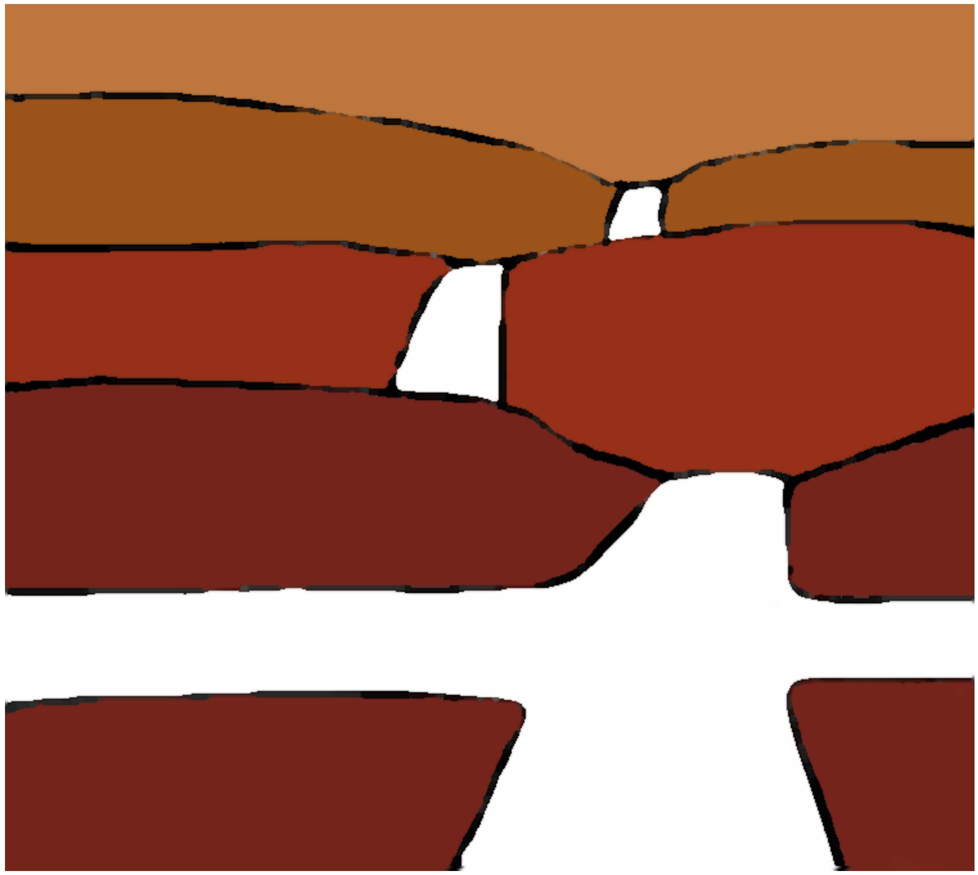

Rural Intersection Safety Handbook

MRC delphi

Transport Canada

Rural Intersection Safety Handbook

Final Report

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Disclaimer

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Contents

-continued

Executive Summary

The Rural Intersection Safety Handbook provides practical and concrete guidance for diagnosing rural intersection safety problems and selecting and implementing appropriate and practical solutions thereto on a case-by-case basis. Intersections are among the most hazardous components of the road. Though seemingly just points along the way, they witness an inordinate percentage of collisions, property damage and fatalities. Between 1995 and 1999, intersection crashes accounted for nearly 22 percent of fatalities on rural roads, and about 28 percent of serious injuries in these crashes.

Transport Canada has established a road safety vision for Canada. By 2010 it intends that Canada will meet road safety targets that make our roads the safest in the world. Launched in 1996 and renewed in 2000, this Road Safety Vision is supported by all levels of government and key public and private sector stakeholders. Among many lines of attack to improving road safety in Canada, the present document represents one of the key tools that Transport Canada has funded to help practitioners address the problem - particularly in rural districts.

While using this handbook will not solve the whole challenge of improving rural highway safety, and will not directly address many of the problems associated with driver behaviour, it is clear that the kinds of improvements contained in the handbook can save lives. That is the purpose of this handbook – to give practitioners the tools to make intersections safer.

The handbook is presented in two parts (all between the same covers). The first, the Introduction, provides a helpful background to the problem and the approach to evaluating intersection safety solutions. It provides statistics that may be of use to practitioners in making the case for new expenditures or to highlight the need for changes to decision-makers. The Introduction also provides guidance on how to use the handbook. The central feature of the handbook is a cost-effectiveness assessment for each road safety solution itemized in the book, designed to quickly aid the practitioner in selecting appropriate measures for their needs. There is also a discussion on risk management tailored to the problem of very low-volume rural roads.

The second part of the handbook is a series of Situation Sheets that are designed to quickly guide the practitioner in identifying the particular type of problem being experienced, the likely causes of that problem, and candidate solutions for its resolution. Virtually all the Situation Sheets (there are 23 topics in total) are formatted the same: they contain a Background discussion, Problem statements, Solutions, an Effectiveness table, and Additional Information including cross references and sources of further technical guidance. A brief summary of each topic is also provided. Each sheet is illustrated by photographs and/or drawings to illustrate or expand concepts contained in the text.

For ease of navigation, the Situation Sheets are categorized into five sections: Intersection Layout; Visibility; Signs, Signals and Pavement Markings; Rail crossings; and Usability. These categories, and the individual topics covered, were identified through consultation with various provincial agencies across Canada to ensure that the information presented is truly reflective of real-world problems. The handbook concludes (in Appendix A) with an Intersection Safety checklist that can be used as a diagnostic tool which will aid in navigating to the proper section for advice.

Sommaire

Le guide intitulé Rural Intersection Safety Handbook donne des conseils pratiques et concrets pour poser un diagnostic sur les problèmes de sécurité aux intersections rurales et pour mettre en œuvre des solutions appropriées et pratiques adaptées à chaque cas. Les intersections sont parmi les composants les plus dangereux des routes. Même si elles peuvent sembler n'être que des points le long de la route, c'est là que se produisent les plus forts pourcentages de collisions entraînant des dommages matériels et des décès. De 1995 à 1999, les collisions survenues aux intersections ont causé près de 22 p. cent des décès sur les routes rurales et environ 28 p. cent des blessures graves.

Transports Canada a créé une vision de sécurité routière pour le Canada. Transports Canada voudrait que d'ici 2010, le Canada atteigne des objectifs en matière de sécurité routière qui rendront les routes canadiennes les plus sûres au monde. Lancée en 1996 et renouvelée en 2000, la Vision sécurité routière est appuyée par tous les ordres de gouvernement et par tous les intervenants importants des secteurs public et privé. Parmi les nombreuses stratégies visant à améliorer la sécurité routière au Canada, le présent document est l'un des principaux outils financés par Transports Canada pour aider les praticiens à résoudre le problème, en particulier dans les régions rurales.

Même si l'utilisation de ce guide ne permettra pas de relever tous les défis de la sécurité routière sur les routes rurales, et même si elle ne résoudra pas directement les nombreux problèmes liés au comportement des conducteurs, il ne fait aucun doute que les améliorations qui y sont suggérées peuvent sauver des vies. C'est l'objectif de ce guide – donner aux praticiens les outils nécessaires pour rendre les intersections plus sûres.

Le guide comporte deux parties, sous la même couverture. La première, l'introduction, présente clairement l'état de la situation et explique l'approche adoptée pour évaluer les solutions pour rendre les intersections plus sûres. Elle renferme des statistiques qui peuvent être utiles aux praticiens comme argument en faveur de nouvelles dépenses ou pour souligner aux décideurs le besoin de changement. L'introduction explique en outre comment utiliser le guide. Son principal élément est une évaluation du rapport coût-efficacité de chaque solution suggérée dans le cahier, évaluation qui peut être consultée rapidement et aider les praticiens à choisir les mesures les plus appropriées à leurs besoins. On y trouve aussi une discussion de la gestion du risque adaptée au problème des routes rurales à très faible circulation.

La seconde partie du guide est un ensemble de feuillets d'exemples conçus pour aider les praticiens à repérer rapidement le type précis de problème à régler, les causes probables de ce problème et des solutions potentielles. Presque tous les feuillets (en tout, 24 situations sont traitées) se présentent de la même façon : ils contiennent une discussion de l'état de la situation, la description du problème, des suggestions de solutions, un tableau sur l'efficacité et des renseignements additionnels, notamment des références et des sources de renseignements techniques. On y trouve également un bref résumé de chaque sujet. Chaque feuillet comporte des photographies ou des schémas illustrant ou expliquant les données du texte.

Pour faciliter la consultation, les feuillets d'exemples sont divisés en cinq sections : disposition de l'intersection; visibilité; panneaux indicateurs, signaux et dessins sur la chaussée; traverses à niveau; facilité d'utilisation. Ces catégories et les sujets individuels abordés ont été déterminés par des consultations avec diverses organisations de toutes les provinces du Canada pour s'assurer que l'information présentée reflète des problèmes réels. Le guide offre également, à l'Annexe A, une liste de contrôle sur la sûreté des intersections, laquelle peut être utilisée comme outil de diagnostic et aider à repérer la section où se trouve le conseil recherché.

Introduction

Background and Purpose

Between 1995 and 1999, intersection crashes accounted for nearly 22 percent of fatalities on rural roads, and about 28 percent of serious injuries in these crashes (Transport Canada Road Safety Directorate, Spring 2005). While it will not solve the whole problem, it is clear that safety improvements at rural intersections can play an important role in saving lives. That is the purpose of this handbook – to give practitioners the tools to make intersections safer.

Number of Collisions by Location

	Fatal	Personal Injury
Urban [1]	936	110,511
Rural [2]	1,539	41,639
Not stated	21	2,075
Total	**2,496**	**154,225**

1 Urban includes (a) metropolitan roads and streets and other urban areas, or (b) a speed limit at the collision site of 60 km/h or less.

2 Rural includes (a) primary or secondary highways, as well as local roads, or (b) a speed limit at the collision site exceeding 60 km/h.

Source: Transport Canada, *Canadian Motor Vehicle Traffic Collision Statistics: 2003*, October 2004

The table at left illustrates one of the principal differences between crashes on rural and urban roadways in Canada: there is a higher proportion of fatalities in rural crashes than in urban crashes. This is a function of speed: while traffic volumes tend to be lower on rural highways, speeds are higher and, as a result, rural highway collisions are often catastrophic in nature.

Other statistics in this introductory section help to illustrate the serious need and benefits of improving safety at rural intersections. Noteworthy are those that relate to alcohol abuse and seatbelt use. Engineers and highway managers cannot dictate the way people behave, but our improving understanding of human behavior has led to an understanding that the roadside and intersections need to be more forgiving and that there needs to be ample warning of impending danger zones. As a result, you will see that many of the solutions offered in this handbook focus on improving the clear zone, traffic controls and warnings. These are often very cost-effective solutions that most agencies can implement with relative ease.

In planning this handbook, a survey was conducted among several Canadian municipal and provincial road agencies with the intent of learning what kinds of information were lacking with respect to the road safety engineering aspects of rural intersection improvement and design. The survey indicated that to date there has been a historic reliance on geometric design and traffic control documents to guide efforts; however respondents also pointed out that these documents do not usually offer much information on road safety considerations and are often specifically written for design and traffic operations specialists. As such, their value to the non-specialist technical individual seeking guidance on how to deal with a specific rural intersection road safety challenge was often found to be minimal.

At the time of the interviews (2005), it was clear that the vast majority of respondent agencies practise a pragmatic and somewhat subjective approach to road safety decisions associated with rural intersections, and – with one exception[1] – have few formal procedures or guidance documents to prioritize, select, or evaluate their countermeasure actions. The purpose of this document is to help fill this important existing knowledge gap.

1. The Province of Alberta has documented a formal approach to countermeasure prioritization, however this process appears to follow a more pragmatic approach to addressing safety issues.

Handbook Organization and Format

The survey, and the associated discussions held with users, indicated that there appeared to exist a substantive need for such a road safety handbook dedicated specifically to rural intersections, and that its guidance should focus on providing practical information for the non-specialist.

In their discussions of specific technical needs, the respondents identified a range of safety problems that were grouped into four common subject areas:

- Geometric design and intersection layout;

- Visibility or conspicuity at or approaching an intersection;
- Traffic control devices at rural intersections; and
- General usability and safety issues that do not fall into the previous subject areas.

This handbook is organized along these four subject areas, with an additional section on rail crossings. The format of its content reflects the survey participants' views that such a document must provide practical advice, have a user-friendly layout, and provide accessible information for the target audience without the extensive use of technical terms.

Rural intersection dangers in Canada

- Percentage of fatally injured drivers aged 65 or older: 25.2%
- Incidence of fatally injured older drivers (65+ years) who were driving improperly prior to the collision: 77.3%
- Incidence of drivers that were killed who committed driving infractions prior to the collision: 62.1%
- Incidence of drivers seriously injured who committed driving infractions prior to the collision: 50.3%
- Incidence of alcohol use among fatally injured drivers: 15.9%
- Non-use of seat belts among fatally injured drivers: 31.8%
- Incidence of driver fatalities with no traffic controls present: 44.0%
- Incidence of serious injuries with no traffic controls present: 49.8%
- Incidence of drivers killed in intersection collisions where the roads were curved: 19.6%
- Percentage killed while making a left turn: 19.0%
- Percentage seriously injured while making a left turn: 14.4%

Source: *Rural Road Safety in Canada: Traffic Collision Trends and Recommended Strategies (Draft)*, Road Safety Directorate, Transport Canada, Spring 2005

The Need for Ongoing Safety Performance Monitoring

Transport Canada funded the preparation of this handbook, and in its mandate for the work it noted the importance of ongoing safety performance evaluation and monitoring. While respondents to our survey reacted favourably to the concept of ongoing performance monitoring programs, very few said they had the funds to carry out such evaluations. It thus appears that the success of any national-level monitoring and evaluation program will require careful coordination by one central body, possess a user-driven approach to the design of its specific organization and logistics, and offer some means of funding participation from key agencies.

We trust that readers and practitioners will find the handbook valuable as they carry out their work and that the insights offered will assist them in implementing better and more timely solutions within their respective jurisdictions.

How to Use This Handbook

The handbook consists of a series of Situation Sheets focusing on key problem areas typically encountered at rural Canadian intersections, as discussed above. Each Situation Sheet is cross-referenced to other sheets as appropriate, and specific references are noted.

The Situation Sheet format is intended to allow the user to easily access information on a specific problem area without having to wade through unrelated data. However, it is recommended that you read the document in its entirety at least once to understand the scope of the contents and their organization. This will allow you to make more effective use of the handbook on an as-needed basis.

Each Situation Sheet is formatted in the same manner and consists of one to three pages, depending on the content. The sheet begins with a brief introductory section called Background. A Summary statement is also included on the front page, and this is followed by discussions of Problems and Solutions. This information is generally presented in point form. Photographs and illustrations are used where deemed appropriate to better communicate or amplify the ideas in the text.

Following the Solutions is a table with the title Effectiveness. This presents the solutions in terms of their effectiveness to address the problems. Effectiveness is measured in potential collision reduction that a solution may achieve. The source(s) of the effectiveness rates are noted in the first column. An assessment of the solution's cost effectiveness is also included, and the solutions are ranked (see a discussion of the assessment methodology on the next page).

At the end of each Situation Sheet, a section called Additional Information will typically provide a list of cross-references and specific references used in the Situation Sheet. A general Bibliography is offered at the end of the document.

The handbook concludes with an Intersection Safety Checklist (Appendix A). This is intended to allow the user to analyze specific intersections and quickly determine the most appropriate Situation Sheet(s) for a given situation.

Target audience

This handbook is intended to provide practical information for the non-specialist working in the field of road safety, road maintenance and infrastructure management. It is intended to be of use at the municipal, township, district and provincial levels of government.

Professional engineers working in the field of road safety are likely to find it of value, especially in the ease of access to information on countermeasure effectiveness.

Cost - Effectiveness Assessment

Road safety solutions are most commonly selected based on their cost effectiveness, and the goal of this handbook has been to put forward countermeasures that are relatively low cost or easy to implement and that would ideally allow programs to be put in place quickly. Cost effectiveness is a function of the solution cost (capital and operations) and the collision reduction that will potentially result from the solution implementation. The Situation Sheets therefore include an indication of the cost effectiveness of each solution, based on the criteria set out in Table 1. The following cost structure was used to develop the cost-effectiveness estimates:

- Low Cost: Often general maintenance activities such as signage and minor roadside upgrades can be accomplished for less than $10,000.
- Medium Cost: Localized intersection lane widening, overhead lighting and traffic signal installation can usually be achieved within a budget of $250,000 per item. However, depending on the location, a combination of activities such as lane widening and signal installation would likely cost more than $250,000.
- High Cost: Items such as road realignments (including roundabouts), and flattening curves would fall into the high-cost category. In addition, some solutions such as removing obstructions could range from very low (cutting back overgrown vegetation) to high cost (purchase and removal of a structure).

The collision reduction is scaled low (0 to 19 percent), medium (20 to 39 percent) and high (40 percent or more), based on an objective review of the published results. The following table indicates how the cost-effectiveness estimates were developed. As you will note, some solutions, while highly effective at reducing collisions, have low-cost effectiveness because they are too costly. Alternatively, some low-cost solutions eliminate relatively low numbers of collisions but may score well as a result of the relatively good rate of return for the amount expended. This indicates that small measures should not be ignored. They can be effective in their own right, or may be considered as staged measures prior to major expenditures on an ultimate solution.

Often the lists of solutions presented in the handbook can be quite extensive and may include countermeasures that duplicate each other, and in some cases ones that – if implemented simultaneously – could be counterproductive. In addition, we can expect that a number of specific factors related to the context of the site under consideration may limit the feasibility of some solutions. In order to address these issues we have attempted to identify options that have the potential to be productive and counterproductive. Productive measures have shown overall improvements in collision reduction in the literature; counterproductive measures are those that showed a net increase in collisions according to the studies referenced.

Cost-Effectiveness Evaluation Methodology

Table 1: **Cost-Effectiveness Evaluation.**

The estimated costs in the table include the implementation or installation of the countermeasure only. They do not include ongoing maintenance costs. In addition, the collision reduction effectiveness estimates only consider reduction in collisions and not reductions in collision severity.

COST		MOST LIKELY COLLISION REDUCTION (%)		
		Low	Medium	High
		0-19	20 - 39	40 plus
Low	0 to $10,000	Medium	High	High
Medium	$10,000 to $250,000	Low	Medium	High
High	$250,000 and over	Low	Low	Medium

Older Drivers

One finding in the Transport Canada Road Safety Directorate study (Spring 2005) was the large percentage of fatally injured drivers who were 65 years of age or older (one quarter of all fatalities). This is a considerable over-representation considering that this age group accounts for slightly more than 12 percent of the population and of licensed drivers.

The study also found that an extremely high incidence (more than three quarters) of fatally injured older drivers were driving improperly prior to the collision.

Cognitive facilities deteriorate as human beings age. Obviously, this may have a detrimental effect on driver performance (see note at left). This is an emerging problem as the 'Baby Boomer' generation comes to retirement age now and over the next 20 years or more. Therefore, where appropriate, we include items to be of particular relevance when considering improvements in your area. These notes are identified by a symbol [▼]. Most of our guidance in this respect has been taken from the Federal Highways Administration volume, *Highway Design Handbook for Older Drivers and Pedestrians*

Risk Management on Low-volume Roads

This handbook considers all types of rural intersections other than freeway interchanges. Among the most common rural intersections are those with very low volumes. Low-volume roads and intersections represent a special case on the road network. Generally defined as facilities carrying Average Annual Daily Traffic (AADT) volumes of less than 400 vehicles, these facilities have such low volumes and low numbers of collisions that reliable statistical analysis of collisions is often impossible. In such instances, a risk management approach to the prioritization and selection of road safety solutions is often appropriate.

The American Association of State Highway and Transportation Officials (AASHTO) provide an excellent discussion of low-volume road facilities in their publication entitled *Guidelines for Geometric Design of Very Low Volume Local Roads* (2001). In that document they point out that for low-volume road situations the development of specific design guidelines is carried out through a risk assessment approach. They further note that their recommended approach to design choices in such situations reduces to a trade-off between "demonstrable differences in construction and maintenance costs" and "the estimated impacts on traffic crash frequency or severity."

This statement further underlines the fact that in these circumstances and under very low-volume conditions, considerations of level of service, travel time savings, driver comfort, and convenience are not relevant, since the basic trade-off involves road safety. In using the AASTHO approach for the design of new very low-volume road intersections, there is a tacit acceptance of the fact that risks in specific instances might be somewhat higher than would be the case for design under the regular AASTHO Green Book Guidelines, but that at the network level the margins of safety on those low-volume roads would be comparable to those achievable in the regular AASHTO Geometric Design Guidelines.

While the traditional (non low-volume) geometric design approach is normally based on the fact that design decisions consider some measure of cost effectiveness, the literature in general – and the AASHTO *Low-volume road Guidelines* in particular – stress the fact that in very low volume road situations, historical collisions statistics alone do not provide a sufficient basis for remedy. This is simply due to the fact that collisions are rare events on low volume roads; therefore to suggest that the collision history on such a facility could properly represent the risk that users face will generally be incorrect.

In reality, cost-effectiveness considerations may not be the sole relevant criteria for a decision to implement a specific countermeasure. Rather, the presence of a risk situation that has a significant potential to result in a very severe injury or fatal outcome may justify action, even in the absence of either significant traffic volumes or any collision history. AASHTO specifically advises that investigators considering road safety countermeasures in any given situation may – in the course of their field review – wish to consider such additional risk indicators as:

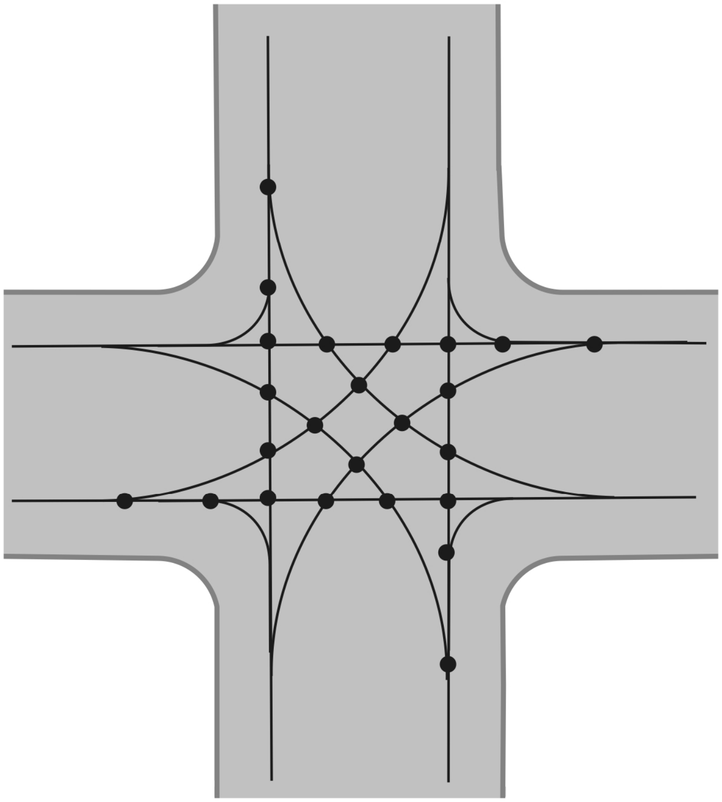
- Skid marks;
- Roadside damage to ditches, vegetation and so forth;
- Scrape or paint marks on roadside barriers;
- Speed data; or
- Concerns raised by police or local residents.

Guidelines in this respect are non-specific, and perhaps the best advice comes from the following excerpt from the AASHO *Low-volume road Guidelines*:

> *The guidelines encourage the designer to exercise engineering judgment based on a thorough knowledge of the principles of highway design, traffic engineering, and highway safety engineering and specific knowledge of local conditions (p. 16).*

Intersection Conflicts

Intersections are natural points of conflict in our road systems. Understanding the specific nature of the conflicts that occur and how they may affect safety is essential to the selection of appropriate solutions and countermeasures. The following drawings illustrate some key points in understanding intersection conflicts. They show, first, how the number of crossing paths at intersections are directly related to conflict points. Generally speaking, the fewer the conflict points, the lower the probability of collisions. Figure 1 and 2 show the conflict areas where collisions typically occur. Figure 3 shows the relative speeds at intersections, which is directly related to crash severity. Together, these drawings should provide a better level of understanding of the links between road geometry and crash frequency and severity.



