - 73% of all injury collisions (high)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

50% - 73% of all injury collisions

Capital Costs

$75,000 (Retrofit) - $1,000,000 (Retrofit)

BCR

1.5 – 20.9

Impact Attenuators

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
75% of fatal collisions with fixed object

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

75% of fatal collisions with fixed object
*assume fatal is injury

Step 2: Adjust average collision reduction factor

a) If "Alberta applicability rating" is *high*, no adjustment is required.
b) If "Alberta applicability rating" is *moderate*, reduce the value by 20%.

75% of injury collisions with fixed object (high)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

35% - 75% of injury collisions with fixed object

Capital Costs

$15,000 (New/Retrofit) - $30,000 (Retrofit)

BCR

4.1 – 13.6

Removal of Fixed Objects

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
   50% of all fatal collisions
   30% of all injury collisions
   88% of fixed object collisions

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

30% of all injuries

Step 2: Adjust average collision reduction factor

a) If “Alberta applicability rating” is *high*, no adjustment is required.
b) If “Alberta applicability rating” is *moderate*, reduce the value by 20%.

30% of all injuries (high)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

15% - 30% of all injuries

Capital Costs

$100 (New) - $1,500,000 (Retrofit)

BCR

0.3 – 15.0

Shoulder Rumble Strips

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
   18% of all injury collisions
   26% reduction (Off road right collisions)

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

   18% of all injuries

Step 2: Adjust average collision reduction factor

a) If “Alberta applicability rating” is *high*, no adjustment is required.
b) If “Alberta applicability rating” is *moderate*, reduce the value by 20%.

   18% of all injuries (high)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

   10% - 18% of all injuries

Capital Costs

$1,500 (New) - $3,000 (Retrofit)

BCR

3.9 – 7.1

Delineator Posts

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
   11% of all collisions
   67% of head-on collisions
   67% of sideswipe collisions
   34% of ROR collisions
   25% of night-time collisions

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

   Assume 11% of all injuries

Step 2: Adjust average collision reduction factor

a) If "Alberta applicability rating" is *high*, no adjustment is required.
b) If "Alberta applicability rating" is *moderate*, reduce the value by 20%.
   11% of all injuries (high)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

   5% - 11% of all injuries

Capital Costs

$75 (New/Retrofit) - $100 (New/Retrofit)

BCR (assuming 10 posts required)

4.2 – 9.6

Edgelines and Centrelines

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
   24% of all injury collisions

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

24% of all injury collisions

Step 2: Adjust average collision reduction factor

a) If "Alberta applicability rating" is *high*, no adjustment is required.
b) If "Alberta applicability rating" is *moderate*, reduce the value by 20%.

19% of all injury collisions (moderate)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

10% - 19% of all injury collisions

Capital Costs (assuming 200m length)

$850 (New/Retrofit) - $2,600 (New/Retrofit)

BCR

5.7 – 12.0

High-visibility Pavement Markings

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
   24% of injury collisions

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

24% of injury collisions

Step 2: Adjust average collision reduction factor

a) If "Alberta applicability rating" is *high*, no adjustment is required.
b) If "Alberta applicability rating" is *moderate*, reduce the value by 20%.

19% of injury (moderate)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

10% - 19% of injury

Capital Costs (assuming 200m length)

$1,000 (New/Retrofit) - $3,000 (New/Retrofit)

BCR

5.6 – 11.9

Increased Sign Retroreflectivity

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
   25% - 42% of all collisions

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

Assume 25% - 42% of all injuries

Step 2: Adjust average collision reduction factor

a) If "Alberta applicability rating" is *high*, no adjustment is required.
b) If "Alberta applicability rating" is *moderate*, reduce the value by 20%.

25% - 42% of all injuries (high)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

25% - 42% of all injuries

Capital Costs (per sign, assume 2 required)

$250 (Retrofit) - $800 (New)

BCR

18.9 – 38.2

Linear Delineation Systems

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
No documented injury collision reductions found.

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

Step 2: Adjust average collision reduction factor

a) If "Alberta applicability rating" is *high*, no adjustment is required.
b) If "Alberta applicability rating" is *moderate*, reduce the value by 20%.

Alberta applicability rated as "high."

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

Capital Costs

$15,000 (Retrofit) - $300,000 (New-includes barrier installation)

BCR

BCR=1.0 for installations on existing barriers if injury reduction is 1.8% (assumed to be much higher)
BCR=1.0 for installations on new barriers if injury reduction is 81%

Wider Pavement Markings

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
   20% of all injury and fatal collisions

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

   20% of all injuries

Step 2: Adjust average collision reduction factor

a) If “Alberta applicability rating” is *high*, no adjustment is required.
b) If “Alberta applicability rating” is *moderate*, reduce the value by 20%.

   16% of all injuries (moderate)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

   10% - 16% of all injuries

Capital Costs

$1,000 (New/Retrofit) - $3,000 (New/Retrofit)

BCR

5.6 – 10.0

New or Upgraded Intersection Lighting

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
   78% of pedestrian injury collisions

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

78% of pedestrian injury collisions

Step 2: Adjust average collision reduction factor

a) If "Alberta applicability rating" is *high*, no adjustment is required.
b) If "Alberta applicability rating" is *moderate*, reduce the value by 20%.

78% of pedestrian injury collisions (high)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

39% - 78% of all injuries

Capital Costs

$5,000 (Retrofit) - $7,000 (Retrofit)

BCR

11.1 – 30.0

Pedestrian Countdown Signals

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
    25% of all pedestrian collisions

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
    Assume all pedestrian collisions are injury collisions

c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

    25% of all pedestrian collisions

Step 2: Adjust average collision reduction factor

a) If "Alberta applicability rating" is *high*, no adjustment is required.
b) If "Alberta applicability rating" is *moderate*, reduce the value by 20%.

    25% of all pedestrian collisions (high)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

    15% - 25% of all pedestrian collisions

Capital Costs

$800 (New) - $2,000 (Retrofit)

BCR

6.8 – 12.0

Wider Sidewalk or Paved Shoulder

Benefits

Step 1: Select average collision reduction factor or range

a) Identify documented CRFs for injury / fatality collisions.
   65% -89% of all pedestrian collisions

b) Where available, focus on the CRFs for all injuries (as opposed to the specific collision types). If injury unavailable, refer to new HSM.
   Assume all pedestrian collisions are injury collisions

c) If Alberta-based or Canada-based, select it.
d) Otherwise, select most reliable CRF.

65% -89% of all pedestrian collisions

Step 2: Adjust average collision reduction factor

a) If "Alberta applicability rating" is *high*, no adjustment is required.
b) If "Alberta applicability rating" is *moderate*, reduce the value by 20%.

65% -89% of all pedestrian collisions (high)

Step 3: Establish collision reduction range

a) If a reasonable range is provided in literature, use it as a starting point.
b) Otherwise, establish range based on land use and speed context, as follows:

The quoted CRF will represent the high end of the range, under the assumption that it represents proper context-sensitive application.

Divide the CRF by 2 to get the low end of the range, to reflect randomness, uncertainty and application in less appropriate conditions. Round to the nearest 5%.

The upper end of the range represents the likely collision reduction within the applicable land use and speed categories.

65% -89% of all pedestrian collisions

Capital Costs

$110 (New/metre) - $500 (Retrofit/metre)

BCR (based on length of 1km)

1.3 – 6.8

OPUS

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