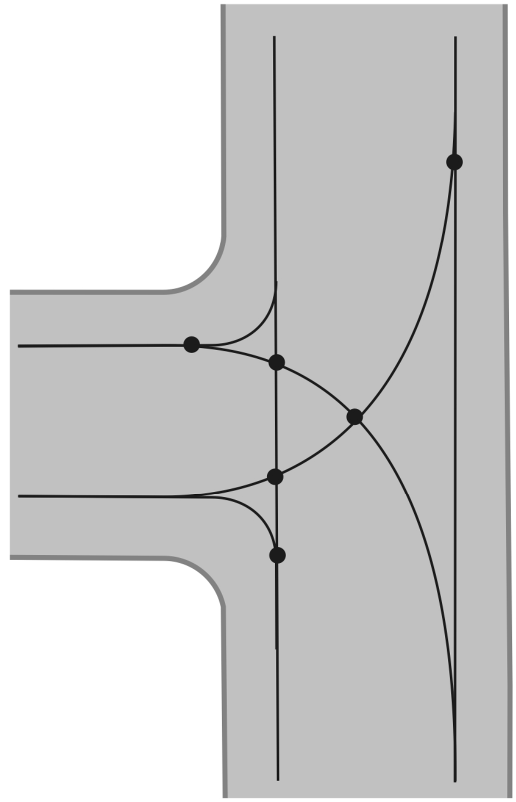
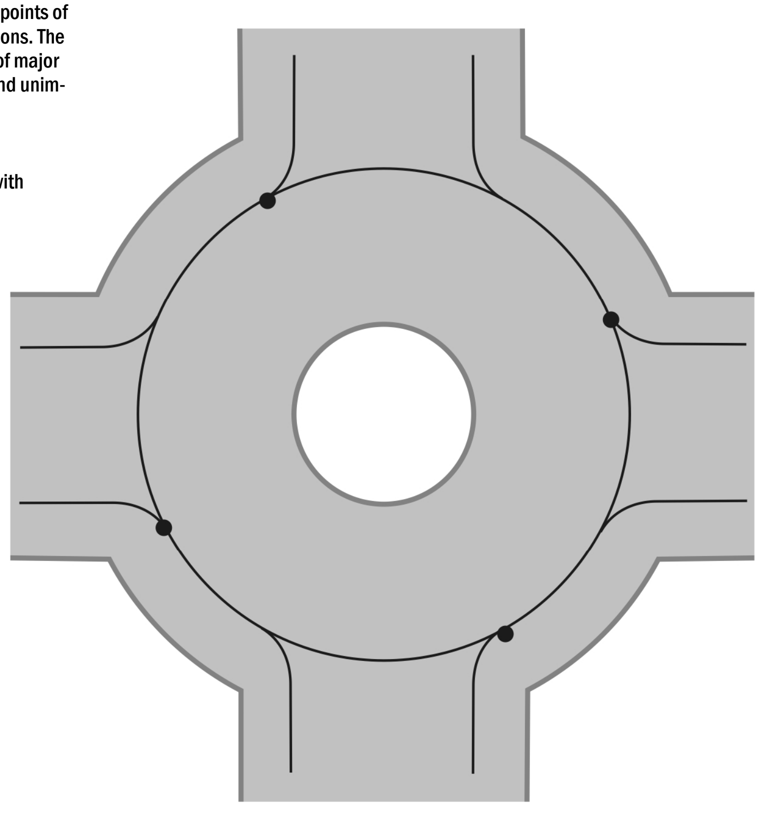


Figure 1: Conflict Points. The conventional four-way intersection is the most common major rural intersection type. T-intersections (upper right) are the most common when driveways are included. Four-way intersections have 24 points of major conflict compared with just 6 for T-intersections. The modern roundabout, in contrast, has just 4 points of major conflict. This is achieved by eliminating left turns and unimpeded through movements.

Not shown in these drawings are minor merging and diverging conflict points or conflicts with vulnerable road users.



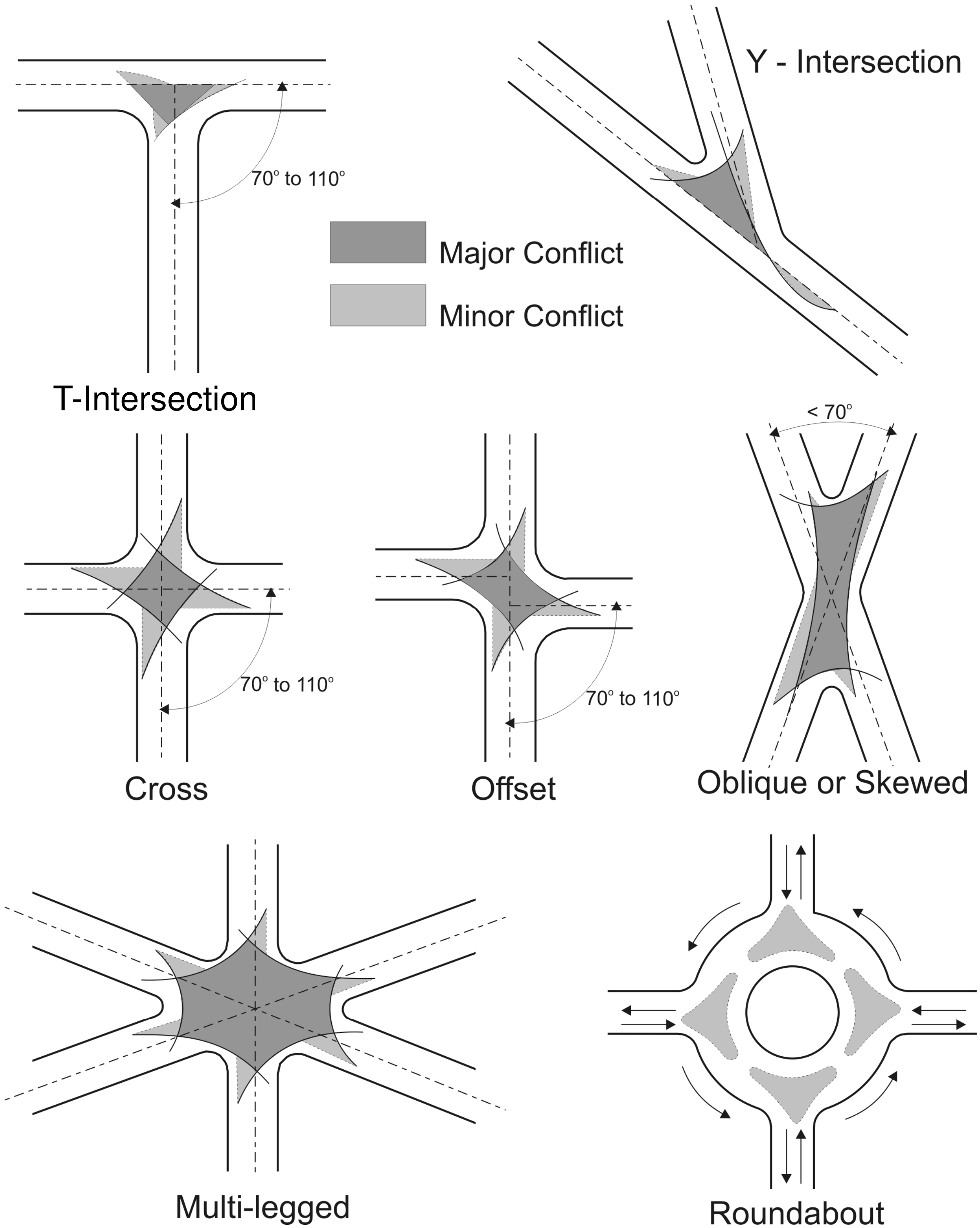


Figure 2: Conflict Areas at Intersections. This figure illustrates areas of traffic conflict for different intersection configurations. Note that right-angle T- and cross intersections have the smallest conflict areas when compared to skewed, multi-legged or offset intersections. Adapted from TAC, *Geometric Design Guide for Canadian Roads* (Part 2), 1999.

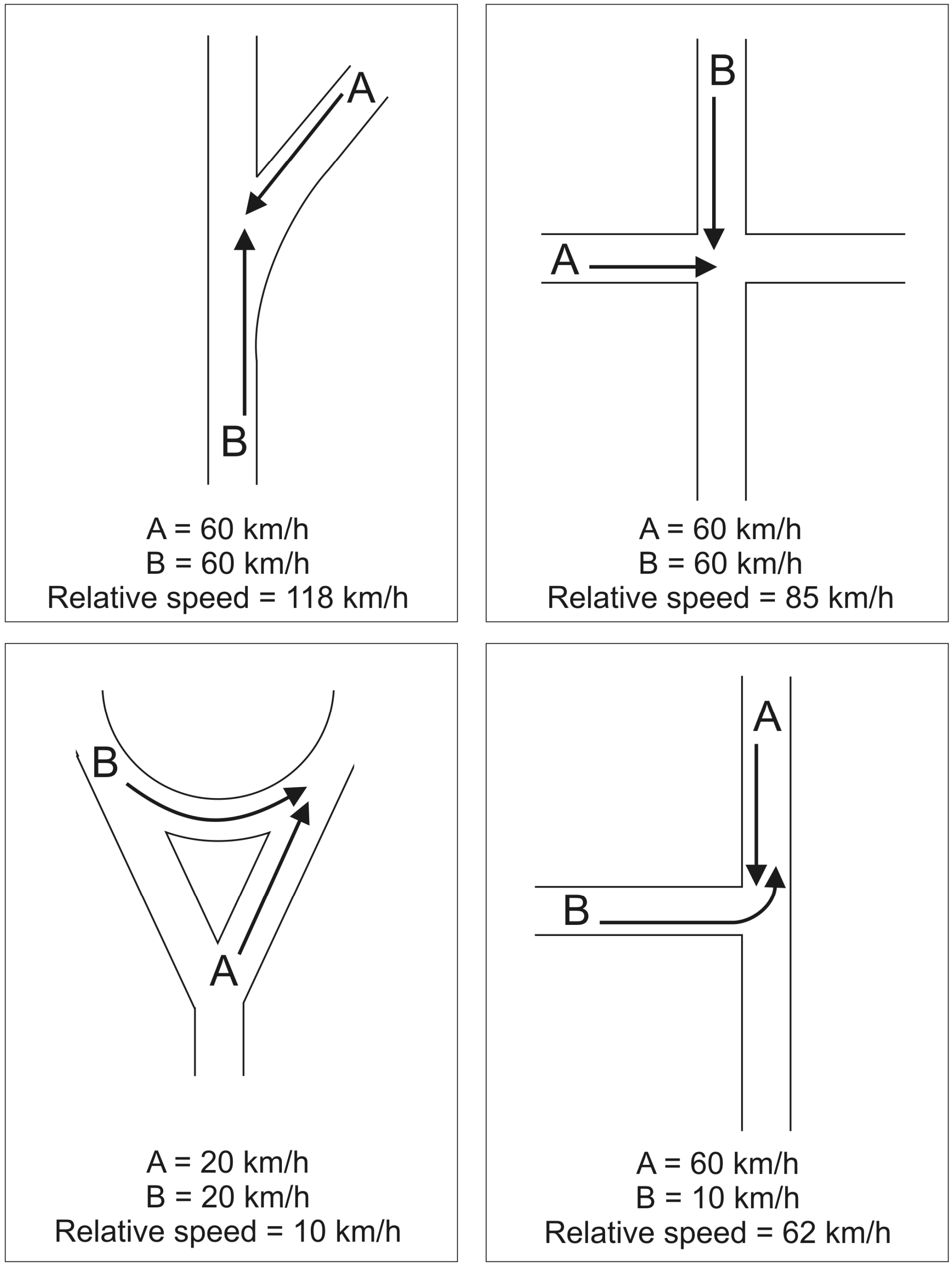


Figure 3: Relative Speeds at Intersections. The drawings show that different intersections tend to result in different speeds at the point of potential conflict. As a result, the severity of crashes tends to be different. Note the typical relative speed at the point of conflict on a modern roundabout is just 10 km/h. Considering this and the small number of conflict points (see Figure 1), it is not surprising that roundabouts are now being promoted for use in Canada. Modern roundabouts are noted from time to time in this handbook. Please refer to Section 2.3.12 of TAC, *Geometric Design Guide for Canadian Roads* (Part 2), 1999, for more information on this topic. Figure adapted from Max Lay, *Handbook of Road Technology,* 1986 (Note: This source does not differentiate between rural and urban intersections.)

A History of Road and Intersection Safety Improvements

It is estimated that approximately 11,000 lives were saved and approximately 500,000 injuries were prevented in Canada between 1979 and 2000 due to road engineering improvements*. This excludes such other factors as vehicle enhancements including airbags and anti-lock brake systems.

In 2002 Transport Canada commissioned a review† to determine the most effective road engineering improvements over the past 40 years in Canada and the United States. The study contained research on the road safety benefits that were achieved due to better road engineering, with a specific focus on improved road design and traffic operations.

For the analysis, experts were asked to rate the effectiveness of a list of countermeasures or solutions in terms of reducing collision frequency and severity. The effectiveness was ranked as shown in the accompanying table. (Note: the maximum point score that any one countermeasure could receive was 78 points.)

The table highlights intersection improvements. Among the 41 improvements listed, 13 were specifically related to intersections (highlighted and bold). There were another 13 that related to intersections as well as other road elements (shown in bold only). The table thus illustrates how important intersection safety is to overall road safety, and why it is important to focus on intersection safety and not just the road itself.

Countermeasure	Points	Date
Divided Highways	67	mid 1960s
Intersection Channelization (left-and right-turn lanes)	**58**	**late 1960s**
Clear Zone widening	**55**	**mid 1970s**
Breakaway Devices (for luminaires, sign bases)	**53**	**late 1970s**
Energy-absorbing Barrier End Treatments	53	early 1980s
Protected Left-turn Phases	**51**	**late 1970s**
Rail Crossing Warning Devices (gates, signals)	**51**	**late 1960s**
Access Management	**50**	**late 1970s**
Rigid Barriers (median and roadside)	50	mid 1970s
Intersection Angle Limits (to 70 degrees or better)	**48**	**mid 1960s**
Horizontal Curve Flattening	**43**	**mid 1970s**
Passing Lanes (along two-lane highways)	42	mid 1970s
Positive Guidance	**42**	**mid 1980s**
Street Lighting	**41**	**mid 1970s**
Decision Sight Distance	**40**	**mid 1970s**
Roundabouts	**40**	**late 1990s**
Two-way Left-turn Lanes	**40**	**mid 1970s**
Climbing Lanes (along mountainous highways)	39	mid 1970s
Rumble Strips (edge line or centreline)	**39**	**mid 1990s**
Signal Display Conspicuity	**36**	**mid 1980s**
Vulnerable Road User Accommodation (s/walks, etc.)	**35**	**late 1980s**
All-red Signal Phases	**35**	**mid 1970s**
Highly Reflective Pavement Markings	**34**	**mid 1980s**
Highly Reflective Signs	**34**	**mid 1980s**
Super-elevation Improvements	34	early 1970s
High Friction/Open-Textured Pavement	33	mid 1980s
Travel Lanes Widening	33	early 1970s
Shoulder Widening	32	mid 1970s
Prohibiting Parking Along Arterials	31	mid 1960s
Longer Taper Lengths	**29**	**late 1970s**
Advance Warning Flashers	**27**	**mid 1980s**
Signal Progression along Corridors	**27**	**late 1960s**
Truck Escape Roads or Ramps	27	late 1970s
Pavement Turn-Guidance Markings	**24**	**late 1970s**
Overhead Flashing Beacons	**22**	**mid 1970s**
Traffic Calming	22	late 1980s
Larger Traffic Signs	**20**	**early 1990s**
Rest Areas	20	mid 1970s
Travel Demand Management	20	mid 1980s
Intelligent Transportation Systems	19	late 1990s
Larger Street Name Signs	**17**	**late 1980s**

*Hamilton Associates & Montufar and Associates, *Roadway Safety Benchmarks Over Time*, prepared for Transport Canada, Road Safety and Motor Vehicle Regulation Directorate, March 2003. Viewable online at www.tc.gc.ca/roadsafety/tp/tp14328/menu.htm

† Ibid.

A Note on Sources

A carefully focused literature search formed the foundation of this report. The intent was to seek studies that included quantified collision reductions as part of their outcomes. A partial list of the sources is included in the appendices. The list is not exhaustive. While valuable, many of the studies consulted could not be used because they were either:

- Based on a small number or sometimes single cases;
- Not conducted in a scientific manner; or
- Conclusions did not result in usable data specific to collision reductions (e.g., a speed reduction study might focus on speed reduction results but not collision reductions).

In the end, a total of approximately twenty reports formed the core source of information for this evaluation. Not surprisingly, many of these are standard reference documents. They included K. W. Ogden's important text *Safer Roads: A Guide to Road Safety Engineering* (1996), the Iowa Safety Management System's *Toolbox of Highway Safety Strategies* (2002), NCHRP's *Report 500. Volume 5: A Guide for Addressing Unsignalized Intersection Collisions,* and the Transportation Association of Canada's *Guide to In-service Road Safety Reviews* (2004), among others. Specific references are provided in the Effectiveness tables.

1

Intersection Layout

Situation Sheet

1.1

Horizontal Curves at Intersections

Background

Horizontal curves occur throughout road networks. Where they occur immediately prior to an intersection, curves can be hazardous, especially if they reduce the visibility of the intersection for the approaching drivers.

Figure 1: Example of a horizontal curve to the left where an Advance Warning sign has been erected to compensate for poor visibility around the curve.

Problems

Some of the most significant issues related to horizontal curves at the approach to an intersection are:

- They may limit the visibility (or conspicuity) of the intersecting roadway as well as associated traffic control devices such as Stop signs or traffic signals.
- Where a minor road intersects a major road on a horizontal curve of the major road a driver's sightline may be restricted, thus reducing the distance available to slow down or stop.
- Vegetation and other roadside obstructions limit the available lateral clearance and visibility available on a horizontal curve, and may limit stopping sight distance to the intersection.
- Sight distances for turning manoeuvres may be limited due to sightline obstructions created by the horizontal curvature.
- If the approach to an intersection is very tight and/or has a high degree of superelevation, cars slowing for the intersection during slippery conditions may find themselves losing control and sliding to the inside of the curve.

(continued on next page)

Summary

On the approach to an intersection a horizontal curve may reduce available stopping sight distance or the ability of a driver to maintain control if the curve is too sharp. In general, the preferred treatment when dealing with an intersection on a curve is to relocate it to a tangent section. In cases where this is not possible, the primary goal should be to maximize visibility throughout the intersection for all movements. A number of different countermeasures are available including the use of advanced warning signs and pavement markings; modifying the alignment within constraints to provide cost-effective improvements in visibility, and the removal of specific visibility obstructions (such as embankments, trees or other vegetation).

SITUATION SHEET 1.1

Horizontal Curves at Intersections

Problems (con't)

- When drivers arrive at an intersection on a curve, it can be difficult for them to determine the correct travel path on the approach because of the curvature of the road. In such cases, drivers may encroach into adjacent lanes or onto available shoulders.

- Drivers stopped at an intersection on a curve may find it difficult to judge the speed of vehicles approaching on the horizontal curve. Errors in judgement of the approach speeds of other vehicles may lead drivers to enter the intersection at an inappropriate time.

Figure 2: In the photo at the right, an advance warning sign (Stop Ahead) has been used because the sight-lines to the intersection are hidden by vegetation on the inside of the horizontal curve.

Solutions

- Flatten or eliminate the horizontal curve through or approaching the intersection.

- Install warning signs to advise drivers of the approaching traffic control measures or intersection (Figure 2).

- Improve the lateral line of sight by removing vegetation and obstacles such as fencing, signs, utility poles and other structures from the inside of the horizontal curve. An example is illustrated in Figure 2 (above) where the problem may be remedied by removing or substantially thinning the vegetation on the inside of the horizontal curve.

- Relocate the intersection to a tangent section of roadway (as illustrated in Figure 3).

- Flashing beacons may be used to supplement warning signs. It should be noted that unnecessary use of warning signs on the approach to an intersection detract from the sign effectiveness and may distract the driver. Care should be taken to avoid sign clutter on the approach to an intersection.

- Use standard pavement markings that are visible at night to supplement the existing roadway signs. Pavement markings should follow the guidelines established in the *Manual of Uniform Traffic Control Devices for Canada* (MUTCDC).

- Reduce the posted speed limit on the approach to an intersection should only be done if a detailed engineering study indicates that such a reduction is warranted AND if suitable speed management measures are put in place to ensure effective compliance with the new speed limit.

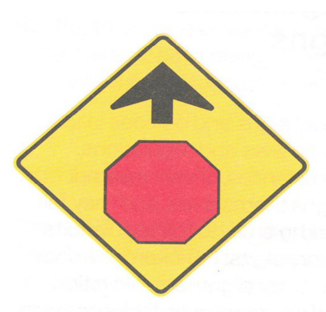
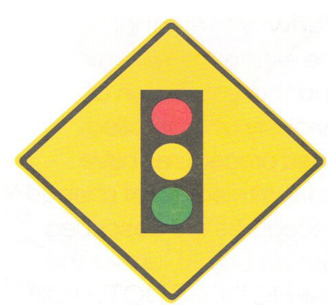


Figure 4: Stop Ahead and Prepare to Stop warning signs, as in these examples, inform the driver of an upcoming intersection that may not be visible due to a horizontal curve. Flashing beacons (called advance warning flashers or AWF) may be placed on either side of the Prepare To Stop sign .



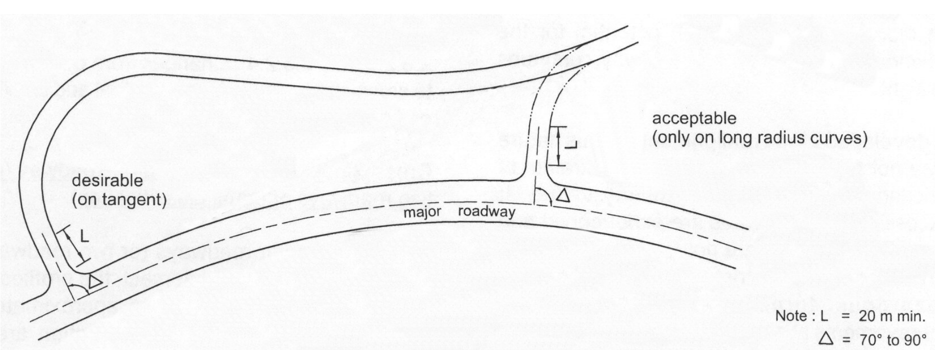


Figure 3: Relocation of an intersection to a tangent section or long radius curve. In some cases this can be an expensive solution; less expensive approaches may also need to be considered, such as closure of the intersection. Refer to Section 2.3.2.2 of TAC for more discussion of this option. Source: Adapted from TAC, *Geometric Design Guide for Canadian Roads* (Part 2), 1999.

Solutions (con't)

Figure 5: Flashing beacons may be used to supplement signs, as shown in the photo. Be aware that numerous warning signs on the approach to an intersection may distract or confuse a driver. Care must be taken to install an appropriate number of warning signs in the correct location on the approach to an intersection.

Figure 6: Use reflective markings for nighttime visibility where the rural intersection is not serviced by overhead lighting. Note the advisory speed tab used in conjunction with the warning sign. Note also that this illustration does not necessarily indicate an intersection.

Effectiveness

Solutions that improve the visibility and recognition of the intersection have the potential to reduce rear-end collisions and right-angle collisions at rural intersections. Generally speaking, the sources cited below do not differentiate between signalized or unsignalized intersections. **Solutions are listed in order of overall cost effectiveness.**

Solution	Collision Type	Potential Collision Reduction		Cost	Overall Cost Effectiveness
		Range	Most Likely		
Install advance warning signs and markings *[TAC (1997), Iowa DOT]*	Total collisions	20% to 35%	25%	Low	High
Install proper pavement markings *[TAC (1997), Ogden, Iowa DOT]*	Total collisions at signalized intersections	20% to 45%	30%	Low	High
	Total collisions at unsignalized intersections	15% to 20%	15%	Low	Medium
Improve sightlines on horizontal curve *[TAC (1997), Ogden, Georgia DOT, Iowa DOT]*	Total collisions	15% to 50%	30%	Low to high	Low to high
Relocate intersection away from horizontal curve *[TAC (1997), Iowa DOT]*	Total collisions	Up to 50%	35%	Medium to high	Low to medium
Flatten horizontal curve *[Ogden, Vermont & Iowa DOT]*	Total collisions	25% to 40%	25%	High	Low

Further Information

Reference should also be made to topics contained in the following other Situation Sheets:

1.6 Intersection Skew

1.7 Corner Radius

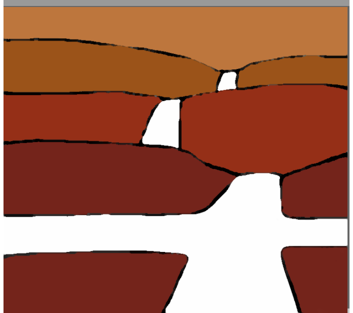
3.3 Pavement Markings

3.4 Sign Clutter on Intersection Approaches

5.2 Approach Speeds and Speed Differential

Situation Sheet

1.2



SITUATION SHEET 1.2

Vertical Curves

Vertical Curves

Background

Vertical curves are common on road networks. If not properly designed, they may create sight distance limitations on the approaches to rural intersections. Vertical curves take two forms – crest curves and sag curves (see Figure 1 below). Sight distance requirements for safety are particularly important on crest curves.

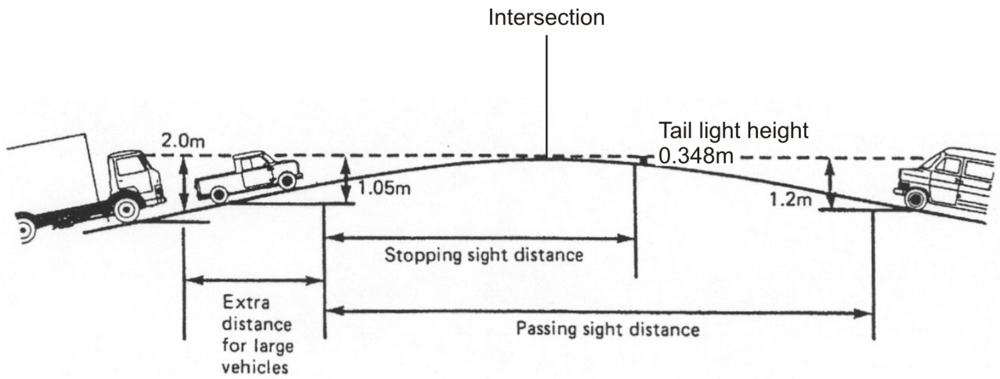


Figure 1: These figures show the concept of stopping sight distance on a crest curve and a sag curve. The sketch above identifies the visibility restrictions on a crest vertical curve. The sketch below illustrates the concept of visibility restrictions caused by a vertical sag curve under night conditions. The forward sight of the driver is limited by the headlight beams of the vehicle. *Source:* Adapted from Ross Silcock Partnership, *Towards Safer Roads in Developing Countries*, UK Transportation and Research Laboratory (Overseas Unit), 1991, p. 50.

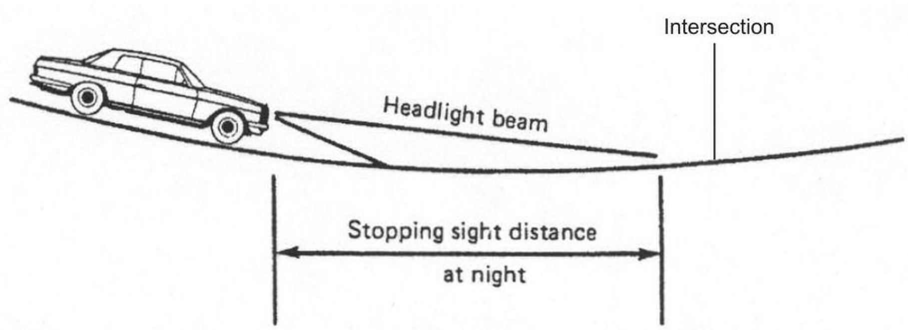


Figure 2: Reduction in vertical curve to improve stopping sight distance. *Left:* Before; *Right:* After. Source: City of Port Alberni.

Summary

Vertical curves can limit sightlines on the approach to and departure from an intersection. A number of countermeasures can be used to deal with this challenge. The preferred treatment is to flatten the profile of the roads at the intersection as required to achieve the needed sight distances. Other countermeasures can include: warning signs, improved pavement markings, installation of traffic signals if warranted, flashing hazard beacons and so forth. In some instances illumination may be appropriate.

Problems

Problems associated with vertical curves at intersection locations include:

- Vertical curves on the approach to an intersection may limit stopping sight distances.
- Vertical curves on the approach to an intersection may reduce intersection conspicuity.
- Vertical curves on the approach to an intersection may limit the sight distances available for turning manoeuvres.
- Downgrades on the approach to an intersection may contribute to increased speed differentials. These grades may also reduce braking effectiveness during periods of poor roadway surface conditions.

Figure 3: If there are changes in the vertical alignment of a roadway (a steep uphill or steep downhill section), an intersection that is located beyond a crest curve may not be visible to a driver. In regions of the country where the terrain is relatively flat, any change in the vertical alignment near an intersection may be a cause for driver confusion. A higher number of rear-end and right-angle collisions may occur at intersections where a vertical curve is located on the approach.

Figure 4: This photo provides an example of the effect that a vertical curve can have on the ability of a driver to see an approaching intersection. A closer look reveals that there are visual clues in the photograph such as platooning vehicles (sometimes indicative) and a warning sign, but the intersection itself is not visible. The combination of a horizontal and vertical curve will tend to make this problem more acute.

Solutions

- Warning signs provide drivers with advanced warning of the approaching intersection. Where the intersection is obscured by the vertical curvature of the road, supplementary tabs may be employed (as in the example in Figure 5). It is typically placed under a standard intersection warning sign.
- Install an overhead flashing hazard beacon above the intersection, visible from all approaches. The overhead beacon should supplement the standard signs and traffic control required at an intersection.
- Lighting the intersection may assist drivers to locate and identify the intersection under nighttime conditions [1].
- Use standard pavement markings that are visible at night to supplement the existing roadway signs. Pavement markings should follow the guidelines established in the MUTCDC.
- On the minor road, supplementary pavement markings such as transverse lines that cross the travel lane on the approach to an intersection may be used to indicate to the driver that the roadway is changing ahead. The effect of these markings on collision reduction has been studied with good results. In extreme cases, transverse rumble strips may be employed.
- If the intersection is signalized, an increase of the amber phase length may be appropriate, particularly if the approach is located on a downgrade [1]. A detailed study of an appropriate amber phase length must be carried out and is dependent on the vehicle speeds through the intersection.
- Adjust the approach profile to provide flatter grades.
- Where a combination of horizontal and vertical curves results in severe sight restrictions, consider flattening one or both curves.

Figure 5: Hidden Intersection tab.

Solutions (con't)

Figure 6: Installation of an overhead flashing hazard beacon above the intersection, visible from all approaches. The overhead beacon should supplement the standard signs and traffic control required at an intersection. This is a commonly used solution, however its effectiveness has not been adequately documented.

Figure 7: Another application of an overhead flashing beacon with the addition of supplementary transverse pavement markings (optical speed bars) on the intersection approach. Use these with caution, as these markings become faded and worn and may not be visible in wintertime.

Effectiveness

Typically, vertical curves are designed to provide enough forward sight distance of the intersection to allow a driver to slow or stop a vehicle if necessary. Solutions offer reductions in the number of collisions of up to 60 percent in some applications where vertical curves are a factor at intersections. **Solutions are listed in order of overall cost effectiveness.**

Solution	Collision Type	Potential Collision Reduction		Cost	Overall Cost Effectiveness
		Range	Most Likely		
Install advance warning signs *[TAC 2004, Iowa DOT]*	Total collisions	20% to 35%	25%	Low	High
Transverse pavement markings/rumble strips *[TAC 2004]*	Total collisions	40% to 60%	40%	Low	High
Install intersection lighting *[Ogden, TAC (Ancillary Features), Vermont DOT]*	Nighttime collisions	20% to 50%	40%	Medium	Medium
Increase amber length of signal *[TAC 2004, Iowa DOT]*	Total collisions	10% to 15%	10%	Low	Medium
Flatten vertical curve *[Ogden, Iowa DOT]*	Total collisions	40% to 50%	40%	High	Low
Overhead flashing beacon *[NCHRP 500]*	This solution has not been satisfactorily quantified.			Low	n/a

Additional Information

This Situation Sheet contains references to topics contained in the following other sections:

2.3 Sign and Traffic Signal Visibility

2.4 Intersection Lighting

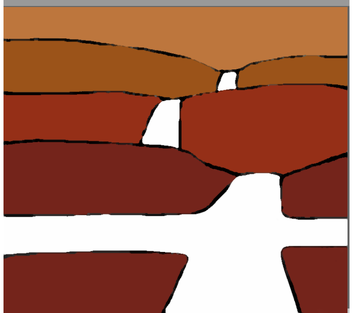
5.5 Large number of Heavy Vehicles

References

1. Fitzpatrick, K., K. Balke, D.W. Harwood & I.B. Anderson, *Accident Mitigation Guide for Congested Rural Two-Lane Highways*, Transportation Research Board, 2000.

Situation Sheet

1.3



SITUATION SHEET 1.3

Access Control

Access Control

Background

Uncontrolled access to any road can create major risks for road users and reduce the efficiency of traffic flows and operational conditions. This is particularly true when driveway access is provided close to an intersection. In such cases, traffic attempting to enter or leave the driveway can interfere directly with vehicles attempting to use the intersection. Since intersections are already areas where drivers are faced with a high workload, and the presence of unexpected vehicles creates additional conflicts in an already complex situation. This can be a particularly challenging hazard to both groups of road users.

Problems

- Queues at the intersection block vehicles wanting to enter or leave the driveway.
- Vehicles wanting to turn left into a driveway on the far side of an intersection may also be blocked. This can result in further blockages to through traffic.
- Road users wanting to turn into or out of driveways may attempt to do so through gaps in intersection lineups. This is a complex and risky task – particularly given that sightlines are often obstructed by the queued vehicles.
- Right turning traffic on the near side of an intersection can interfere with right turning traffic with the potential for an increase in both rear-end and sideswipe collisions.
- Vehicles moving into or out of driveways close to an intersection can interfere with road users who have just completed a turn and who are not expecting slow moving traffic. Rear-end and right-angle collisions may result from such situations.
- Corner driveways may provide opportunities for drivers to shortcut around intersections, creating risks for the shortcutting drivers, users of the corner property, through traffic on both roadways – and in a settled area – pedestrians and cyclists.

Figure 1: In this situation, the commercial entrance in advance of the intersection results in increased driver confusion in determining where to come to a stop or to turn. Compensation has been provided by adding a flashing beacon over the Stop sign. Better lane markings could also be provided, but the best solution is to reduce and relocate the driveway.

Summary

Intersections are subject to a high risk of collisions when there are numerous or wide driveways at or near the intersection. The distance between an intersection and a driveway is termed the corner clearance. This distance is intended to provide adequate space for turning vehicles to slow, manoeuvre, and to prevent vehicle queues from spilling back into the driveway. Agencies should work for the relocation of accesses away from intersections.

Solutions

Where possible, for improperly located driveways, the following solutions should be considered [1]:

- Move driveways to the side street if possible.
- Install curb to define driveway location.
- Consolidate adjacent driveways.
- If it is left-turning vehicles at the entrance that tend to interfere with the intersection operations, the turn could be prohibited.
- If the interference is coming from right-turning vehicles, countermeasures may include providing a right-turn lane or prohibiting the turn [1].

At the policy level, a number of solutions are available, including:

- Regulating the minimum spacing of driveways on intersection approaches.
- Limiting driveways on facilities intended to carry high volumes of traffic.
- Regulating the minimum corner clearance.
- Restricting non-commercial driveways to maximum widths: 4.25 to 7.3 metres wide (widest for farm vehicles where the design vehicle is typically a slow-moving vehicle SMV).
- Restricting commercial driveway widths to 4.25 to 4.9 metres per lane.
- Driveways could be provided with wider radii in locations where there are high-speed differentials between through traffic and turning vehicles. Wider radii permit vehicles to maintain higher speeds as they exit the travel way. This solution may not be suitable in locations with significant pedestrian activity.

Effectiveness

Intersections are the most common sites of collisions on any road. The presence of driveways and entrances at or near intersections simply compounds an inherently unsafe environment. The provision of access controls therefore can be an important strategy for reducing collisions. Effectiveness can be quite high, running up to a 60 percent reduction in access-related collisions and 50 percent of all collisions. This Situation Sheet has itemized several solutions to the problem and illustrates the effectiveness of improved access control as studied in various jurisdictions. Yet it is recognized that access control is often not a matter that can typically be dealt with as a strictly technical problem – it is often a matter of jurisdictional policy that can be supported by sound technical findings. It is therefore recommended that, where problems are encountered, practitioners should convey their observations to the appropriate departments so that they may be properly addressed at the policy level.

Solution	Collision Type	Potential Collision Reduction		Cost	Overall Cost Effectiveness
		Range	Most Likely		
Improve access control at intersections *[TRB Access Management Manual, TAC (2004) , Vermont DOT]*	All collisions	30% to 50%	35%	Medium	Medium
	Driveway-related collisions	50% to 60%	50%	Medium	High
	Side - swipe & merge collisions	10% to 30%	15%	Medium	Low

Additional Information

Reference should also be made to topics contained in the following Situation Sheet:

5.4 Gap Identification

References

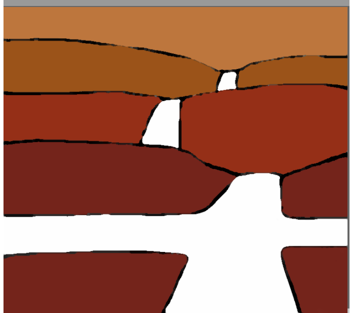
1. Vogt, Andrew, *Crash Models for Rural Intersections: Four-Lane by Two-Lane Stop-Controlled and Two-Lane by Two-Lane Signalized*, U.S. Department of Transportation FHWA-RD-99-128, 1999 .

See also:

Transportation Research Board, *Access Management Manual*, 2003.

Situation Sheet

1.4



SITUATION SHEET 1.4

Turning Lanes

Turning Lanes

Background

Intersections are provided in order to allow vehicles to move from one roadway to another. Such movements necessarily involve turning manoeuvres.

Left turns

Left turns alone account for one in five fatalities at intersections [1].Collisions associated with left-turn manoeuvres (left-turn, rear-end, side-swipe) may be reduced by providing exclusive left-turn lanes, especially on high-volume and high-speed roadway approaches. Left-turn lanes remove the turning vehicles from the through traffic stream, reducing vehicle conflicts and turbulence with through traffic approaching from behind the turning vehicle. Left-turn lanes also provide a sheltered location for drivers to wait for a gap in opposing traffic. This improvement may encourage drivers to be more selective in choosing gaps to complete the left-turn manoeuvre and may reduce the potential for high-severity collisions between left-turning and opposing through traffic.

Right turns

The provision of exclusive right-turn lanes may also reduce collision types typically associated with right-turn manoeuvres (rear-end, side-swipe), by removing vehicles that are decelerating to turn right from the through traffic stream. This is particularly important on high-volume, high-speed roadways.

Problems

The provision of turning lanes can provide significant benefits, but their design must be carefully considered, since they may also introduce risks that were not previously present.

In the absence of a left turn lane:

- Without the provision of a turning lane, vehicles performing left-turn manoeuvres from the major roadway must do so from the through lane. This creates vehicle conflicts and turbulence with through traffic approaching from behind the turning vehicle.

Things to watch for when providing a left turn lane:

- Intersection crossing distances will in-

Summary

Many intersection safety problems can be traced to difficulties in accommodating turning manoeuvres. Left-turn lanes may be provided when the number of left-turning vehicles at an intersection is nearing capacity and/or a hazard is created due to high speed or high volume. The literature offers ample evidence of the effectiveness of left- and right-turn lanes.

Problems (con't.)

crease, thus increasing pedestrian exposure to traffic.

- Improperly offset left turn lanes may result in opposing left turning vehicles that are waiting an opportunity to turn, creating sightline obstructions for each other to oncoming traffic. This may result in unnecessary increases in high severity side and right-angle collisions.
- If a left turn lane is too short, vehicle queues may extend into the through lane, thus not providing the expected benefit in collision reduction, and in fact increasing the risk of high-severity rear end and side-swipe collisions.
- If the left turn lane is too short to accommodate the required vehicle deceleration on a high speed facility, the risk of high-severity rear end and side swipe collisions may increase.
- If queues in the through lane exceed the length of the left turn lane, impatient drivers on undivided roads may be tempted to drive in the lane for opposing traffic to gain access to their left turn lane. Obviously, this is undesirable.

In the absence of a right turn lane:

- Vehicles performing a right turn move must decelerate in the through lane. This creates a greater likelihood of rear-end and sideswipe collisions.

Things to watch for when providing a left turn lane:

- Intersection crossing distances will increase, thus increasing pedestrian exposure to traffic.
- If a right turn lane is too short vehicle queues may extend into the through lane, thus not providing the expected benefit in collision reduction, and in fact increasing the risk of high-severity rear end and side-swipe collision.
- If the right turn lane is too short to accommodate the required vehicle deceleration on a high speed facility, the risk of high-severity rear end and side swipe collisions may increase.

Solutions

Left turns:

- Remove left-turning vehicles from the through traffic stream by providing a left-turn lane. This will reduce conflicts with through traffic travelling in the same direction.
- Improve left-turn lane geometry by increasing the entrance taper and deceleration lengths.
- Where possible, offset opposing left-turn lanes to improve sightlines for opposing vehicles.

Right turns:

- Remove slow-moving right-turning vehicles from the through traffic stream by providing a right-turn lane. This will reduce conflicts with through traffic travelling in the same direction.
- Improve right-turn lane geometry by increasing the entrance taper and deceleration lengths.
- Consider right-turn channelization in areas where pedestrians are not present (this is generally an urban/suburban solution).

Signalization:

- At an unsignalized intersection traffic signals can be installed (if warranted) to accommodate heavy turning volumes.
- At signalized intersections, signal timing may be adjusted to accommodate heavy turning volumes.
- Provide a protected left-turn signal phase.
- Through striping to delineate the turning path, provide positive guidance to drivers turning left at signalized intersections.

Modern roundabouts (a special case):

- Modern roundabouts can facilitate heavy turning movements by allowing all vehicles to circulate in one direction around a central island. The modern roundabout – which operates under the principle of "Yield on entry", and has a very specific design configuration – is widely used in the United States, and is gaining acceptance in Canada, but is still novel in most Canadian jurisdictions. Its benefits are substantial (see Effectiveness section), but the locations where it is appropriate must be carefully considered and a modern roundabout should only be implemented in the context of expert advice and experienced design services. While roundabouts are widely applied in urban, suburban, and rural contexts in Europe, Great Britain, Australia, New Zealand, and elsewhere, they are primarily used in urban and suburban situations in North America.

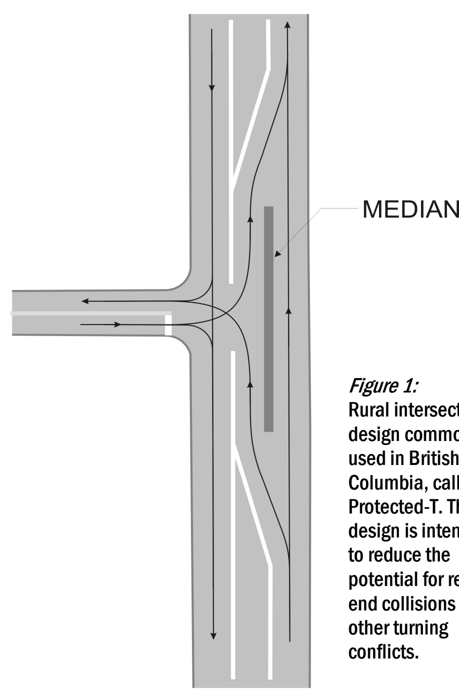


Figure 1:
Rural intersection design commonly used in British Columbia, called a Protected-T. The design is intended to reduce the potential for rear-end collisions and other turning conflicts.

Effectiveness

Turning lanes are provided when the number of turning vehicles at an intersection is nearing capacity and/or a hazard is created due to the high volume or low speeds. There is ample evidence of their effectiveness, as illustrated by the data below. **Solutions are listed in order of overall cost effectiveness and by type of intersection.**

Solution	Collision Type	Potential Collision Reduction		Cost	Overall Cost Effectiveness
		Range	Most Likely		
Unsignalized					
Install left-turn lane(s) *[NCHRP 500, Vol 5.]*	Total collisions Signalized intersection collisions Unsignalized intersections Left-turn collisions	28% to 44% 20% to 35% 10% to 65% 20% to 75%	30% 25% 30% 40%	Medium to high	Low to high
Increase the left-turn lane length *[Iowa DOT]*	Total collisions	30%	30%	Medium	Medium
Install modern round-about *[NCHRP 500, Vol 5.]*	Total collisions Injury and fatal collisions Rear-end collisions	38% to 58% 90% May increase	50% 90% n/a	High	Medium
Install traffic signal at unsignalized intersection if warranted *[Ogden, Iowa DOT, TAC (2004)]*	Total collisions Turning collisions Right-angle collisions Rear-end collisions Injury and fatal collisions	20% to 35% Increase of 20% to 100% 30% to 80% Increase of 30% to 70% 25% to 30%	25% Ineffective 50% Ineffective 25%	Medium Medium Medium Medium Medium	Low to high
Signalized					
Implement protected left-turn phase at signalized intersection *[TAC (2004)]*	Total collisions Left-turn collisions	25% to 50% Up to 35%	30% 25%	Low Low	High High
Optimize/actuate traffic signals if warranted *[Ogden, Iowa DOT, TAC (2004)]*	Total collisions	10% to 20%	15%	Low	Medium
Install right-turn channelization *[TAC (2004), Ogden & Iowa DOT]*	Total collisions Right-turn collisions Rear-end collisions Merge/overtaking collisions Pedestrian collisions	20% to 40% Up to 50% May increase May increase May increase	30% 35% n/a n/a n/a	Medium	Low to medium
Not quantified					
Improve offset left-turn condition *[NCHRP 500, Vol 5.]*	The effectiveness of this solution has not been quantified			Low	n/a

Additional Information

This Situation Sheet contains references to topics contained in the following other sections:

2.3 Sign and Traffic Signal Visibility

5.5 Large Number of Heavy Vehicles

References

1. Transport Canada Road Safety Directorate, *Rural Road Safety in Canada: Traffic Collision Trends and Recommended Strategies* (in preparation, 2005).

Acceleration Lanes

Background

Acceleration lanes are appropriate on rural roads where there is congestion and speeds are high. These lanes create a separate area in the cross section that allows vehicles to accelerate to highway speeds before entering the through traffic lanes. Although right-turn acceleration lanes are fairly common features at intersections, left-turn acceleration lanes are typically associated only with intersections on divided highways that experience a high frequency of rear-end collisions associated with speed differentials caused by left-turning vehicles entering the traffic stream.

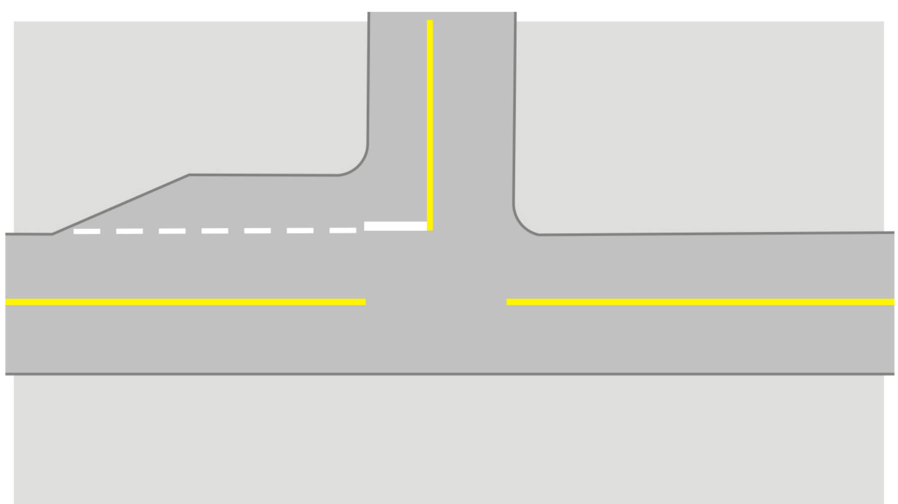


Figure 1: Right-turn acceleration lane – schematic layout.

Summary

Typically associated with higher standard rural roads, acceleration lanes are used to permit a vehicle entering the roadway to accelerate to the speed of the through vehicles on the roadway before merging.

Problems

Issues associated with the absence of acceleration lanes and the improper design of acceleration lanes include:

- If the lane is excessively long or poorly marked, through traffic may mistake it for an additional through lane.
- Intersection widening is typically necessary to accommodate the lane. If pedestrians are present, the pedestrian crossing distance time and pedestrian exposure to traffic will increase.
- In the absence of an acceleration lane, speed differentials created by vehicles turning onto a highway will result in an elevated risk of collisions. This is of particular concern at intersections with a high volume of turning trucks.

Solutions

Potential solutions may include:

- Provide an acceleration lane of appropriate length.
- Improve pavement markings.
- Provide median refuge island for pedestrians.
- Install left-turn acceleration lane.
- Utilize a lane-away (see box).

The lane-away or added lane can be used for acceleration and deceleration. They do not require a yield or merge. This is an advantage in terms of construction cost and right-of -way acquisition. In addition, the lane-away helps operations and safety on downstream upgrades with more than 5 percent heavy trucks. Disadvantages include violating driver expectations if they think the lane continues or if there are weaving movements from the lane-away to a left– turn lane; and more lanes to cross means more potential conflicts.

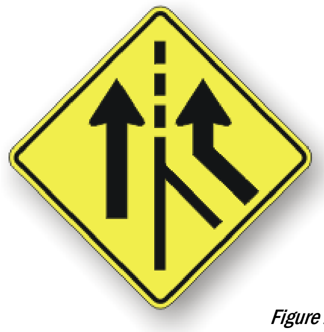


Figure 2:
Added Lane sign.

Effectiveness

An acceleration lane is provided to permit a vehicle entering the roadway to accelerate to the speed of the through vehicles on the roadway before merging.

Solution	Collision Type	Potential Collision Reduction		Cost	Overall Cost Effectiveness
		Range	Most Likely		
Install proper pavement markings *[TAC (2004) , Ogden & Iowa DOT]*	All collisions at signalized intersections	20% to 45%	30%	Low	High
	All collisions at unsignalized intersections	15% to 20%	15%	Low	Medium
Install proper acceleration lane *[TAC (2004) , Ogden]*	Lane-change collisions	40% to 60%	45	Medium	High
Provide pedestrian refuge *[Ogden]*	Pedestrian collisions	20% to 60%	30%	Low	High

Additional Information

This Situation Sheet contains references to topics contained in the following section:

5.4 Large Number of Heavy Vehicles

References

1. Adapted from Transportation and Road Research Laboratory, *Towards Safer Roads in Developing Countries: A Guide for Planners and Engineers*, First Edition 1991, Section 4.2.7.

Situation Sheet

1.6

SITUATION SHEET 1.6

Intersection Skew

Intersection Skew

Background

Typically, intersections should meet at an angle as close to 90 degrees as possible. Most road design guidelines suggest that the range of acceptable intersection angles lies between 70 and 110 degrees. At angles outside of this range drivers may find themselves in a poor position to judge the speed and distance of approaching vehicles. In some cases, such skews also create situations where left turning vehicles may traverse the intersection at elevated speeds and also travel partly in the opposing traffic lane.

Figure 1: Roads that intersect at sharp angles can create problems for large turning vehicles and they extend the length of time and distance that is needed to enter or cross the intersecting road. The photograph shows a skewed intersection with the minor road in the left of the photograph. In this example, there is an unusual additional problem with the minor roadway in that it could be confused with the through travel path of the major road. This section offers solutions to problems such as these.

Summary

Skewed intersections have one or more of the approaching legs entering the intersection at an angle other than 90 degrees. In such cases it may be difficult for the driver to see approaching vehicles, particularly if the volume of heavy vehicles/trucks is high. Intersection realignment at an angle closer to 90 degrees, relocation of the stop bar and pavement markings to maximize sight distances, and installation of traffic signals (if they are warranted) are all potential solutions.

Problems

- Roads that intersect at acute angles make it difficult for drivers to see approaching vehicles on some of the crossing legs.
- ▼ Older drivers often experience a restricted range of head and neck mobility. At an intersection with an excessive skew, this can create difficulties in determining appropriate gaps in approaching traffic.
- Acute angles may create difficulties for turning manoeuvres. This is of particular concern for heavy trucks, as these vehicles may encroach into the opposing lane of traffic.
- Drivers may experience difficulty in judging the relative position and speed of an approaching vehicle and to decide when to enter or cross the major road..
- The amount of time required for vehicles and pedestrians to cross the intersection is increased due to increased intersection width. There is a resulting increase in exposure to risk of collision.
- Drivers performing turning manoeuvres at the obtuse angle may do so with a higher operating speed. This may result in an increased collision severity.

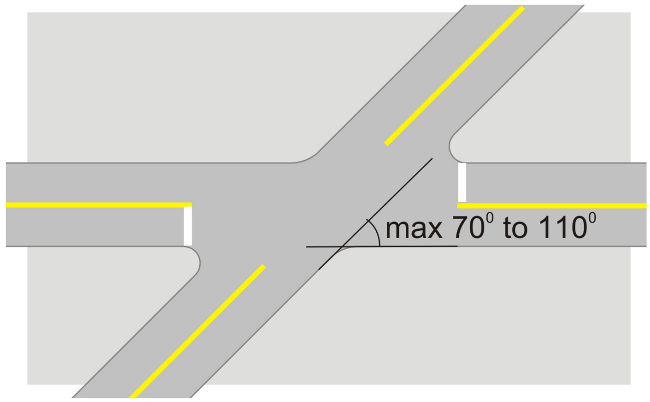


Figure 2: This is an example of a skewed intersection. For safety, maximum skew angles should be between 70 and 110 degrees, with 90 degrees being ideal.

Solutions

Realign intersection to improve skew angle. There are various ways to achieve this:

- Where the skew angle is 60 degrees or less, the intersection should be redesigned to achieve an intersection as close to 90 degrees as possible [2]. Some literature reviewed suggests that intersecting roadways of less than 80 degrees should have the intersecting angle improved [3]. A detailed review of the specific situation will need to be carried out to determine an angle that is appropriate.
- Figure 3 illustrates some potential intersection realignment options. Diagrams A and B are examples of a redesign for the minor roadway to create an intersection closer to 90 degrees. While eliminating the skewed intersection, the addition of curves to the minor roadway may impede visibility on the approach to the intersection; this is discussed elsewhere under Situation Sheet 1.1 - Horizontal Curves. In such a situation, the approaches would generally have advance warning signs and be clear of all obstructions.
- Create a staggered intersection by separating the intersection into two 90 degree angle, 3-legged intersections (Figure 4). Although this is not the most desirable countermeasure, it may be acceptable in some situations. The result is a requirement for through traffic on the minor roadway to travel through two intersections.
- If warranted, install traffic signals. Use caution as traffic signals have the potential to reduce certain collision types (right-angle) while they may increase other types (such as rear-end collisions).

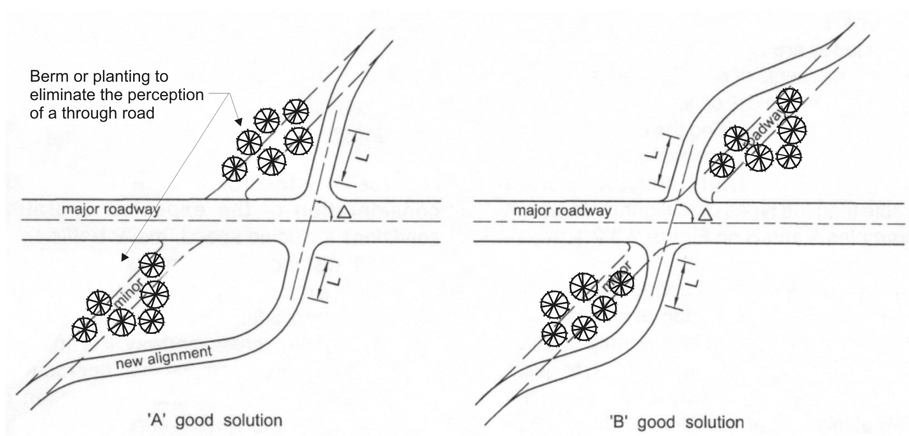


Figure 3: Examples of skewed intersection countermeasures. Source: TAC, *Geometric Design Guide for Canadian Roads* (Part 2) 1999.

Solutions (con't)

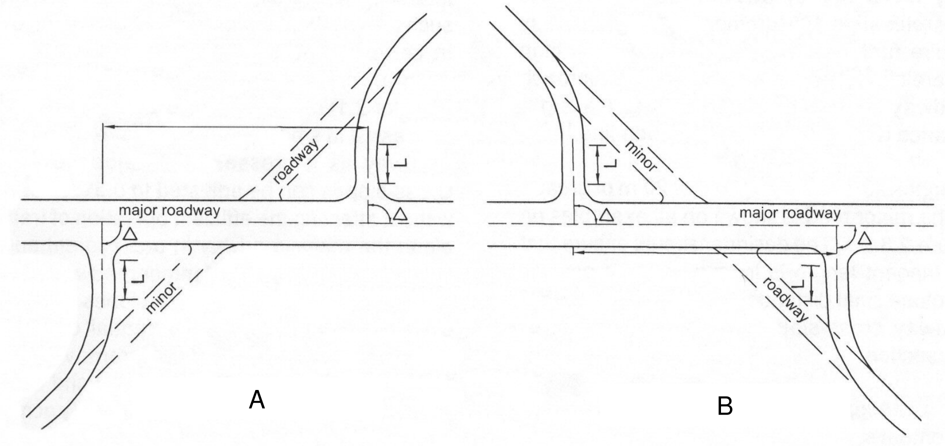


Figure 4: Offset or staggered intersections. Ogden (p. 193) argues that this modification is often very effective in reducing both collision frequency and severity. Of the two options shown at left, Option B is preferred. In Option B, crossing drivers on the minor road must make a left turn and then a right, which tends to be preferred to a right followed by a left (as the left turn occurs on the major road and offers less comfort for the driver). Source*: TAC, Geometric Design Guide for Canadian Roads* (Part 2), 1999.

Effectiveness

The cost to remedy skewed intersections can be high, as some alternatives involve the creation of new road alignments, and this often requires the acquisition of property. Nonetheless, the potential for collision reduction through the proper application of this solution is high. Where it is deemed too costly to make alterations to the road, the installation of signals is also highly effective.
Solutions are ranked in order of overall cost effectiveness.

Solution	Collision Type	Potential Collision Reduction		Cost	Overall Cost Effectiveness
		Range	Most Likely		
Stagger intersections *[Ogden, NCHRP 500, Vol. 5]*	Total collisions Rear-end collisions Turning collisions Head-on collisions	40% to 80% 60% to 80% 40% to 60% 40% to 80%	50%	High	Medium
Install traffic signal at unsignalized intersection if warranted *[Ogden, Iowa DOT, TAC (2004)]*	Total collisions Turning collisions Right-angle collisions Rear-end collisions Injury and fatal collisions	20% to 35% Increase of 20% to 100% 30% to 80% Increase of 30% to 70% 25% to 30%	25% Ineffective 50% Ineffective 25%	Medium Medium Medium Medium Medium	Low to high
Improve skew angle *[TAC (2004), Iowa DOT, NCHRP 500, Vol. 5]*	Total collisions	30% to 50%	35%	Medium to high	Low to medium

Additional Information

This Situation Sheet contains references to topics contained in the following other sections:

1.1 Horizontal Curves at Intersections

4.1 Rail Crossing Geometry

(Where the skew problem involves a railroad) See also: Transport Canada, *Technical Standards and Inspection, Testing and Maintenance Requirements, RTD 10, Road/Railway Grade Crossings*

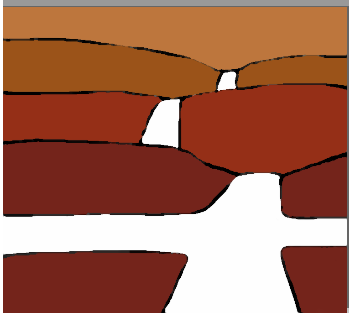
5.4 Gap Identification

References

1. Transportation Association of Canada, *Geometric Design Guide for Canadian Roads*, September 1999. Section 2.3.2.2.

2. Wolshon, Brian, *Toolbox on Intersection Safety and Design, Chapter 5 Geometric Design*, ITE, Sept. 2004.

3. U.S. Department of Transportation Federal Highway Administration, *Toolbox of Countermeasures and Their Potential Effectiveness to Make Intersections Safer*, April 2004.



Corner Radius

Background

The corner radius of an intersection will govern not only what kinds of vehicles can easily move through the junction, but also the speeds at which they can do so. In addition, the choice of corner radius can substantially affect pedestrian safety in areas (such as rural villages or junction settlements) where such activity can be expected to be present. The effects of improperly sized corner radii are highlighted in Figures 1 and 2.

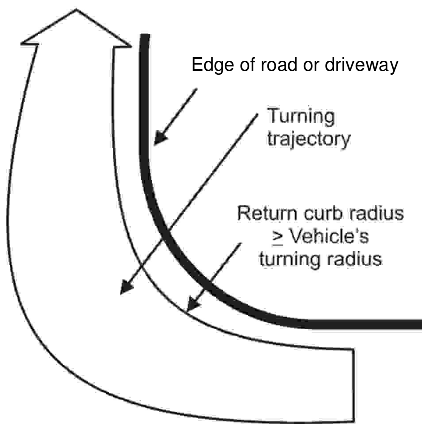
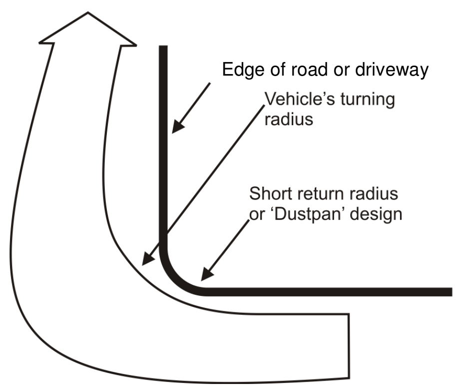


Figure 1: Corner radius too large.
Large corner radii tend to encourage higher vehicle speeds and may encourage drivers to not comply with the operation rules of an intersection (e.g., failure to stop or yield). Intersections with large corner radii also create longer crossing distances for pedestrians and other vulnerable road users. Although rural intersections typically have low volumes of pedestrians, their potential presence should still be considered. The combination of higher speeds and greater crossing distance increases the risks of vehicle-pedestrian collisions. Other collision types that may be characteristic for larger corner radii include high-speed collisions.

Figure 2: Corner radius too small.
A corner radius may be too small due to a number of factors including physical constraints at the intersection. Small corner radii relative to the vehicle operating speeds may result in vehicles venturing into the opposing traffic lanes. This is of particular concern for heavy vehicles/trucks. For additional information on heavy vehicles refer to Situation Sheet 5.4 – Large Number of Heavy Vehicles. Drivers that turn a corner with a small radius may track their wheels on the shoulder and that may cause the driver to lose control of the vehicle or potentially collide with pedestrians. Small corner radii may be unexpected by drivers, causing them to significantly slow their vehicle. This may increase the risk of rear-end collisions.



Summary

Corner radii are designed based on vehicle size and speed. If an inadequate radius is installed it may increase the risk of collisions occurring at the intersection. Countermeasures include adjustment of the radius to the appropriate design vehicle, installation of turning lanes or islands, or the use of supplementary warning signs.

Problems

Radius too large

- May promote higher vehicle operating speeds, encouraging drivers to ignore traffic control (failure to stop or yield).
- Creates wide unused portions of roadway which reduce the positive guidance offered to drivers. This may result in driver confusion.
- Intersection crossing distances are increased, as is pedestrian exposure to traffic.

Radius too small

- The corner radius may not accommodate a large truck performing a right-turn manoeuvre. This can create problems with vehicle off-tracking. Vehicle off-tracking can result in deterioration of the roadway shoulders and pavement edge, and mounting the curb of the channelization island. This is of particular concern to vulnerable road users such as cyclists and pedestrians.
- Turning vehicles may encroach into the opposing lanes.
- Drivers may attempt to increase the turning radius by moving to the left prior to initiating the right-turn manoeuvre. This may mislead drivers approaching from behind that the vehicle is performing a left turn. This situation may encourage drivers in the through traffic stream to pass the turning vehicle on the right.
- Turning vehicles must slow substantially to perform turning manoeuvres. This creates conflicts with vehicles in the through traffic stream.

Solutions

Radius too large

- The illustration in Figure 3 demonstrates the differing radii in each corner of a skewed intersection. Such a situation may require a channelized island to guide and direct vehicles through a right-turn manoeuvre. In this case, the Before condition has a large, paved open area in the middle of the intersection, potentially increasing the risk of collisions and making the road extremely unsafe for vulnerable road users (which may not be a factor if VRUs are not commonly present).
- Apply right-turn channelization.
- Decrease corner radius to accommodate an appropriate design vehicle. Consider the use of compound curves to minimize pedestrian crossing distances.
- Use pavement markings to paint a tighter radius or a channelized lane. This is a relatively inexpensive countermeasure but may be inappropriate during winter weather conditions.

Radius too small

- Increase corner radius to accommodate an appropriate design vehicle. Consider the use of compound curves to minimize pedestrian crossing distances.
- Flare the approach to the intersection to reduce conflicts between through traffic and turning vehicle and assist large trucks in negotiating the turn. It should be noted that on high-speed facilities and in situations where turning vehicles significantly impede the flow of through traffic, consideration should be given to including a right-turn auxiliary lane as part of the design. Guidance on this matter is provided in the TAC *Geometric Design Guide*.
- Where a redesign is not possible or not feasible, include a speed advisory sign at the intersection for reduced speeds around the corner.

Vulnerable road users

High speed intersections can be particularly risky for vulnerable road users. When pedestrians and cyclists are present in an area, large radius turning movements should be discouraged and only used after careful consideration of their potential impacts on non-motorized road users. While vulnerable road users are present only rarely in the rural context, there are still many situations (rural settlements, rural communities bordering major urbanized regions, junction settlements and commercial developments) where their potential presence should be carefully considered.

Solutions (con't)

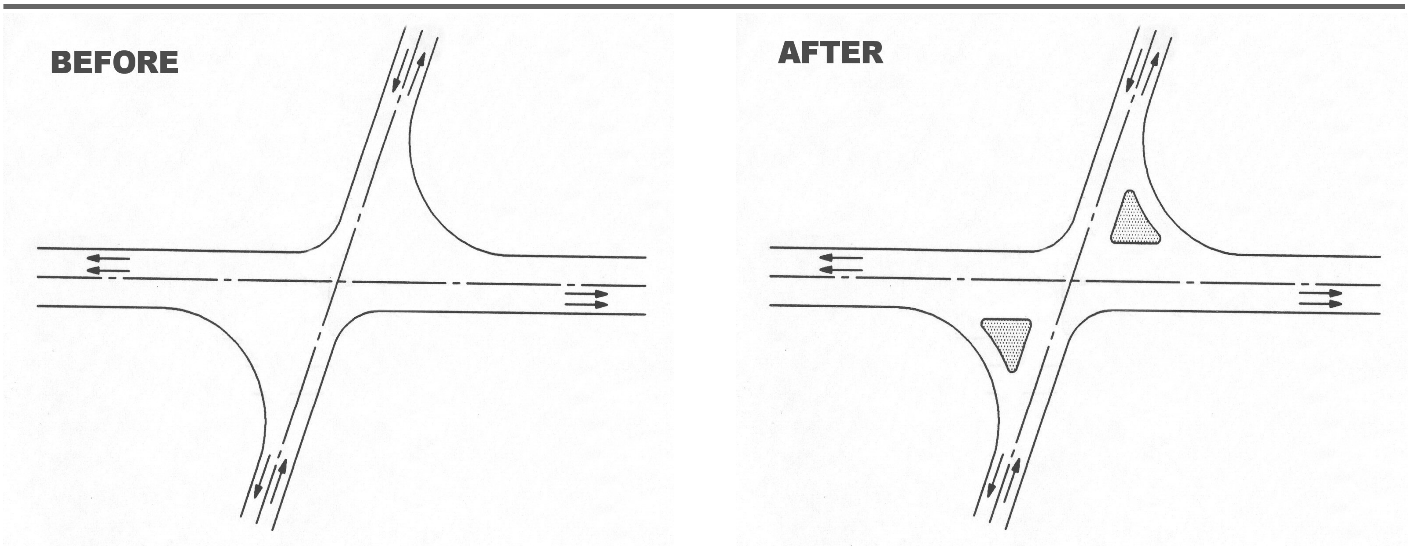


Figure 3: The illustration above demonstrates the difference in radii created by a skewed intersection that may require a channelized island to guide and direct vehicles through a right-turn manoeuvre. In this example, the Before condition has a large, paved open area in the middle of the intersection, potentially increasing the risk of collisions and making the road extremely unsafe for vulnerable road users. The installation of pedestrian refuge and handicapped accessible features is appropriate where there are vulnerable road users at the intersection. Pedestrian refuges have the potential to reduce pedestrian collisions by up to 60 percent. Source: TAC, *Geometric Design Guide for Canadian Roads* (Part 2), 1999.

Effectiveness

Radii improvements at rural intersections have the potential to reduce all collisions by up to 25 percent and may have a significant effect on right-angle collisions. **The following solutions are listed in order of overall cost effectiveness.**

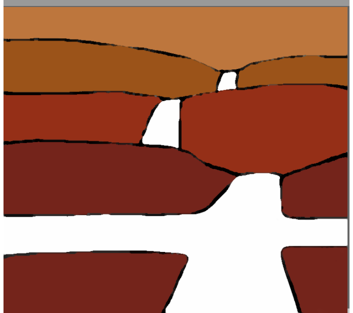
Solution	Collision Type	Potential Collision Reduction		Cost	Overall Cost Effectiveness
		Range	Most Likely		
Provide pedestrian refuge *[Ogden]*	Pedestrian collisions	20% to 60%	30%	Low	High
Install right-turn channelization *[TAC (2004), Ogden & Iowa DOT]*	Total collisions	20% to 40%	25%	Medium	Medium
Increase corner radius *[Vermont DOT]*	Total collisions	25%	25%	Medium	Medium
Decrease corner radius *[NCHRP 500, Vol. 5]*	The effectiveness of this solution has not been quantified			Medium	n/a

Additional Information

This Situation Sheet contains references to topics contained in the following other sections:

1.5 Acceleration Lanes

5.4 Large Number of Heavy Vehicles



Cross Slope

Background

Cross slope is provided on a road to facilitate the drainage of surface water. When two roads meet at an intersection - particularly if on a grade – adjustments may be required to the cross slope used on the respective roadways in order to blend the profile of the intersecting minor road with the cross slope of the major road. This should result in a smooth transition through the intersection for drivers. As well as increasing comfort this also reduces driver workload. Lower driver workloads are typically associated with a lower risk of collisions. Figure 1 provides an example of the blending of the profile of the minor road with the cross section of a major intersecting facility.

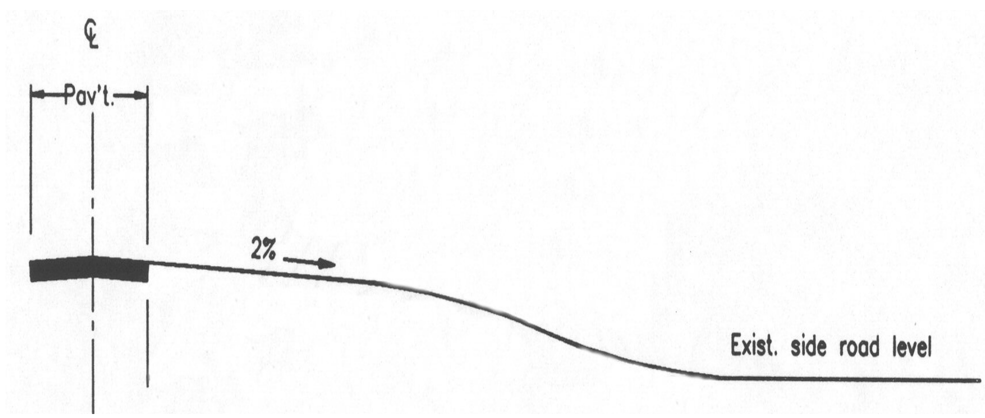


Figure 1: This figure shows the cross slope of a roadway on the left and the profile of an intersecting side road on the right. Typical cross slopes are 2 percent but can vary with horizontal and vertical alignment changes. Source: TAC, *Geometric Design Guide for Canadian Roads* (Part 2), 1999.

Summary

Providing for a smooth transition through an intersection is an important element of the design process. Such transitions require the blending of the profiles and cross sections of the roadways involved to varying degrees, depending on their relative classifications. Poor transitions can result in undesirable (rough) driveability – a factor which can affect the care and control of the vehicle and the resulting workload imposed on the driver. If drainage is not carefully considered in the course of developing the respective roadway cross section and profile transitions, inappropriate operating conditions in wet or freezing weather may result. The fundamental countermeasure available in this situation involves the redesign and reconstruction of the intersection to provide a suitable junction.

Problems

Poor junction profile and cross section design can result in:

- Poor driveability and driver care and difficulty controlling the vehicle.
- Poor drainage and wet or icy weather driveability.
- High driver workload and a resulting elevated risk of collisions.
- Sudden changes in cross slope that can result in a vehicle vaulting when travelling at speed through the intersection.
- In some extreme cases in rural areas, improper blending of approach intersection profiles and cross sections may result in sightline restrictions.

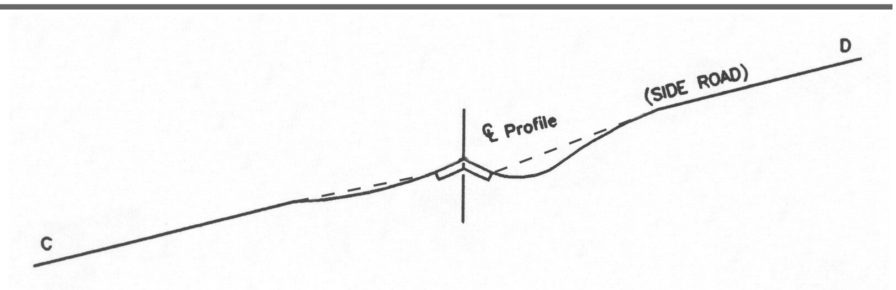
Solutions

- Redesign and reconstruction of the intersection is the only effective countermeasure for this issue.
- As an interim measure pending reconstruction of the intersection, enhanced maintenance activities may be desirable under difficult (wet or icy) conditions (refer to Situation Sheet 5.1 – Maintenance Activities).

Additional Information

This Situation Sheet contains references to topics contained in the following other section:

Sheet 5.1 Maintenance Activities



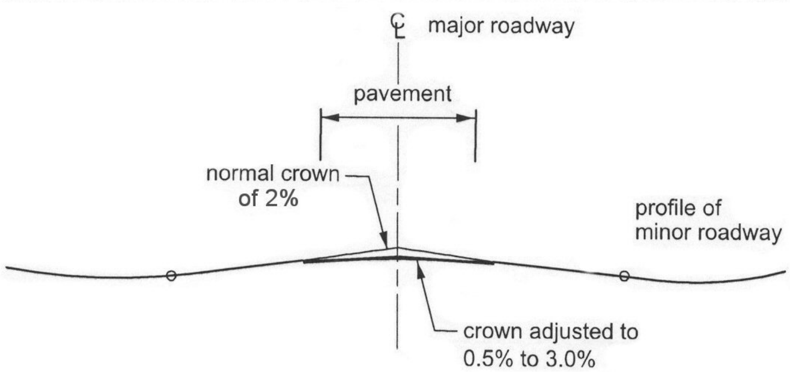


Figure 2: Illustrated in this figure is the cross slope or crown that is reduced to provide a smooth transition through the intersection for vehicles on both the major and minor roads. On gravel roads, the crown may approach 4 percent. Source: TAC, *Geometric Design Guide for Canadian Roads* (Part 2), 1999.

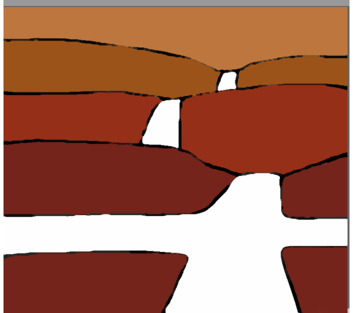
Effectiveness

The literature does not contain enough comparative results for this solution. Users are encouraged to undertake before and after studies when undertaking this type of improvement.

Solution	Collision Type	Potential Collision Reduction		Cost	Overall Cost Effectiveness
		Range	Most Likely		
Improve cross slope	All collisions	The effectiveness of this solution has not been determined		Low to high	n/a

Situation Sheet

1.9



Intersection Configuration

Background

The configuration of an intersection affects both its operational and safety performance characteristics. Different intersections create varying levels of conflict among their respective traffic streams. In the rural context, many intersection configurations are the result of historical developments in travel patterns, land development, topographical constraints, and the presence of jurisdictional boundaries. While conventional configurations usually present readily manageable challenges from a road safety standpoint, legacy intersections sometimes bring with them unique challenges and operational characteristics. Understanding and dealing with the issues to which these give rise can be a challenge. Figure 1 illustrates the range of "conventional" intersection configurations traditionally discussed in geometric design guidelines. In reviewing the road safety performance of an intersection, there may be a need on occasion to examine the potential for alternative configurations. In other cases, clarification of the configuration and improved positive guidance may be sufficient to improve intersection performance.

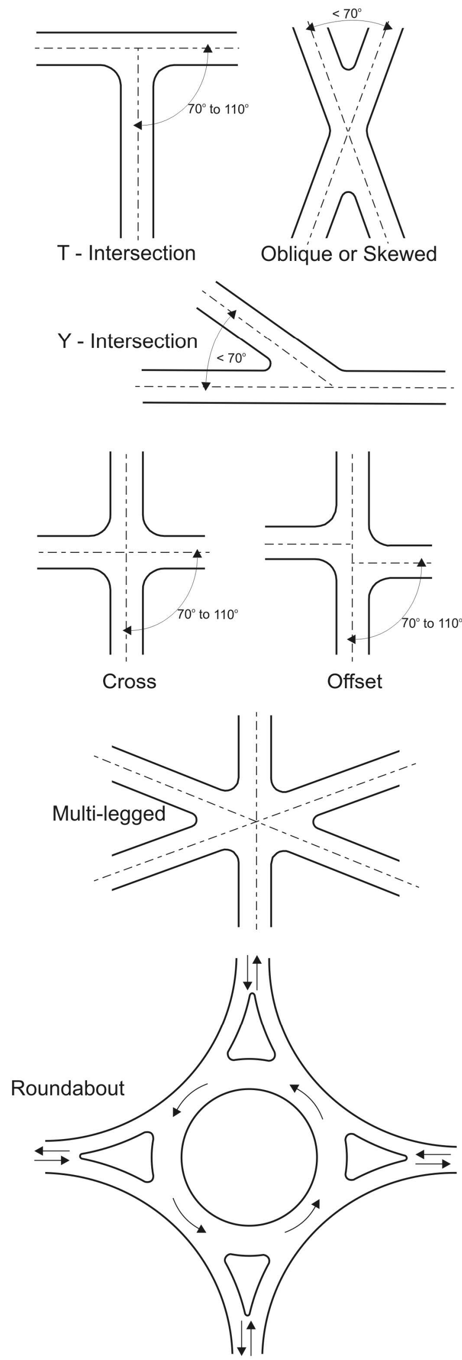


Figure 1: Intersection configurations. Adapted from *TAC Geometric Design Guide for Canadian Roads*, Figure 2.3.1.1.

Summary

Intersection configurations directly affect operational and road safety performance. In some instances, legacy configurations of historical rural intersections may be unsuited for present day traffic loadings, and an examination of the intersection in the context of potential changes in configuration may reveal some unforeseen opportunities for improvement in a difficult operational or road safety situation. In others, more traditional approaches involving signage, pavement markings, and other positive guidance measures may be more cost effective and appropriate to the situation at hand.

SITUATION SHEET 1.9

Intersection Configuration

Problems

The types of intersection configuration that create particular challenges vary widely. They can include:

- Undesirable skew angles (see Section 1.6).
- Offset intersections: inappropriate offsets (too close) may result in excessive speeds through the intersection because of the perceived relatively small offset involved.
- Offset intersections: where the minor road through movement is offset to the right, traffic travelling through on the minor road must execute left turns on the major roadway – a situation which is less desirable than having such left turns occur from the minor roadway (see Section 1.6).
- Multi-leg intersections: intersections with more than four legs are rare and violate driver expectations. They can be particularly problematic for occasional users (such as tourists), or where traffic volumes are beginning to increase to the point where the intersection traffic control is inadequate to properly manage delays. Providing adequate positive guidance and natural travel paths in such situations can be particularly challenging.
- Rotary or legacy traffic circle intersections: In some places in Canada, legacy rotary or traffic circle intersections are used in rural situations where relatively high-speed traffic (50km/h to 70km/h) is handled in low-deflection, large-radius, “roundabout” intersections. Little is known of the safety record of these facilities, but they tend to violate current expectations with the advent of the modern roundabout.

Solutions

When intersection configurations appear to be the source of poor road safety performance, the root problem is generally the unexpected nature of the movements required or the additional driver workload imposed by the unusual configuration and the signing and/or other positive guidance measures provided. While a reconfiguration of the intersection may be appropriate – particularly in the context of its historical development (as illustrated in Figure 2), it is often more cost effective and realistic to approach the solution from the standpoint of addressing the root driver guidance and informational needs.

Typical solutions could include:

- Installation of advance warning signs to spread information loading for drivers and provide notice of unexpected or unusual situations.
- Installation of overhead flashing beacons to increase conspicuity of the intersection (may not be suitable for high skew angle intersections).
- Improve the skew angle of approach intersection legs where this appears appropriate and possible (see Section 1.6).
- Assess the potential of a modern roundabout configuration to deal with such situations (see Section 1.4).

Figure 2: A Before and After view of a five-way intersection in rural Prince Edward Island. In the After situation (shown in the right-hand image), the northbound approach has been realigned to meet with the through road east of the intersection. This example shows an imperfect solution to the problem, since two other legs still intersect at skewed angles, and the design also allows for serious movement conflicts. This was presumably deemed acceptable by the local authority due to the very low volumes on the minor legs. (*Courtesy:* Province of Prince Edward Island)

Figure 3: A flashing beacon has been included at this four-legged intersection.

Effectiveness

The following solutions are listed in order of overall cost effectiveness.

Solution	Collision Type	Potential Collision Reduction		Cost	Overall Cost Effec-tiveness
		Range	Most Likely		
Install advance warning signs *[TAC (2004), Iowa DOT]*	Total collisions	20% to 35%	25%	Low	High
Overhead flashing beacon *[TAC (2004), Kentucky DOT]*	Total collisions Right-angle collisions Rear-end & left turn collisions	30% to 50% 0% to 25% 10% to 15%	30% 20% 10%	Low Low Low	High High Medium
Improve skew angle *[TAC (2004), Iowa DOT, NCHRP 500, Vol. 5]*	Total collisions	30% to 50%	35%	Medium to high	Low to medium
Install modern roundabout *[NCHRP 500, Vol. 5]*	Total collisions Injury and fatal collisions Rear-end collisions	38% to 58% 90% May increase	50% 90% n/a	High	Medium

Additional Information

This Situation Sheet contains references to topics contained in the following other sections:

1.6 Intersection Skew

5.4 Large Number of Heavy Vehicles

References

1. Fitzpatrick, K., Balke, K., Harwood, D.W. & Anderson, I.B., "Accident Mitigation Guide for Congested Rural Two-Lane Highways", Transportation Research Board, 2000.

2. Preston, Howard, Schoenekar, Ted, "Bypass Lane Safety, Operations, and Design Study", Minnesota Department of Transportation, 1998-1999.

3. Neuman, Timothy R., Pfefer, Ronald, Slack, Kerwin L., Kennedy, Hardy, Kelly, Hamood, Douglas W., Potts, Ingrid B., Torbic, Daren J., Lohlman Rabbami, Emilia R., *NCHRP Report 500: Guidance for Implementation of the AASHTO to Strategic Highway Safety Plan Volume 5: A Guide for Addressing Unsignalized Intersection Collisions*, TRB, 2003.

4.Underwood, Robin, "Some Aspects of Traffic Operations on Two-Lane Rural Roads – Some Australian Experiences". Compendium of Technical Paper for the 66th ITE Annual Mtg. ITE, 1996.

2

Visibility

Situation Sheet

2.1

Intersection Sight Distance

SITUATION SHEET 2.1

Intersection Sight Distance

Background

Intersections are areas of high driver workload. In such locations, the need to provide excellent sightlines is critical to the safety performance of the intersection. Intersection sight distance requirements are set out in a variety of publications including the TAC *Geometric Design Guide for Canadian Roads*.

Figure 1:
The minimum sight distance needed is dependent on the speed of the approaching vehicles on the roadway . Source: *Access Management Manual*, TRB, 2003.

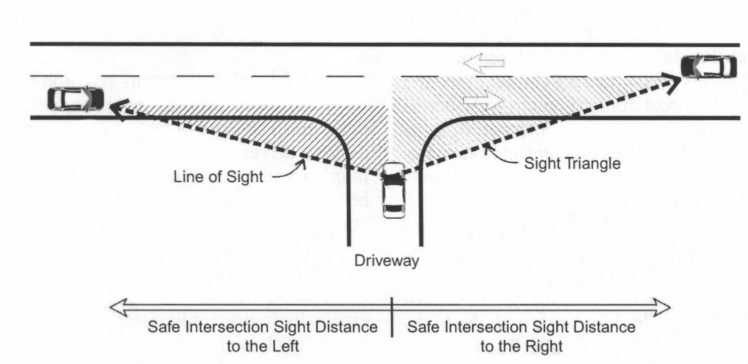


Figure 2:
The signs in this photo have obstructed the sight distance for vehicles waiting to enter the intersection.

Summary

Adequate sight distances should be maintained at all corners of an intersection. Where required sightlines are obstructed by an obstacle, the obstacle should be removed. If this is not possible a review of the type of traffic control should be carried out. Other low-cost options include relocating the stop bar to maximize the visibility for a stopped vehicle.

Problems

- Sight distance obstructions increase the risk of collisions at rural intersections by reducing the time available for a driver to identify a vehicle, make a decision, and react. Obstructions can include vegetation, buildings, fences, electrical boxes, signs, horizontal or vertical curves, or snow banks.
- Poor sight distance at intersections may increase the potential for collisions. During the winter season snow clearing can also create sight obstructions.

Figure 3: The presence of trees has reduced the sight distance to approaching vehicles at this intersection. While the problem is not notable in this photograph, snow accumulation can also be a significant cause of poor visibility at intersections.

Solutions

Uncontrolled intersection countermeasures may include [1]:

- Cutting back vegetation and/or embankments, and removing/relocating walls, fences, signs or other obstructions to increase the visibility to the left and right of the intersection (as illustrated at right).
- Placing two-way stop signs on the minor roadway where desired sight distance values cannot be obtained in all four approaches to the intersection.

Stop-controlled intersection countermeasures may include [1]:

- Cutting back vegetation and/or embankments to increase the visibility to the left and right of the intersection. This is also appropriate for signalized intersections.
- Removing walls, fences, signs or other obstructions to increase the visibility to the left and right of the intersection.
- Relocating the painted stop bar closer to the intersection to provide greater sight distances for the driver.
- Installing all-way stop signs (Stop signs on all approaches to the intersection).

Other countermeasures may include:

- Ensuring winter maintenance does not create unnecessary sight line obstructions.

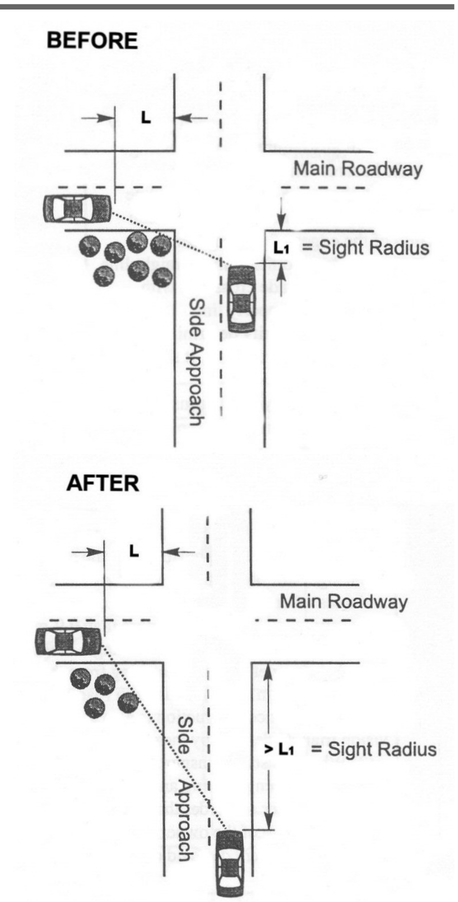
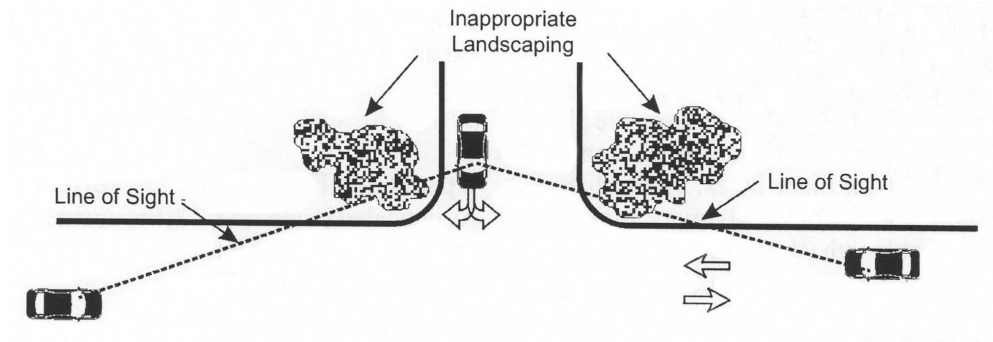


Figure 4: Clearing sight obstructions near intersections is considered a low-cost process but some obstacles such as buildings, or environmentally sensitive features may not feasibly be removed/relocated. Studies indicate that clearing vegetation or roadside objects such as signs may potentially reduce the collisions by 20 percent [2]. Source: *Access Management Manual*, TRB, 2003.

Solutions (con't)

Figure 5:
In order to increase the visibility to the left and right of the intersection, it is sometimes necessary to cut back vegetation and/or embankments.
Source: *Access Management Manual*, TRB, 2003.



Effectiveness

Numerous solutions are available, with potential collision reductions of up to 60 percent noted in some studies. **Solutions are listed in order of overall cost effectiveness. Note that warrants should be used for some of these solutions.**

Solution	Collision Type	Potential Collision Reduction		Cost	Overall Cost Effectiveness
		Range	Most Likely		
Install 2-way stop control if warranted *[TAC(2004), Ogden, Iowa DOT]*	Total collisions Rear-end collisions	Up to 60% Increase of 40% to 60%	40%	Low	High
Convert to all-way stop control if warranted *[TAC (2004), Lovell & Hauer, Iowa DOT, NCHRP 500, Vol. 5]*	Total collisions	45% to 55%	50%	Low	High
Install 2-way yield control if warranted *[Ogden]*	Total collisions	10% to 20%	15%	Low	Medium
Increase sightlines *[Ogden, TAC(2004), Georgia DOT, Iowa DOT]*	Total collisions	15% to 50%	30%	Low to high	Low to high

Additional Information

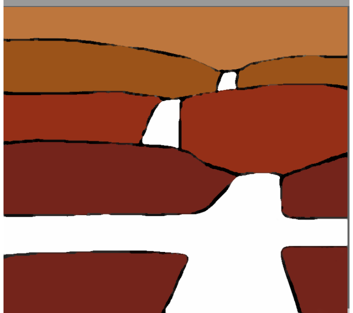
This Situation Sheet contains references to topics contained in the following section:

5.1 Maintenance Activities

References:

1. Fitzpatrick, K., K. Balke, D. W. Harwood & I. B. Anderson, *Accident Mitigation Guide for Congested Rural Two-Lane Highways*, Transportation Research Board, 2000.

2. Neuman, Timothy R., et al, *NCHRP Report 500: Guidance for Implementation of the AASHTO to Strategic Highway Safety Plan Volume 5: A Guide for Addressing Unsignalized Intersection Collisions*, TRB, 2003.



Stopping Sight Distance

Background

> *The avoidance of collisions and the efficiency of traffic operations depend to a large extent on the judgment, capabilities and responses of individual drivers. Therefore the provision of sufficient sight distance for drivers to perceive potential conflicts and to carry out the actions needed to negotiate an intersection safely is essential* [1].

The minimum sight distance criterion for vehicles approaching an intersection is stopping sight distance. The value used in any given situation is based on the design speed. On occasion relatively complex situations are encountered at an intersection that make it desirable to provide more than the stopping sight distance. In these cases, provision of "decision sight distance" (DSD) is desirable. This concept was introduced in Canada only in 1986. As a result, there are numerous roads in the country that do not incorporate DSD considerations in the design.

The increased weight and variable braking characteristics of trucks and buses typically increase the required stopping distance for these vehicles; however truck and bus drivers can typically see further than a passenger car due to an increased driver eye height. Although this advantage often extends the stopping sight distance available for trucks and buses, in some instances there is no advantage. Examples include horizontal sight distance restrictions and sag vertical curves where visibility is cut off by an overhead obstruction.

> **Decision sight distance** is the distance required for a driver to detect an unexpected or otherwise difficult-to-perceive information source or hazard in a roadway environment that may be visually cluttered, recognize the hazard or its potential threat, select an appropriate speed and path, and initiate and complete the required safety maneuver safely and efficiently. Because decision sight distance gives drivers additional margin for error and affords them sufficient length to maneuver their vehicles at the same or reduced speed rather than to just stop, its values are substantially greater than the stopping sight distance.
>
> *AASHTO, A Policy on Geometric Design of Highways and Streets, 1994 (pp. 126-127).*

Problems

Poor sight distance contributes to:

- Inability to perceive the intersection to react as necessary.
- Inability to perceive the intersection control measures to react as necessary.
- Inability to perceive the back of an intersection vehicle queue to react as necessary.
- Lack of conspicuity in flat rural areas. Adequate sight distance may be available, but the intersection may simply not be noticed.

Summary

The physical distance that a driver requires to identify and react to a potential hazard is termed sight distance. The minimum sight distance criterion for vehicles approaching an intersection is stopping sight distance. Complex situations may make it desirable to provide more than the stopping sight distance to enhance safety. In this case, the use of design sight distance (DSD) is recommended.

Figure 1: The intersecting road is located on the inside of a curve and there is vegetation near the road. The situation offers very poor visibility, particularly for left-turning traffic from the minor leg. To improve overall visibility and stopping sight distance on the major road, vegetation should be cut back to enable passing drivers time to see the exiting traffic. Also note the lane striping on the major road, which is continuous through the intersection. Proper practice is to break the markings as they pass through an intersection.

Solutions

Potential countermeasures include:

- Increase the available stopping sight distance on a horizontal curve by removing obstructions to obtain lateral clearance.
- Modify horizontal and vertical alignment to obtain required sight distance.
- Improve signing and delineation.
- Install larger warning or regulatory signs if warranted.
- Provide intersection lighting.
- Install transverse rumble strips on the minor approach to the intersection.

Collisions related to failure to yield or failure to stop are a common problem. Where it is determined that this is due to the limited sight distance, a number of jurisdictions take the following staged approach to countermeasures [2]:

- Install Stop Ahead sign.
- Increase the size of the Stop or Stop Ahead sign.
- Add a flashing red beacon or intersection control red/amber beacon.
- Place actuated flashers on the top of Stop sign.

Other countermeasures may include:

Provide turn lanes or prohibit left turns (refer to Situation Sheets 1.4, 1.5).

- Install or improve advance warning signs.
- Provide improved delineation of intersection.

While the signage can be effective countermeasures, it is important to avoid excessive signage that results in clutter (see Situation Sheet 3.4 Sign Clutter).

Also noteworthy: the flashing symbolic "signal ahead" sign has been found to be effective. In contrast, "Prepare to Stop when Flashing" signs have been found to be the warning sign most often incorrectly identified by drivers [3].

In Praise of the Dust Plume

There was a time when it was usual for low-volume rural roads to go unpaved. Paved roads allow vehicles to travel faster today but, paradoxically, this may have contributed to a higher rate of collisions at intersections, particularly in flat farm country. With a gravel road, a vehicle would generate a plume of dust as it travelled along. Oncoming traffic could readily see the approach, and could take appropriate action at the intersection. This opportunity occurs less and less in rural areas. Paved roads offer a smoother ride, but there is no ready substitute for a good plume of dust!

Effectiveness

A range of measures shown below have demonstrated potential for collision reduction related to stopping sight distance. **Solutions are listed in order of overall cost effectiveness.**

Solution	Collision Type	Potential Collision Reduction		Cost	Overall Cost Effectiveness
		Range	Most Likely		
Install advance warning signs *[TAC (2004), Iowa DOT]*	Total collisions	20% to 30%	25%	Low	High
Install proper pavement markings *[TAC (2004), Ogden & Iowa DOT]*	Total collisions at signalized intersections	20% to 45%	30%	Low	High
	Total collisions at unsignalized intersections	15% to 20%	15%	Low	Medium
Transverse pavement markings/rumble strips *[TAC (2004)]*	Total collisions	40% to 60%	40%	Low	High
Intersection lighting *[Ogden, TAC (1997), Vermont DOT]*	Nighttime collisions	20% to 50%	40%	Medium	Medium
Improve sightlines on horizontal curve *[TAC (2004), Ogden, Georgia DOT, Iowa DOT]*	Total collisions	15% to 50%	30%	Low to high	Low to high
Flatten vertical curve *[Ogden, Iowa DOT]*	Total collisions	40% to 50%	40%	High	Low
Overhead flashing beacon *[TAC (2004), Kentucky DOT]*	The effectiveness of this solution has not been satisfactorily quantified			Low	n/a
Install larger Stop sign *[NCHRP 500, Vol. 5]*	The effectiveness of this solution has not been satisfactorily quantified			Low	n/a

Additional Information

This Situation Sheet contains references to topics contained in the following other sections:

1.4 Turning Lanes

1.5 Acceleration Lanes

3.3 Pavement Markings

3.4 Sign Clutter on Intersection Approaches

References:

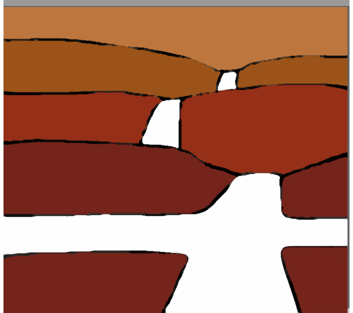
1. Transportation Association of Canada (TAC), *Geometric Design Guide for Canadian Roads*, September 1999 (Section 2.3.3.1).

2. U.S. Department of Transportation Federal Highway Administration, *Toolbox of Countermeasures and Their Potential Effectiveness to Make Intersections Safer*, April 2004.

3. Fitzpatrick, Kay, Angelia H. Parham, Marcus A. Brewer, *Treatments for Crashes on Rural Two-Lane Highways in Texas*, Texas Department of Transportation, 2002. *Note:* TAC published an *Advanced Warning Flashers Application and Installation Guide* in 2005. However a companion study of AWF effectiveness was still underway at press time. For up-to-date information see tac-atc.ca on the World Wide Web.

Situation Sheet

2.3



Sign and Traffic Signal Visibility

Background

For any intersection of any kind to function properly all signs, traffic signals and other positive guidance elements must be clearly visible and conspicuous to the driver. Failure to provide visible and conspicuous information to the driver in a timely and appropriate manner will compromise the safety performance of the intersection.

Figure 1: Late summer is often a time when warning signs can be obscured by overgrown vegetation. In winter, snow can also be a significant factor in obscuring signage.

Problems

Poor visibility of signs and traffic signals may result from a number of factors including:

- Obstructions.
- Condition of sign face and in particular, lack of retroreflectivity at night.
- Sign size (too small for conditions).
- Font size sign too small for conditions.
- Excessive signing and sign clutter (see section 3.4).
- Use of non-standard signs.
- Improper placement/mounting of traffic signs.
- Improper placement/mounting of traffic signal installations.
- Improper specification of traffic signal equipment (lens size, backboard, lens visors, supplementary signal heads, and so forth).
- Conflict with unrelated background sign or building clutter.

Summary

Failure-to-stop or failure-to-yield collisions are sometimes the result of poor traffic control device visibility. Ensure that signage is not obscured, that rural intersections are identifiable from the driver's perspective, and that all signs and positive guidance elements are conspicuous, visible, legible, and readily identifiable.

SITUATION SHEET 2.3

Sign and Traffic Signal Visibility

Solutions

The condition of the sign or traffic signal should be monitored through a maintenance schedule as discussed in Situation Sheet 5.1.

Countermeasures to improve the visibility of sign traffic controls include [1]:

- Remove obstructions.
- Increase the sign size if warranted.
- Use larger letters on the sign.
- Illuminate the sign or intersection.
- Upgrade retroreflective material used for the sign.
- Add beacons on advanced warning signs if warranted.
- Reduce sign clutter (refer to Situation Sheet 3.4).

Countermeasures to improve the visibility of traffic signals include [1]:

- Install/improve advance warning devices.
- Install larger signal lenses.
- Install lens visors.
- Install back plates to enhance the contrast between the signals and their surroundings – especially effective on east-west approaches experiencing sun glare [2].
- Improve location of signal or signal heads.
- Use additional signal heads if warranted.
- Remove sight obstructions.
- Increase the amber phase.
- Consider advance warning flashers (AWF).

If sign or traffic signal non-compliance occurs at night, consider illuminating the intersection (refer to Situation Sheet 2.4).

One source suggests that rumble strips do not reduce failure-to-stop crashes [3]; however a number of agencies use transverse rumble strips to advise drivers of upcoming intersections/traffic control devices. One source has found that approach rumble strips reduced failure-to-stop collisions by at least 50 percent [2]. They should be placed at right angles to the vehicular traffic movement (normally on the minor road) and in such a manner that they do not adversely affect the pavement skid resistance under wet/dry conditions.

Figure 2: Damage to a Stop sign and No Entry sign (the back of which is visible) was probably caused by a snow plough. It has rendered the No Entry sign virtually impossible to read and has reduced the legibility of the Stop sign. Damage like this should be repaired immediately on discovery.

Effectiveness

Rural intersections are often difficult to identify from the driver's perspective, and in some cases the Stop/Yield signs or traffic signals are also difficult to identify. There is a wide slate of cost-effective solutions available. The table differentiates between unsignalized and signalized rural intersections and includes some solutions that are not quantified. **Solutions are listed in order of overall cost effectiveness.**

Solution	Collision Type	Potential Collision Reduction		Cost	Overall Cost Effectiveness
		Range	Most Likely		
Unsignalized					
Remove sign/signal sight obstructions *[Iowa DOT]*	Total collisions	45%	45%	Low to high	Medium to high
Install post-mounted delineators *[Ogden, Vermont DOT]*	Total collisions	20% to 30%	25%	Low	Medium to high
Install intersection lighting *[Ogden, TAC 2004, Iowa DOT]*	Nighttime collisions	20% to 75%	40%	Medium	Medium
Install transverse rumble strips *[NCHRP 500, Vol. 5]*	Failure-to-stop/rear-end collisions	Up to 50%	50%	Medium	Low to high
Signalized					
Install yellow back plates on traffic signal heads *[TAC 2004]*	Left-turn collisions	15% to 30%	15%	Low	Medium to high
Improve the location of the traffic signal heads *[TAC 2004]*	Total collisions	25% to 40%	30%	Medium	Medium
Increase the size of the signal light *[TAC 2004]*	Total collisions	10% to 20%	15%	Low	Medium
Install advance warning flashers *[Sayed, et al]*	Total collisions	8% to 18%	10%	Low	Medium
Not Quantified					
Improve sign sheeting quality	n/a	Commonly used measure		Low	n/a
Install overhead flashing beacons *[NCHRP 500, Vol. 5]*	Has not been satisfactorily quantified			Low	n/a
Increase font size on signs	Has not been satisfactorily quantified			Low	n/a
Install larger Stop sign *[NCHRP 500, Vol. 5]*	Has not been satisfactorily quantified			Low	n/a

Additional Information

This Situation Sheet contains references to topics contained in the following other sections:

2.4 Intersection Lighting

3.4 Sign Clutter on Intersection Approaches

5.1 Maintenance Activities

References

1. Fitzpatrick, K., K. Balke, D.W. Harwood & I.B. Anderson, *Accident Mitigation Guide for Congested Rural Two-Lane Highways*, Transportation Research Board, 2000.

2. Fitzpatrick, Kay, Angelia H. Parham, Marcus A. Brewer, *Treatments for Crashes on Rural Two-Lane Highways in Texas*, Texas Department of Transportation, 2002.

3. Preston, Howard & Richard Storm, *Reducing Crashes at Rural Thru-Stop Controlled Intersection*, CH2M Hill, n.d.

Situation Sheet

2.4

SITUATION SHEET 2.4

Intersection Lighting

Intersection Lighting

Background

Nighttime illumination of rural intersections provides additional light to that of vehicle headlights and often indicates to a driver that particular attention is needed on the approach to the lighted area.

It is not cost effective to provide such lighting in all cases. The quality and quantity of illumination required can vary depending on the road surface reflection characteristics, and other factors including the presence of pedestrians. Full intersection lighting provides coverage of an intersection in a uniform manner over the travelled portion of the roadway. Partial lighting only provides illumination of key decision areas, potential conflict points, and/or hazards in and on the approach to an intersection. On occasion, illumination is provided simply to mark an intersection. This lighting is typically referred to as sentry or delineation lighting. [2]

Figure 1: Lighting is generally not cost effective in rural applications. It may be justified however where pedestrians are frequent or where the nature of collisions indicates that there is a problem with conspicuity of the intersection at night.

Problems

Poor visibility at night contributes to the following:

- Difficulty recognizing and locating the intersection.
- Difficulty recognizing and locating Stop/Yield signs and traffic signals.
- Difficulty identifying roadside hazards, horizontal curves and vertical curves at the intersection.

Poor lighting can be as troublesome as no lighting, especially if there are pedestrians:

- Poorly designed lighting may create shadows that "hide" pedestrians and thus increase the risk of pedestrian/vehicle collisions.

Summary

Lighting should provide a uniformly lit road surface against which vehicles, pedestrians (if there are any) or other objects are seen in silhouette. Poorly lit intersections are hard to detect and have dark spots that hide vulnerable users and roadside obstacles. A history of a substantial number of nighttime rear-end, right-angle or turning collisions may indicate a problem with intersection visibility at night. In such conditions, illumination should be considered.

Solutions

The installation of roadway lighting will do three things [3]:

- Identify to drivers exactly where the intersection is located, thus improving driver perception and reaction time.
- Enhance a driver's available sight distance.
- Improve the visibility of non-motorists (vulnerable road users).

To determine if nighttime visibility is a problem at a particular intersection, the practitioner should look for substantial patterns in nighttime crashes. In particular, nighttime rear-end, right-angle or turning crashes may indicate a problem with visibility.

Providing sufficient illumination where there is none may result in a reduction of collision severity [4] and a reduction in nighttime collisions of 20 to 50 percent [1 and 3].

Any lighting installation should attempt to reduce the contrast between the dark roadway on the approach to the intersection and the brightly lit intersection. This can be achieved through a proper illumination plan and the location of the individual luminaires. Existing installations should be evaluated to ensure that there are no dark spots that could lead to collisions, especially those involving pedestrians.

If a power source is not available to provide illumination at the intersection, alternative measures may be taken:

- Use signs with upgraded retroreflective sheeting.
- Update pavement markings with durable finishes offering sufficient retroreflective properties, or use reflective delineators on the roadside to help provide guidance to drivers.

For additional guidance refer to TAC's guide to *Illumination of Isolated Rural Intersections,* which provides a new Canadian warrant for illumination of rural intersections. The warrant indicates whether full intersection lighting, partial lighting or delineation lighting is needed, and provides a method for selecting and prioritizing intersections at which lighting will be beneficial. It also identifies an appropriate lighting system.[2]

Figure 2: Although this is an urban intersection, the effect of durable pavement markings is still evident. Such a treatment may be employed at rural intersections where it is not possible to provide illumination.

Figure 3: Pedestrians are much more visible when roadway lighting is installed.

Effectiveness

Where it is determined that illumination is required, it is important to ensure a properly designed installation. Lighting should provide a uniform amount of light, where intended, on the roadway against which vehicles, pedestrians or other objects can be identified.

Solution	Collision Type	Potential Collision Reduction		Cost	Overall Cost Effectiveness
		Range	Most Likely		
Install intersection lighting *[Ogden, TAC (1997), Iowa DOT, NCHRP 500, Vol. 5]*	Nighttime collisions	20% to 50%	40	Medium	Medium to high
Install intersection lighting *[Ogden, TAC (1997), Iowa DOT]*	Nighttime collisions	20% to 75%	40	Medium	Medium

Additional Information

References:

1. Preston, Howard, Schoeneker, Ted, *Safety Impacts of Street Lighting at Isolated Rural Intersections*, Minnesota Department of Transportation, 1998-1999.

2. Transportation Association of Canada, *Illumination of Isolated Rural Intersections,* 2001.

3. Neuman, Timothy R., Pfefer, Ronald, Slack, Kerwin L., Kennedy, Hardy, Kelly, Hamood, Douglas W., Potts, Ingrid B., Torbic, Daren J., Lohlman Rabbami, Emilia R., *NCHRP Report 500: Guidance for Implementation of the AASHTO to Strategic Highway Safety Plan Volume 5: A Guide for Addressing Unsignalized Intersection Collisions*, TRB, 2003.

4. Wolshon, Brian, *Toolbox on Intersection Safety and Design*, Chapter 5 - Geometric Design, ITE, Sept. 2004.

3

Signs, Signals and Pavement Markings

Situation Sheet

3.1

SITUATION SHEET 3.1

Intersection Control

Intersection Control

Traffic Signals, Stop Signs and Advanced Techniques

Background

The control of traffic flows in intersections can be achieved through a variety of strategies ranging from the use of two-way minor-road stop-controlled intersections to full four-way traffic signals. A variety of technologies is available for traffic control purposes, and the selection of the appropriate technique and control strategy is normally determined by some kind of warrant procedure.

When traffic control devices and technologies are properly selected, designed, and located, they provide vital information to road users in a timely and efficient manner and thus help ensure driver and pedestrian compliance with traffic regulations. This in turn can help substantially improve the safety performance of such intersections.

Figure 1: This three-legged intersection has Stop or Yield signs on each leg. Caution must be given to permitting such applications. If all-way controls cannot be defended by warrants, they should not be used. Note: the Yield sign is inappropriately applied in this situation.

Summary

Choosing the correct traffic control strategy for an intersection is critical to its successful long-term operational and safety performance. Such strategies are normally selected based on specific warrants – an essential step in the planning and design process. Improper use of traffic control devices can result in driver frustration, poor operational performance, reduced driver compliance, and degraded safety performance.

Problems

Improper use of traffic control devices can result in driver frustration, poor operational performance, reduced driver compliance, and degraded safety performance. In particular, the following problems may be observed:

- A collision history that displays a high proportion of right-angle and turning movement collisions;
- Elevated speeds through the intersection, possibly contributing to high severity collisions – particularly in rural areas;
- Excessive delays that lead to driver frustration and non-compliance with traffic regulations – thus increasing the risk for all users of the intersection;
- Red-light running: primarily in urban areas but also evident in small rural settlement communities along major highways carrying significant volumes of traffic;
- The use of traffic signals at isolated rural intersections: such signals violate driver expectations and can present a major hazard to drivers using the facilities upon which they are located. Collisions occurring at such rural intersections generally involve high speeds and high severity outcomes including both serious injuries and fatalities.
- Other unwarranted and inappropriate deployments of traffic control devices – such as stop or yield signs - that are not expected by drivers particularly on the major road legs of rural intersections.

Solutions

Before any traffic control device is installed or if there have been a number of incidents occurring at an intersection, applicable warrants should be used to determine whether traffic signals, all-way stop controls, or two-way stop or yield controls are warranted.

Where Stop signs are warranted, ensure the signage is the appropriate size and gives the right message (refer to Situation Sheet 3.2 - Road Signs). Also ensure that there is consistency in the traffic control devices used at similar intersections.

Where signals are not warranted but there are numerous collisions on record, an intersection control beacon should be considered. Depending on the situation, the beacon would flash yellow in two directions, red in two directions, or all-way red beacons with Stop signs. Care should be taken in the use of all-way stop controlled intersections in rural situations. As noted elsewhere in this handbook, the effectiveness of overhead beacons has not been quantified

Where signals are warranted, signal phasing should be assigned for the volumes in each direction and determination of the need for a dedicated phase should be made (refer to Situation Sheet 1.4 on turning lanes at intersections).

The FHWA has proposed an alternative low-cost approach to improving intersection conspicuity and speed management. It is intended for two-way-stop-controlled intersections on high-speed, two-lane, two-way rural roads. The concept (Figure 2) is largely untried in North America but it holds promise (see illustrations below). The Agency is seeking jurisdictions willing to test the concept [2].

While modern roundabouts can provide a suitable alternative to both Stop and Signal controlled intersections, they have not been widely deployed in Canada in high-speed rural environments. Until such time as

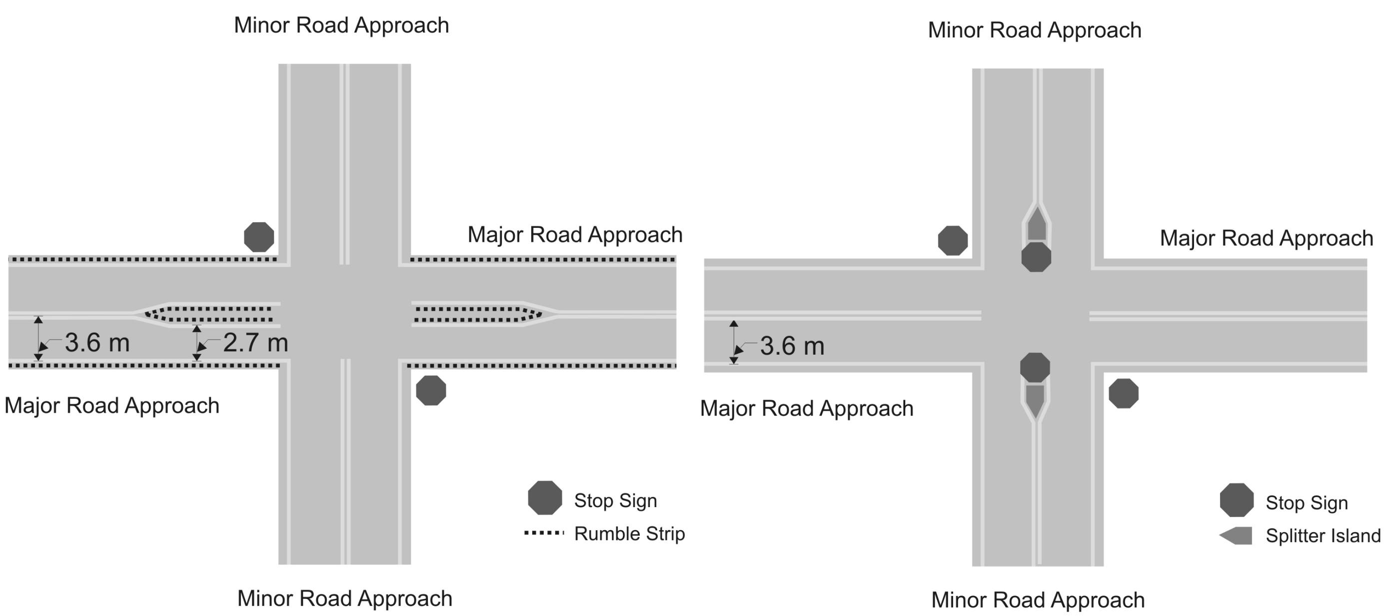


Figure 2: FHWA's proposed low-cost improvements for rural intersections. In the sketch at left, the major approaches are narrowed from the standard 3.6 metres (12 feet) to 2.7 metres (9 feet) by the use of striping and rumble strips. The measures are intended to improve driver awareness of the minor leg and, through narrowing the laneway, to reduce travel speed through the intersection. In the sketch at right, all changes are to the minor leg. Here the lanes are narrowed using channelization or splitter islands, which require the driver to slightly alter the travel path when coming to a stop. The design is expected to reduce the frequency of drivers running Stop signs. Again, this design increases driver awareness of the intersection and channelizes the traffic on the minor road approaches. The design has been successfully applied in Alberta, as well as overseas in France and New Zealand. The FHWA also proposes that the two concepts could be combined into a single application where deemed necessary.

domestic experience with this technology in this application has been gained and assessed, considerable caution should be exercised in their use in the rural intersection context. Finally, remember that the excessive use of specific devices where not warranted can result in driver disregard or contempt. It is also a common mistake to assume that signals will necessarily make a dangerous intersection safer.

Effectiveness

Most road agencies have adopted warrant processes to determine an appropriate type of intersection control for individual intersections.

Solution	Collision Type	Potential Collision Reduction		Cost	Overall Cost Effectiveness
		Range	Most Likely		
Install 2-way stop control if warranted *[TAC (2004), Ogden, Iowa DOT]*	All collisions Rear-end collisions	Up to 60% Increase of 40% to 60%	40%	Low	High
Convert to all-way stop control if warranted *[TAC (2004), Lovell & Hauer, Iowa DOT, NCHRP 500, Vol. 5]*	All collisions	45% to 55%	50%	Low	High
Remove unwarranted traffic signals *[TAC (2004), Iowa DOT]*	All collisions Rear-end collisions Right-angle collisions	30% to 55% Up to 70% Up to 50%	35% 20% Increasingly ineffective	Low Low	High Medium
Install traffic signal at unsignalized intersection if warranted *[Ogden, Iowa DOT, TAC (2004)]*	Total collisions Turning collisions Right-angle collisions Rear-end collisions Injury and fatal collisions	20% to 35% Increase of 20% to 100% 30% to 80% Increase of 30% to 70% 25% to 30%	25% Ineffective 50% Ineffective 25%	Medium	Low to high.
Install 2-way yield control if warranted *[Ogden]*	All collisions	10% to 20%	15%	Low	Medium
Overhead flashing beacons *[NCHRP 500, Vol. 5]*	The effectiveness of this solution has not been quantified.			Low	n/a

Additional Information

This Situation Sheet contains references to topics contained in the following other sections:

1.4 Turning Lanes

2.1 Intersection Sight Distance

3.2 Road Signs

5.4 Large Number of Heavy Vehicles

References

1. *Traffic Control Devices: Uses and Misuses,* FHWA Intersection Safety Brief No. 6, 2004.
2. *Concept Illustration Video: Proposed low cost treatments for two way stop controlled intersections on high speed two lane two way rural highways*, FHWA, 2005

Road Signs

Background

- Road signs provide vital information to drivers so that they may make appropriate decisions at the correct time. They may provide directional assistance, travel information, warnings, or regulatory direction. Signing is highly standardized across the country through the Manual on Uniform Traffic Control Devices for Canada (MUTCDC). In many cases, Provinces have elected to supplement the direction provided by the MUTCDC with supplementary legislation and regulations that complement, but do not conflict with the national guide.
- Sign formats, sizes, applications, placement, symbology, and wordings are all covered under the MUTCDC provisions. The use of non-standard signs violates driver expectations and can be expected to create difficulties for drivers of any facility upon which they are deployed.

Figure 1: Example of inadequate signage. The intersection lacks stop controls either because the sign is missing or because it is obscured by overgrown vegetation. Some jurisdictions, including Saskatchewan, will permit this application on low-volume rural intersections.

Summary

Road signage is a vital component of any effective road system. It provides essential direction and guidance to the road user, and as such, is highly standardized across the country. Compliance with standardized signing practices helps ensure that driver expectations are met and thus encourages both compliance and appropriate driver behaviour - particularly in critical driver decision situations.

Problems

Potential problems include:

- Lack of signage (missing or damaged).
- Non-standard design and sign inconsistency.
- Sign clutter detracts from sign effectiveness.
- Poor maintenance.
- Signage not located in proper location.
- Signage obscures sightlines at the intersection.
- Poor retroreflective properties or loss of retroreflectivity over time.
- Signs are out of alignment with driver line of sight.
- Signs not visible due to obstructions such as overgrown foliage.
- Inappropriate application of a regulatory sign.
- Signs not mounted at proper height or perpendicular to the driver's view.

Solutions

Countermeasures for collisions arising from inadequate signs include [2]:

- Understand and adhere to the design guidance provided in MUTCDC.
- Ensure sign functions are relevant and necessary and that the information is updated or replaced as necessary.
- Illuminate intersection to improve visibility of existing signage if warranted.
- Ensure signage is properly located.
- Ensure signs exhibit appropriate retroreflective characteristics.
- Verify that existing signs are still performing their required functions and conveying their message under both daytime and nighttime conditions.
- Ensure all signs are cleaned regularly and properly maintained (see also Situation Sheet 5.1).
- Ensure supporting structures are in sound condition.
- Ensure signs are not obscured by foliage or roadside installations.
- Mount signs at proper height and ensure sign post(s) are vertical and that the sign face is perpendicular to the driver's view.

Effectiveness

Solutions are listed in order of overall cost effectiveness.

Solution	Collision Type	Potential Collision Reduction		Cost	Overall Cost Effectiveness
		Range	Most Likely		
Remove sign/signal sight obstructions *[Iowa DOT]*	Total collisions	45%	45%	Low to high	Medium to High
Improve signing *[TAC (2004), TRL]*	This solution has not been satisfactorily quantified			Low	High
Relocate signs to appropriate location (including proper distance and horizontal / vertical mounting measurements)	This solution has not been satisfactorily quantified			Low	n/a

Additional Information

This Situation Sheet contains references to topics contained in the following other section:

5.1 Maintenance Activities

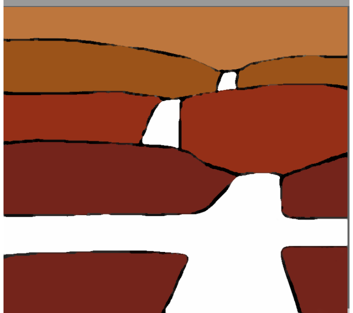
References:

1. Ogden, K. W., *Safer Roads: A Guide to Road Safety Engineering*, Ashgate Publishing Company, 2000.

2. Fitzpatrick, K., K. Balke, D. W. Harwood and I. B. Anderson, *Accident Mitigation Guide for Congested Rural Two-Lane Highways*, Transportation Research Board, 2000.

Situation Sheet

3.3



SITUATION SHEET 3.3

Pavement Markings

Pavement Markings

Background

Retroreflective pavement markings provide essential guidance for drivers – particularly at night or under severe weather conditions. In addition to providing critical information about a vehicle's lane position, pavement markings help delineate the horizontal alignment of a roadway – providing drivers with early cues about upcoming curves, lane drops, road narrowings, the presence of intersections, and other critical roadway features that may require a specific decision and/or action on the part of the driver.

As with road signing and traffic signal installations, the selection and application of pavement markings is highly standardized through both the *Manual of Uniform Traffic Control Devices for Canada* (MUTCDC) and specific provincial practices which are sometimes defined in legislation. As a result, the non-standard use of pavement markings should be avoided, since failure to conform to such practices will violate driver expectations and increase the risk of collisions.[1].

Figure 1: Incorrect use of road markings is as problematic as inadequate road markings. In this example, a skip dash has been applied between the travel lane and the shoulder to signify the presence of a rest stop, however it appears like a passing lane. Following MUTCDC guidelines, the proper application in this case would be a solid line. A sign would be used to denote the rest stop.

Summary

Retroreflective pavement markings provide essential guidance for drivers – particularly at night or under severe weather conditions. At intersections in particular, pavement markings can provide valuable positive guidance as to lane choice, stop locations, and appropriate travel paths through the intersection. Maintaining pavement markings in good condition with adequate retroreflective properties is essential to preserving their functionality. The application of pavement markings should always follow the practices outlined in the MUTCDC and/or associated provincial practices as defined in legislation or distinct provincial practice guidelines.

Problems

Typical problems associated with pavement markings at rural intersections include:

- Worn pavement markings that do not provide adequate guidance with respect to lane delineation, required stopping locations, pedestrian crossings, or other key intersection features. This problem is very common across the country and is generally at its worst in the late winter and early spring periods when pavement markings are often worn to their worst state of repair just prior to the spring line painting programs of most road agencies.
- Pavement markings that are present but that lack the required retroreflective properties to make them sufficiently visible under nighttime conditions.
- Lack of coordination of pavement markings with signing. In some cases, signing and pavement markings must be closely coordinated – such as the case of a STOP sign and its associated STOP BAR, or an approach lane turn designation and an overhead sign or a traffic signal installation.
- Inappropriate or non-standard use of pavement markings that may lead drivers to misunderstand the intended function of an area of pavement. Figure 1 provides a good example of such a case.

Solutions

Inadequate intersection pavement markings can lead to poor lane discipline (sideswipe collisions), inappropriate stopping locations (right angle and rear-end collisions), and a variety of errors in driver judgement that generally increase the risks of collisions at the location. A variety of countermeasures are available that can help deal with the problems noted earlier.

- The use of more durable and visible pavement markings such as thermoplastic technologies. These can help extend the life of pavement markings and can be particularly useful in areas where traffic and seasonal wear is particularly aggressive. (See Situation Sheet 5.1)
- Provide signs to supplement pavement markings. A good example of such an application is shown in Figure 2.
- Consider using retro-reflective raised pavement markers (referred to as rpm's or "cat's eyes") to highlight crosswalks or to supplement centerline markings – particularly in areas of wet climate or on highly curvilinear alignments. Caution should be exercised in the use of rpm's to highlight curvilinear alignments, since the research has shown that in some cases, such edge or centerline delineation may lead to higher operating speeds on the facility.
- If rpm's are used, they should normally be recessed or of the low-profile type to prevent their destruction in the course of winter maintenance operations.
- Consider the use of transverse rumble strips on the minor road approaches to the intersection. Such devices are intended to stimulate the driver to look around and to check for actions they may be required to take. They are normally accompanied by supplementary signing or pavement markings that provide the appropriate direction to the road user once they have passed across the strip. Such installations may be particularly appropriate in locations where sightline obstructions exist, where approach speeds are known to be excessive, or where there is a history of "Running Stop Sign" crashes (see Figure 3).
- Consider the use of the MUTCDC defined wider pavement markings as appropriate and warranted.
- Consider the addition of pavement markings on rural intersection minor road approaches where they are not currently provided if appropriate.

Figure 2: While there are no data to demonstrate their effectiveness, the use of words on the pavement in support of signage is a legitimate application. Note how the sign and pavement markings work to reinforce one another. Section D of the MUTCDC contains the appropriate specifications for the use of words on pavements. This example is from Alberta.

Figure 3: This photo illustrates the use of grooved transverse rumble strips on the approach to an intersection. This type of treatment is appropriate to rural areas where there are no residences nearby as they can be noisy. They are sometimes used on long stretches of roadway such as in the prairies when the intersection is not readily apparent, or where there is a history of "Running Stop Sign" crashes.

Effectiveness

Solution	Collision Type	Potential Collision Reduction		Cost	Overall Cost Effectiveness
		Range	Most Likely		
Install proper pavement markings *[TAC (2004), Ogden & Iowa DOT]*	All collisions at signalized intersections All collisions at unsignalized intersections	20% to 45% 15% to 20%	30% 15%	Low Low	High Medium
Double the rate of pavement marking application (i.e., twice a year) [*Iowa DOT]*	Total collisions	15%	15%	Low	Medium

Additional Information

This Situation Sheet contains references to topics contained in the following other sections:

1.2 Vertical Curves

5.1 Maintenance Activities

References:

1. Ministry of Transportation of Ontario, *Pavement, Hazard and Delineation Markings*, OTM Book 11, March 2000.

2. U.S. Department of Transportation Federal Highway Administration *Toolbox of Countermeasures and Their Potential Effectiveness to Make Intersections Safer*, April 2004.

3. Fitzpatrick, K., K. Balke, D.W. Harwood & I. B. Anderson, *Accident Mitigation Guide for Congested Rural Two-Lane Highways*, Transportation Research Board, 2000.

Situation Sheet

3.4

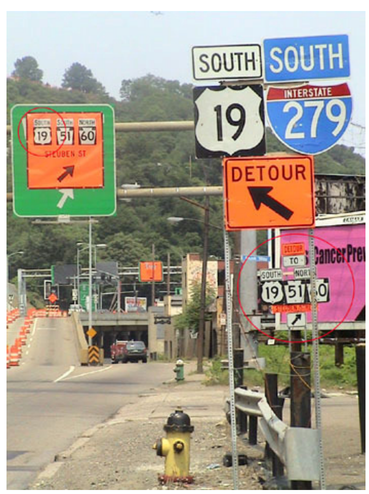
SITUATION SHEET 3.4

Sign Clutter on Intersection Approaches

Sign Clutter on Intersection Approaches

Background

Traffic signing fulfills a basic information requirement for drivers. However, excessive signing on an intersection approach may create a situation where the driver cannot discriminate critical from non-critical information. Such situations increase the chance of confusion and resulting driver error. Figures 1 and 2 illustrate the challenges that sign clutter can present, and highlight the fact that clutter may not arise directly from the required road signing per se, but may derive from commercial and other signing that is also present on the roadside.



Examples of Sign Clutter

Figure 1: Oversize sign could cause the driver to easily miss the regulatory speed reduction sign. Excessive amounts of text are often not fully comprehended by the passing driver.

Figure 2: Too many signs on a single post can be just as bad. This example of sign clutter is compounded by confusing messages.

Summary

Driver confusion may result from the presence of too much signing or “sign clutter” on intersection approaches. Eliminating unnecessary traffic signing, spreading critical signing so that the driver has more time to read and comprehend the messages being delivered, and ensuring that non-highway roadside advertising etc. does not interfere with the functionality of traffic signing are primary countermeasures that can help deal with the sign clutter problem.

Problems

Excessive signing can lead to a number of problems:

- Driver confusion resulting from an inability to sort out critical from non-critical information. Driver confusion and resulting higher driver workload has been shown to be correlated to a higher potential for collisions.
- Driver hesitation on the approach to an intersection due to uncertainty. Such hesitation can result in conflicts with adjacent and following vehicles, thus increasing the potential for sideswipe and rear-end collisions on the approach.
- Driver failure to stop at a required Stop sign. This type of error can result in very high severity collisions at two-way stop controlled minor road intersections with major high-speed highways.
- Driver failure to yield under a required Yield condition.
- Excessive speeds on the approach to intersections in situations where advance warning signs, speed advisory tabs, and other associated intersection and traffic control early warning devices are not noticed by drivers because of distractions created by roadside sign clutter.
- Excessive sign clutter may in some cases create potential sight line obstructions on the approach to, or in various quadrants of an intersection. Figure 3 illustrates this problem.

Solutions

Potential countermeasures available to deal with sign clutter include:

- Eliminate non-critical road and traffic signing.
- Spread signing farther apart in order to provide additional time for drivers to read, understand, and act upon critical information.
- Remove commercial and private signing that conflicts with and reduces the effectiveness of required road and traffic signing.
- Where way-finding is complex – such as at major entry points to tourist sites or destination areas – provide a slip-off and separated rest area with clear mapping and other supplemental information that may be useful to the driver. Such facilities are particularly effective in heavily used seasonal tourist areas.

Additional Information

This Situation Sheet contains references to topics contained in the following other section:

2.1 Intersection Sight Distance

3.2 Road Signs

Figure 3: In this variation on sign clutter, this group of signs near the intersection creates a potential visibility problem for turning vehicles that would be particularly acute in winter when snow banks would reduce the low angle view (see also 2.1 Intersection Sight Distance).

Effectiveness

Solution	Collision Type	Potential Collision Reduction		Cost	Overall Cost Effectiveness
		Range	Most Likely		
Provide adequate spacing between signs (based on local standards)	The effectiveness of this solution has not been determined			Low	n/a
Remove unnecessary signs (based on local standards)	The effectiveness of this solution has not been determined			Low	n/a

4

Rail Crossings

Situation Sheet

4.1

SITUATION SHEET 4.1

Rail Crossing Geometry

Rail Crossing Geometry

Background

Roadway geometry on the approach to a rail crossing can have a significant impact on the road safety and operational performance of the crossing. If not properly designed, crossing geometry can limit available sightlines, adversely impact the performance of crossing vehicles and contribute to undesirable driver behavior.

Figure 1: Rail level crossing at extreme angle to the road. Note the clear sightline area.

Problems

Some of the most significant issues associated with roadway geometry on the approach to a rail crossing include:

Horizontal curves

- Limited visibility (or conspicuity) of the rail crossing.
- Vegetation and other roadside obstacles limit the available lateral clearance and visibility available on the horizontal curve, and may limit stopping sight distance to the rail crossing.
- Excessive skew angles can make it difficult for drivers to see approaching trains.

Vertical grades

- Excessive roadway grades on the approach to the rail crossing can impact a vehicles ability to stop safely when necessary and to accelerate across a railway after stopping.
- Roadway grades can result in low clearance vehicles becoming caught on the tracks.
- Stopping sight distances on the approach to a rail crossing can be limited.
- Limited visibility (or conspicuity) of the rail crossing.

Summary

Although this situation sheet identifies the most significant issues typically associated with roadway geometry on the approach to a rail crossing and provides guidance on potential solutions, it is important to note that no modification to a rail crossing should be made without contacting the appropriate railway authorities and conducting a comprehensive Road/Railway Grade Crossing Safety Assessment to determine compliance with the requirements of applicable grade crossing regulations and the technical standards contained in Transport Canada's RTD10 Road/Railway Grade Crossing Technical Standards and Inspection, Testing and Maintenance Requirements document.

Problems (con't)

- Vehicle occupants may experience discomfort when crossing superelevated sections of track if the roadway profile does not match the plane of the tracks.

Close proximity of intersections/ driveways

- Vehicle queues from the intersection may extend across the railway (a problem typically encountered in suburban areas and rural towns).
- Increased driver workload and the potential for driver error resulting from the compounded decision making process required by the driver.

Clear sightline obstructions

- Sightline area obstructed by vegetation and/or terrain, activities on adjacent lands and rail/road infrastructure (control cabins, etc.)

Changing Roadway/Railway Characteristics

- Over time, the characteristics of a roadway (such as traffic volumes, vehicle operating speeds and adjacent land uses) and/or railway (maximum rail operating speeds, train volumes) may change. This can have a significant impact on the successful operational and safety performance of the crossing.

Figure 2: Railway equipment placed near the rail line and close a crossing can create blind spots for drivers and the engineer. Although there is not enough data to quantitatively demonstrate the effectiveness of moving objects from the sight triangle, it is obvious that such obstacles should be moved where possible.

Solutions

Horizontal curves

- Realign roadway to improve stopping sight distance and/or rail crossing skew angle.
- Ensure warning signs and pavement markings are consistent with MUTCDC and RTD10 requirements. Where traffic engineering studies indicate the sign is warranted, installation of a "Prepare to Stop at Railway Crossing Sign" may be appropriate (see Situation Sheet 4.2 Rail Crossing Warnings).
- Clear vegetation and remove obstacles to improve lateral sightlines on the curve.
- Install a grade crossing warning system if warranted.
- Consider illumination of the rail crossing if warranted.

Vertical grades

- Flatten grades on the approach to the rail crossing to improve stopping sight distance.
- Roadway grades on the approach to a rail crossing should be as level as possible to accommodate expected vehicle operating speeds, to ensure safe acceleration crossing times for heavy vehicles required to stop at the tracks and to prevent the hang-up of low clearance vehicles.
- On the approach to superelevated track sections, roadway grades can be modified to match the plane of the railway. Grades should safely accommodate the expected operating speeds for the roadway facility.
- Ensure warning signs and pavement markings are consistent with MUTCDC and RTD10 requirements. Where traffic engineering studies indicate the sign is warranted, installation of a "Prepare to Stop at Railway Crossing Sign" may be appropriate (see Situation Sheet 4.2 Rail Crossing Warnings).

Solutions (con't)

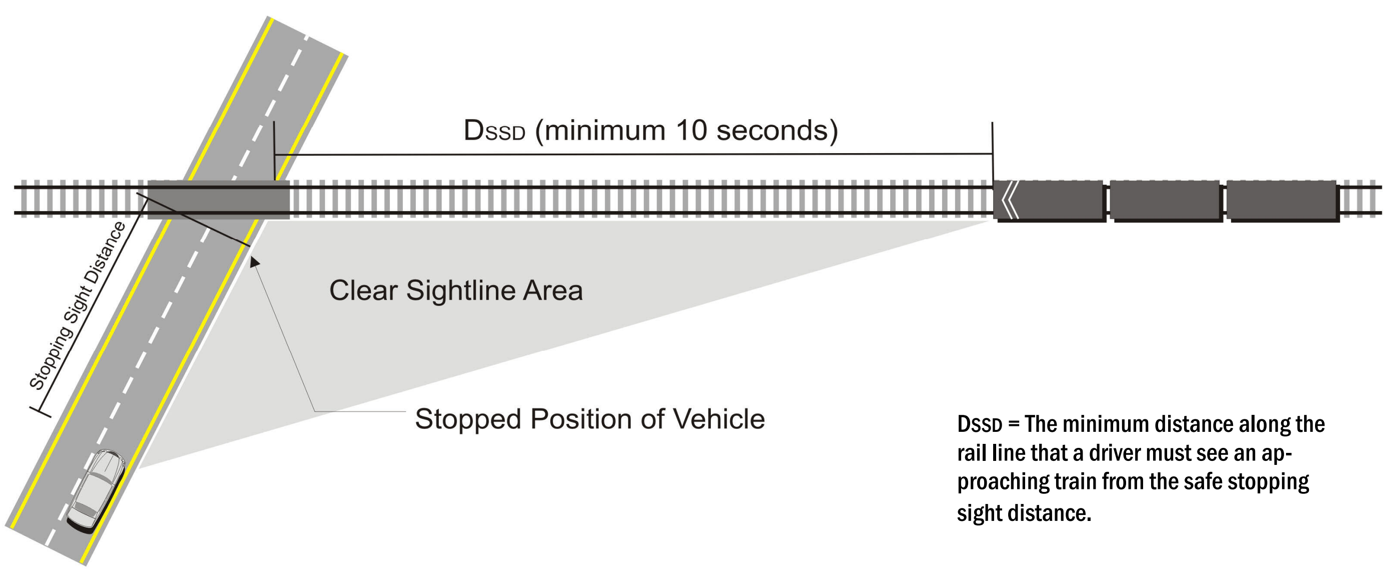
- Install a grade crossing warning system with cantilevered light units if warranted to improve rail crossing conspicuity.
- Consider illumination of the rail crossing if warranted.

Close proximity of intersections/ driveways

- Relocate intersections and driveways a minimum of 30 m from the rail crossing.
- If traffic signals create vehicle queues that extend across the rail crossing consider preemption of the traffic signals by the grade crossing warning system.

Clear sightline obstructions

- Remove vegetation and obstacles from within the required clear sightline area.
- In the event that obstacles cannot practically be removed consider the installation of a grade crossing warning system if warranted.
- Ensure advanced warning signs are consistent with MUTCDC and RTD10 requirements. Where traffic engineering studies indicate the sign is warranted, installation of a "Prepare to Stop at Railway Crossing Sign" may be appropriate (see Situation Sheet 4.2 Rail Crossing Warnings).
- Lower train speeds. Maximum railway operating speed is an important variable in determining the required Clear Sightline Area for a rail crossing.
- Install grade crossing warning system if warranted.
- Obstructions within the railway right of way may also warrant a grade crossing warning system equipped with gates.
- Changing Roadway/Railway Characteristics
- Warrants for grade crossing warning systems should be reviewed to ensure appropriate warning devices are in place.
- Conduct a detailed engineering study to determine if grade separation is appropriate.
- Prior to making any modification to a rail crossing, a comprehensive Road/ Railway Grade Crossing Safety Assessment must be conducted to determine compliance with the requirements of applicable grade crossing regulations and the technical standards contained in Transport Canada's RTD10 Road/Railway Grade Crossing Technical Standards and Inspection, Testing and Maintenance Requirements document.



DSSD = The minimum distance along the rail line that a driver must see an approaching train from the safe stopping sight distance.

Figure 3: Minimum sightlines for drivers approaching an at-grade crossing without a warning system. Transport Canada's *Technical Standards and Inspection, Testing and Maintenance Requirements (RTD 10)*, from which this drawing is adapted, notes: "If clearing of sightline obstructions for existing train and vehicle speeds is impracticable, it may be practicable to attain sightlines by reducing vehicle or train speeds, reducing road gradients or the crossing clearance distance, or restricting use by heavy or long vehicles. Alternately, the crossing may be closed or access to the grade crossing may be restricted in accordance with the Grade Crossing Regulations". Note: in Canada, the engineer is not always required to signal the train's approach to an intersection.

Solutions (con't)

Figure 4: Intersections located in close proximity to a rail; crossing can cause significant road safety and operational concerns.

Effectiveness

Solutions are listed in order of overall cost effectiveness.

Solution	Collision Type	Potential Collision Reduction		Cost	Overall Cost Effective-ness
		Range	Most Likely		
Improve/update pavement markings *[Ogden]*	Total collisions	20% to 30%	20%	Low	High
Install flashing lights *[Ogden,Kentucky DOT]*	Vehicle-train collisions Fixed-object collisions	10% to 80% May increase by 10% to 40%	65% n/a	Low n/a	High n/a
Install barriers or gates *[Ogden, Kentucky DOT]*	Vehicle-train collisions Fixed-object collisions	25% to 90% Increase of 10%-40%	75% n/a	Medium n/a	High n/a
Install warning signs *[Kentucky DOT, Ogden]*	All collisions	10% to 70%	15%	Low	Medium
Install over/underpass *[Ogden]*	Vehicle-train collisions Fixed-object collisions	100% 40% to 60%	100% 50%	High	Medium
Provide lighting *[Ogden]*	Vehicle-train collisions Fixed-object collisions	10% to 20% 20% to 30%	15% 20%	Medium	Low to high
Relocate obstacles in sight triangle *[Ogden]*	The effectiveness of this solution has not been determined			Low to high	n/a

Additional Information

This Situation Sheet contains references to topics contained in the following other sections:

1.1 – Horizontal Curves

2.1 - Intersection Sight Distance

References

Transport Canada, *Technical Standards and Inspection, Testing and Maintenance Requirements*, RTD 10, Road/Railway Grade Crossings.

Situation Sheet

4.2

SITUATION SHEET 4.2

Rail Crossing Warnings

Rail Crossing Warnings

Background

Rail crossing warning devices provide drivers with a message of warning, guidance and in some instances mandatory action. They are an essential component of any rail crossing. These devices are typically divided into passive and active categories. Passive devices typically consist of regulatory and warning signs, and supplemental pavement markings. Active devices are those that provide warning of the approach or presence of a train and include flashing light signals, bells, automatic gates and active advanced warning signals. Requirements and warrants for the application of both categories of warning devices are governed by applicable grade crossing regulations and the technical standards contained in Transport Canada's *RTD10 Road/Railway Grade Crossing Technical Standards and Inspection, Testing and Maintenance Requirements* document [1].

Figure 2: Railway warning signals are often elevated to offer better conspicuity of the crossing at a distance. In this example, the signals have been elevated to compensate for poor visibility of the level crossing due to vertical curvature of the road.

Summary

Ensuring that appropriate rail crossing warning devices are in place is critical to the successful long-term operational and safety performance of any rail crossing. Although warning devices are typically selected based on specific warrant, no modification to a rail crossing should be made without contacting the appropriate railway authorities and conducting a comprehensive Road/Railway Grade Crossing Safety Assessment to determine compliance with the requirements of applicable grade crossing regulations and the technical standards contained in Transport Canada's RTD10 Road/Railway Grade Crossing Technical Standards and Inspection, Testing and Maintenance Requirements document.

Problems

Some of the most significant issues that can impact the effectiveness of existing rail crossing warning devices include:

- Visibility of the rail crossing and its warning devices are limited by the roadway alignment and/or other obstructions.
- Poor visibility of the rail crossing particularly at night.
- Removing obstacles from within the clear sightline area is not practical.
- Changing characteristics of the roadway (traffic volumes, operating speeds, nearby land development, etc.) or railway (train speeds, number of train crossings, etc.) have made the existing warning devices inappropriate.

Solutions

- Ensure warning signs and pavement markings are consistent with MUTCDC and RTD10 requirements. Where traffic engineering studies indicate the sign is warranted, installation of a "Prepare to Stop at Railway Crossing Sign" may be appropriate (see Situation Sheet 4.2 Rail Crossing Warnings).
- Install grade crossing warning system if warranted. Gates may also be warranted in certain situations.
- Provide cantilevered grade crossing warning light units if warranted (see Figure 3).
- Illuminate the rail crossing if warranted.
- Place retroreflective tape on the back of railway crossing signs and poles. This treatment produces a strobe-like effect as approaching headlights shine through the gaps between the rail cars.
- Conduct a detailed engineering study to determine if grade separation is appropriate.
- Although this situation sheet identifies the most significant issues typically associated with rail crossing warning devices and provides guidance on potential solutions, no modification to a rail crossing should be made without contacting the appropriate railway authorities and conducting a comprehensive Road/Railway Grade Crossing Safety Assessment to determine compliance with the requirements of applicable grade crossing regulations and the technical standards contained in Transport Canada's *RTD10 Road/Railway Grade Crossing Technical Standards and Inspection, Testing and Maintenance Requirements* document.

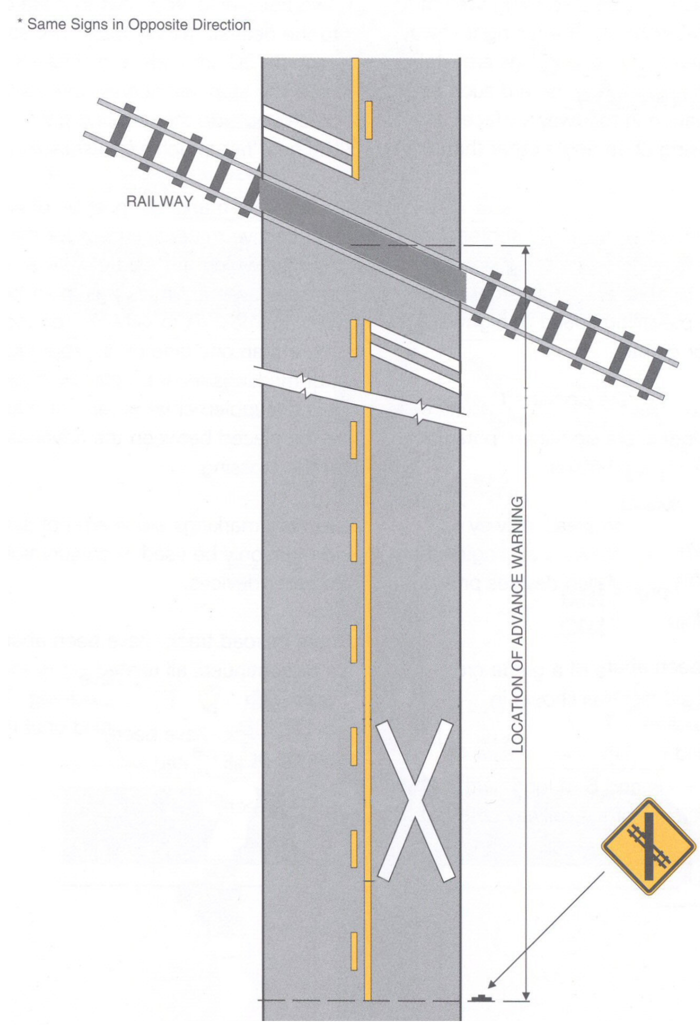


Figure 2: This illustrates a typical rail crossing with an advance warning sign and pavement markings.

Solutions (con't)

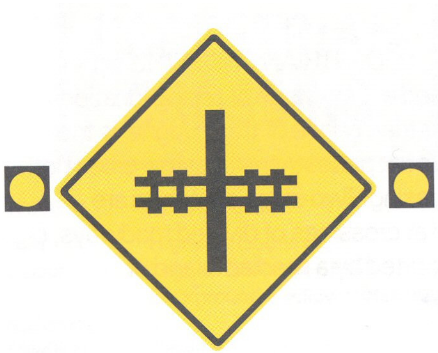


Figure 3:
In addition to *Transport Canada's Technical Standards and Inspection, Testing and Maintenance Requirements, Draft RTD 10, Road/ Railway Grade Crossings* (2002), the MUTCDC contains information on the application of rail crossing warning signs. In this figure a "Prepare to Stop at Railway Crossing" sign is displayed. Two alternating flashing beacons interconnected with the rail crossing warning system are typically used.

As of March 4, 2005, the U.S. Federal Railroad Administration is requiring railroads to install yellow or white reflective materials on locomotives and freight rail cars. All locomotives must have this reflectorization installed by 2010 and all freight cars by 2015 [2]. As much of the North American rolling stock crosses the international border, expect to see the impact of this regulation to be noted on many rail cars in Canada. However, this should not prevent responsible agencies from remaining diligent and applying other solutions such as those offered in this Situation Sheet.

Effectiveness

Solution	Collision Type	Potential Collision Reduction		Cost	Overall Cost Effectiveness
		Range	Most Likely		
Improve/update pavement markings *[Ogden]*	Total collisions	20% to 30%	20%	Low	High
Install flashing lights *[Ogden,Kentucky DOT]*	Vehicle-train collisions Fixed-object collisions	10% to 80% May increase by 10% to 40%	65% n/a	Low n/a	High n/a
Install barriers or gates *[Ogden, Kentucky DOT]*	Vehicle-train collisions Fixed-object collisions	25% to 90% Increase of 10%-40%	75% n/a	Medium n/a	High n/a
Install warning signs *[Kentucky DOT, Ogden]*	All collisions	10% to 70%	15%	Low	Medium
Install over/underpass *[Ogden]*	Vehicle-train collisions Fixed-object collisions	100% 40% to 60%	100% 50%	High	Medium
Provide lighting *[Ogden]*	Vehicle-train collisions Fixed-object collisions	10% to 20% 20% to 30%	15% 20%	Medium	Low to high

Additional Information

This Situation Sheet contains references to topics contained in the following section:

4.1 Rail Crossing Geometry

References

1. Transport Canada's *Draft Technical Standards and Inspection, Testing and Maintenance Requirements*, RTD 10, Road/Railway Grade Crossings are available on the World Wide Web at http://www.tc.gc.ca/railway/RTD10/foreward.htm.

2. Caird, J.K., Creaser, J.I., Edwards, C.J., and Dewar, R.E., *A Human Factors Analysis of Highway-Railway Grade Crossing Accidents in Canada, TP 13938E*, Montreal: Transportation Development Centre, Transport Canada, 2002.

2. *Urban Transportation Monitor*, January 21, 2005, p. 5.

5

Usability

Situation Sheet

5.1

SITUATION SHEET 5.1

MAINTENANCE ACTIVITIES

Maintenance Activities

Background

Consistent, timely, and effective maintenance practices are essential to preserving the operational and road safety functionality of any roadway. In the case of intersections in general, the concentration of functional elements (such as approach lanes, turning lanes, sightline requirements, traffic and road signing, pavement markings and advance warning devices) must work together as a system of traffic control that provides clear and unambiguous positive guidance to drivers and other road users traversing the junction. Without adequate maintenance, such an integrated system will not function as required.

Problems

Because of the variety of elements that must be cared for in an intersection, maintenance problems take many different forms including:

- Overgrown vegetation that can impede sightlines on the approach to, or within the intersection area.
- Winter maintenance operations that result in snow banks in and around the roadside quadrants of the intersection, and creation of sightline obstructions for vehicles approaching, entering, and leaving the intersection.
- Deteriorated pavements that create care and control issues for drivers as they proceed through the intersection can result in avoidance and other manoeuvres that may interfere with correct lane discipline. This creates potential conflicts with other vehicles within or on the approaches to the intersection.

(continued on page 2)

Figure 1: Roadside shrubbery has been allowed to grow to a height at which it now threatens to obscure the Stop sign. It already obscures sight lines. Poor maintenance such as this presents a significant risk to drivers.

Summary

Effective and appropriate maintenance practices for rural intersections are essential. Maintenance problems tend to be very obvious – even to the untrained eye – and their resolution usually requires simply the execution of the appropriate measure to eliminate the hazard created by the lack of maintenance. Road agencies usually have well-defined and standardized maintenance practices that provide the necessary direction for the allocation of resources and staff to such activities. These policies should be reviewed regularly and desirably, should be complemented with a risk management policy that provides both prioritization guidelines for the allocation of maintenance resources, and risk mitigation policies to deal with situations where appropriate levels of maintenance cannot be preserved.

Problems

- Poor drainage can also interfere with driver care and control of the vehicle. Drainage problems can be particularly severe on the approaches to the intersection – particularly if combined with pavement rutting and/or freezing temperatures that might result in a complete loss or drastic reduction of friction between the vehicle tires and the roadway surface.
- As noted elsewhere in this handbook, poorly maintained signing can result in drivers not receiving the information they need to use the intersection properly (lane designations, stop signs, advance warning signs etc.). Clean, properly sized and placed sign panels that possess adequate levels of retroreflectivity are essential elements of adequate signing for an intersection.
- Inadequately maintained pavement markings – like poorly maintained signs – can result in inappropriate driver behaviour. Experience has shown that inappropriate driver behaviour will tend to increase the likelihood of collisions.
- Inadequate nighttime visibility can be created by a complete lack of illumination, or by missing or improperly functioning intersection lighting elements. In some cases, locations where lighting may not have been justifiable in the past may come to require and warrant illumination as traffic growth occurs over the years. Poor or inadequate lighting can result in dark areas within a rural intersection where a pedestrian or other vehicle is hidden from view from other traffic. Obviously this is not a desirable situation.

Solutions

Maintenance practices in road agencies are generally set out in well-defined and standardized procedures documents that are adopted by the agency as a matter of policy. As a result, dealing with maintenance shortcomings usually does not require some new effort or technology. Initially, the remedy for a maintenance shortcoming simply involves the early execution of the required maintenance activity. In more general terms, it requires agency compliance with established policies that respond to the kinds of problems noted above.

A number of key policy-related points bear mentioning here:

- Maintenance shortcomings that are critical to ensuring an adequate level of road safety performance in an intersection should be dealt with promptly. Maintenance policies should define minimum response times appropriate to the level of risk created when a critical element is not dealt with. In addition, regular monitoring of maintenance activities should be carried out to ensure that necessary response time thresholds and quality performance targets are met.
- Where maintenance guidelines are consistently being violated and rural intersection infrastructure is being allowed to deteriorate beyond reasonable limits on a regular basis, the prioritization of intersections and intersection elements for remedial treatment is strongly recommended. In this manner, the most critical risk elements and locations resulting from poor maintenance can be dealt with first, while agency resources are available.
- Regular reviews of maintenance policies should be undertaken to ensure that the policies are appropriate for the resources allocated to their implementation. Where resources are scarce, specific policies that set out interim risk mitigation measures can provide a desirable and prudent response to dealing with such situations.

Figure 2: Regulatory Speed sign clearly in need of replacement. Signs should not be allowed to deteriorate to this point.

Situation Sheet

5.2

Approach Speeds and Speed Differential

Background

Traffic speeds have an influence on road safety performance both on road segments and in intersections. Recent research suggests that it may not be speed that influences the chance of a crash occurring, so much as the difference in speeds between vehicles. This is important to rural intersection design. Absolute speed is important because the design of an intersection must be based on assumptions regarding the speed of traffic using it. Traffic speed can be measured in many ways (average speed, maximum speed, median speed etc.) but in recent years it has generally come to be accepted that the most appropriate value of speed for design purposes is the 85th percentile operating speed: the speed at or below which 85% of the traffic chooses to travel.

(continued on page 2)

Figure 1:
Any intersection will result in speed differential as vehicles slow to turn. The problem is exacerbated, as in this case, where the intersection is not obvious. Here, a Hidden Intersection warning sign has been installed, and a speed reduction zone has been introduced to the road segment.

Summary

A pattern of speed-based collisions at rural intersections can result from the fact that drivers may be consistently exceeding the design speed of the intersection, or the fact that turning vehicles may – by virtue of their significantly slower speeds when traversing the intersection – create potential conflict situations with through traffic. In either case, effective speed management techniques and/or geometric measures may help mitigate both of these effects.

Background, con't.

The difference in speeds between vehicles in a traffic stream is important in intersection designs because by their very nature, intersections are a location where many things can happen: people will slow down, accelerate, and in some cases, travel at a constant highway speed – depending on what they are doing and their level of familiarity with the road. When differences in speeds occur between vehicles, a potential conflict may be created, and it is this effect that creates the risk of a collision.

Safety problems at rural intersections can result both from vehicles exceeding the assumed design speed that was chosen for the intersection, and turning vehicles that interfere with higher speed through traffic. At rural intersections, speed-based safety problems can be particularly critical because of the generally higher operating speeds than at their urban counterparts, with the result that collisions tend to involve an increased likelihood of significant levels of personal injury or of a fatality.

Problems

Excessive approach speeds and large speed differentials can create a number of different problems:

- High speeds on minor road approaches can result in overshooting of the stop bar or other traffic control device – with the potential for a high-severity, high speed right angle collision outcome.
- Vehicles attempting to brake and negotiate a horizontal curve at the same time are in an inherently unstable dynamic attitude. Depending on the road alignment and physical sight line provisions at the intersection high approach speeds on the minor road may lead to loss of control or run-off-the-road collisions as vehicles attempt to track their way around a horizontal curve as they brake for an intersection stop or other traffic control condition.
- High approach speeds on the major road may reduce the potential for a through vehicle to take appropriate avoidance action when faced with an inappropriate minor-road vehicle entry into the intersection.
- High approach speeds on the major road may reduce the ability of a through vehicle to adjust their speed or lateral location to avoid a vehicle travelling in the same direction that is slowing to turn right or left in the intersection.
- Slow moving vehicles entering the major road from the minor road and just beginning to accelerate, may generate large speed differentials relative to through traffic on the main road – with an increased risk of a high-severity collision.
- The presence of significant numbers of heavy trucks traversing a rural intersection (not uncommon in resource and agricultural regions), may create significant speed differentials that can create high risk conflicts with slower moving passenger cars.

Solutions

Solutions to the two basic types of problems outlined above (excessive absolute speeds and speed differences between vehicles) can take various forms:

Speed Management

Speed management measures can be used to help better communicate appropriate speed choices to drivers approaching the intersection particularly on the minor road. While such measures are still being extensively researched, they generally use both geometric changes and traffic control devices to deliver the speed adjustment message.

Such measures can include:

- Improved advance warning signing;
- The use of transverse rumble strips to bring the driver's attention to the fact of the approaching intersection and the need to reduce speeds.
- The use of painted edge lines on the immediate approach to the intersection as a means of better communicating the presence of the intersection and the resultant need to adjust speeds;
- Various patterns of pavement markings to provide improved driver perception of their speed and the need to adjust appropriately for the upcoming intersection. A variety of patterns have been used for these purposes elsewhere and caution should be used in selecting this countermeasure, since its effectiveness appears highly variable.
- Enhanced, repetitive, and regular speed enforcement can play a complementary role to all of the above measures and should always be used in support of any speed management effort. Unfortunately speed enforcement tends to provide its benefits only over the time period that it is present.

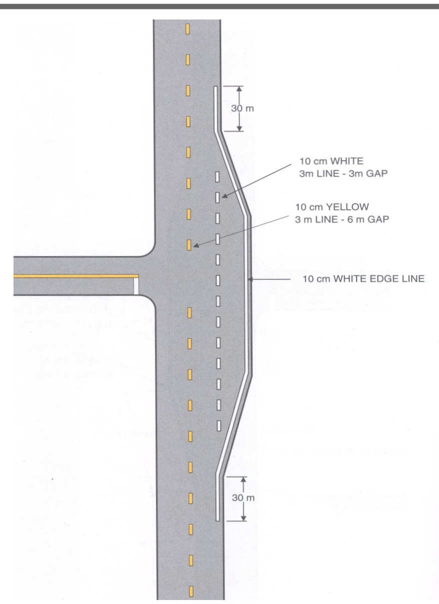


Figure 2: Example of a flared intersection to allow fast moving vehicles to safely maintain speed as they overtake a left -turning vehicle. Caution should be used in applying this solution. It can be hazardous when logging trucks with long overhangs are present (compare with Figure 1, Situation Sheet 1.5). Source: *Ontario Traffic Manual*.

Geometric Changes

Geometric changes can help induce changes in driver behaviour by virtue of the physical clues they provide:

- Modern roundabouts have a proven ability to reduce vehicle speeds through intersections. As noted earlier in this handbook, such facilities have not yet been widely deployed in the rural intersection context in this country and any effort to do so should be undertaken under the guidance of an experienced and expert roundabout design group.
- Staggering intersections in such a manner as to reduce the potential for minor road traffic to drive directly through the junction inadvertently.
- European agencies have experimented extensively with a variety of speed management measures at both rural intersections and on the approaches to settled communities along high speed rural highways. Their efforts include a variety of measures, but little conclusive evidence as to consistent speed and significant speed reductions.
- Geometric changes can also be used to reduce potential speed differential effects on safety through the provision of left turn auxiliary lanes, right turn auxiliary lanes, and acceleration lanes onto the major road from the minor facility as appropriate and warranted (see Situation Sheet 1.4 Turning Lanes).

Effectiveness

Solutions are listed in order of overall cost effectiveness.

Solution	Collision Type	Potential Collision Reduction		Cost	Overall Cost Effectiveness
		Range	Most Likely		
Install proper pavement markings *[TAC 2004, Ogden & Iowa DOT]*	Total collisions at signalized intersections Total collisions at unsignalized intersections	20% to 45% 15% to 20%	30% 15%	Low Low	High Medium
Transverse pavement markings/Rumble strips *[TAC (2004)]*	Total collisions	40% to 60%	40%	Low	High
Speed enforcement *[Georgia DOT]*	Total collisions	27%	20%	Medium	Medium
Stagger intersections *[Ogden, NCHRP 500, Vol. 5]*	Total collisions Rear-end collisions Turning collisions Head-on collisions	40% to 80% 60% to 80% 40% to 60% 40% to 80%	50%	High	Medium
Install modern roundabout *[Ogden, NCHRP 500, Vol 5.]*	Head-on collisions Angle collisions Rear-end collisions	30% to 80% 30% to 80% May increase	70% 70%	High	Medium
Narrow the lane widths *[TAC (2004)]*	This solution has not been satisfactorily quantified			Low	n/a

Additional Information

This Situation Sheet contains references to topics contained in the following other sections:

1.6 Intersection Skew

3.1 Intersection Control

3.3 Pavement Markings

5.4 Large Number of Heavy Vehicles

Situation Sheet

5.3

Roadside Hazards near Intersections

Background

In North America, collisions with fixed objects account for approximately 30 percent of road fatalities and an additional 10 percent of road fatalities are attributed to non-collision rollovers. Although these statistics are not specific to intersections, they suggest that the roadside environment at intersections can have an important role to play in improving road safety.

The approach to providing a roadside environment that reduces the consequences of an errant vehicle leaving the roadway is termed the *forgiving roadside*, defined: "one free of obstacles that could cause serious injury to occupants of an errant vehicle. To the extent possible, a relatively flat, unobstructed roadside recovery area is desirable, and when these conditions cannot be provided, hazardous features in the recovery area should be made breakaway or shielded with an appropriate barrier" [1]

It should be noted that roadside barriers can also cause injury to vehicle occupants when struck. As a result, the installation of roadside barrier should be considered a treatment of last resort.

Figure 1: Utility poles can present a significant hazard to drivers encroaching on the roadside. In this set of before and after photos, utility poles located adjacent to the roadway have been removed to provide an obstacle free recovery zone for errant vehicles. *Source:* City of Port Alberni.

Summary

Roadside environments consisting of hazardous obstacles and non-traversable cross section elements can contribute to increased collision severity in the event of an errant vehicle leaving the roadway. The preferred method of addressing this concern is through the provision of a forgiving roadside. A forgiving roadside is achieved through the provision of a relatively flat and unobstructed recovery zone that permits an errant driver to regain control of the vehicle and return to the roadway. If the required recovery zone can not be achieved, other options include making obstacles breakaway or shielding the obstacle with barrier.

SITUATION SHEET 5.3

Roadside Hazards near Intersections

Problems

The available recovery zone is limited by the presence of roadside hazards. Examples of roadside hazards typically encountered at intersection locations can include:

- Fixed objects including utility poles, light standards, electrical boxes, mailboxes, sign posts, rock outcrops and culvert ends projecting from the roadway slope.
- Non-traversable roadway cross section elements including ditch lines, critical fore slopes (steeper than 3:1), steep backs slopes and transverse slopes created by intersection roadways/driveways.

Shoulder width and condition is another factor that can contribute to collisions associated with a loss of vehicle control and encroachment on to the roadside:

- Narrow shoulder widths can limit the space available for drivers to perform evasive manoeuvres at intersections.
- Vehicle off-tracking at intersection corner radii can contribute to deteriorated shoulder conditions and a potential for loss of vehicle control.

Solutions

Reduce the risk of a run-off-road incident:

- Widen roadway shoulders to provide drivers with a recovery area to perform evasive manoeuvres.
- Pave roadway shoulders to provide a smooth transition from the travel lane for drivers performing evasive manoeuvres.
- Widen and/or pave shoulders to accommodate vehicle off-tracking.

Provide opportunities for the driver of a vehicle to recover and return to the roadway:

- Remove obstacles and hazards from within the recovery zone.
- Flatten steep fore slopes, back slopes and transverse slopes to a traversable cross section.
- Regrade ditch lines to achieve a traversable cross section.

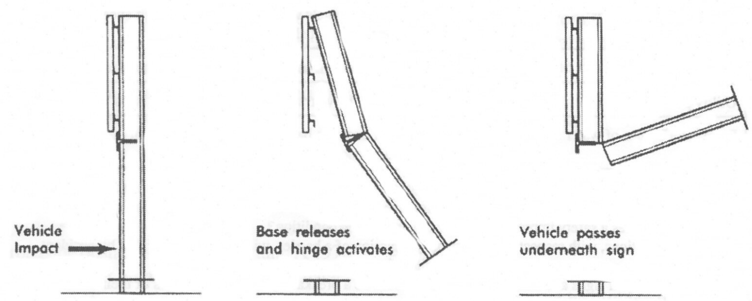
Figure 2: Utility poles present a significant hazard to drivers when located too close to the travel lane as in this example. Note also the poorly maintained cable barrier on the right.

Solutions (con't.)

Reduce the severity of a potential collision:

- Equip obstacles including sign posts, light standards and utility poles with breakaway devices.
- As a last resort assess the cost-effectiveness of shielding the obstacle with roadside barrier or a crash cushion.

Figure 3: The use of breakaway devices is one method of reducing the severity of potential fixed object collisions. In this figure, the posts of a large roadside sign have been equipped with a hinged breakaway technology.



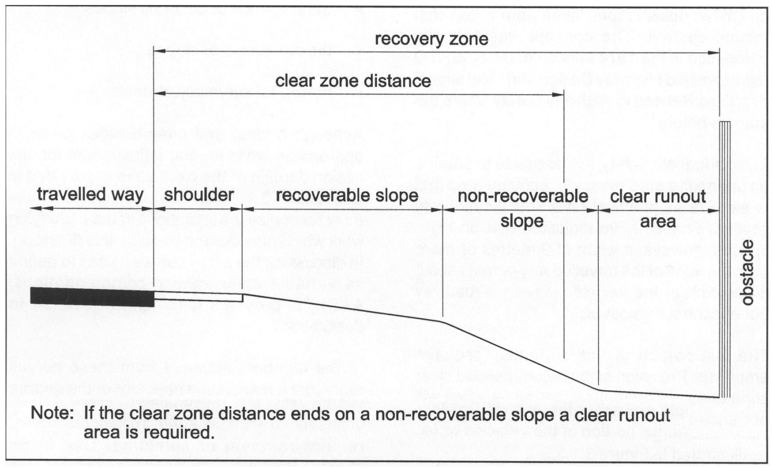


Figure 4: This figure illustrates elements of the recovery zone. Providing the required recovery zone is the preferred mitigating measure for improving roadside safety.

Additional Information

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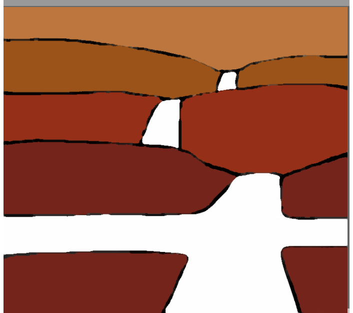
1. "Road Safety Issues" *Transportation Research Circular 435*. TRB Washington, DC, 1995

2. *Volumes 5 and 8: A Guide for Reduction of Collisions Involving Utility Poles*, NCHRP Report 500, TRB 2004.

Effectiveness

No studies were identified that offered data specific to intersections. Nonetheless, *NCHRP 500, Vol. 5* indicates that the problems encountered at intersections are similar to those on the overall road section. As a result, the effectiveness values presented below are derived from general roadside studies.

Solution	Collision Type	Potential Collision Reduction		Cost	Overall Cost Effectiveness
		Range	Most Likely		
Install breakaway posts/poles in clear zone *[Ogden]*	Fixed object collisions	30% to 50%	35%	Low	High
Remove fixed objects from the clear zone *[Iowa DOT, Ogden]*	Fixed object collisions	45% to 80%	45%	Low to high	Medium to high
Install paved shoulders *[Ogden, TAC (2004)]*	Total collisions	20% to 60%	25%	Medium	Medium
Increase the clear zone distance *[Georgia DOT]*	Total collisions	14% to 55%	20%	Medium to high	Low to Medium
Increase roadway shoulder width *[Iowa DOT]*	Total collisions	15% to 30%	15%	Medium	Low
Flatten the roadway side slopes *[Vermont DOT, TAC (2004)]*	Total collisions	10% to 20%	15%	Medium	Low



Large Number of Heavy Vehicles

Large Number of Heavy Vehicles

Background

Heavy vehicle have a set of operating characteristics that differ from passenger vehicles. As a result, elements of an intersection design may require special consideration when accommodating increased volumes of heavy vehicle traffic.

Figure 1: This video capture shows a pole trailer, a vehicle that is both long and heavy and which has a long, dangerous overhang. Vehicles such as this tend to be uncommon and temporal users of rural road facilities, thus most intersections would not be designed for them. On the other hand, provinces such as Alberta allow long combination vehicles (LCVs) to operate on designated rural roads. In these cases, the province has established an intersection design to accommodate the longer vehicle types.

Problems

Heavy trucks are less manoeuvrable than passenger cars and as a result, have a different set of operating characteristics. Some of the most significant problems associated with heavy vehicles at intersection locations include:

- Heavy vehicles performing right turn manoeuvres at the intersection off-track onto unpaved shoulders, sidewalks, and channelization islands, and/or encroach into adjacent or opposing lanes.
- Due to their lower acceleration rates and longer lengths, trucks typically require additional time to clear an intersection or accelerate to match the speed of the main traffic stream. This can contribute to significant speed differentials between through traffic and heavy trucks entering

Summary

Heavy vehicles are a key consideration in the design of intersections. The most significant issues associated with increased volumes of heavy vehicles at an intersection include the ability of the intersection geometry to accommodate the necessary turning manoeuvres and speed differentials resulting from the low acceleration rates of the trucks. These issues can have a significant impact on the road safety and operational performance of an intersection.

and exiting the major roadway increasing the likelihood of rear-end and right angle collisions.

- Left turn storage lane lengths are strongly influenced by the volume of heavy vehicles using the lane. When an increased volume of heavy vehicle traffic uses the left turn lane, vehicle queues may extend into the through lane contributing to an increased risk of rear-end collisions.
- Driver sight lines for a vehicle in a left-turn lane are obstructed by the presence of heavy vehicles in the opposing left turn lane.
- Long overhanging loads (such as Alberta log haul trucks and pole trailers) typically sweep outside of the wheel path when the truck performs a turning manoeuvre. These loads can be hazardous to other vehicles on the roadway particularly when vehicles attempt to pass a turning trucks.
- Long trucks crossing an intersection at night may not be may not be visible to oncoming vehicles.

Solutions

- Corner radii should be sufficiently large to accommodate off-tracking of the selected design vehicle. Although not typically a problem at urban intersections, it is also desirable to keep the radii small to reduce pedestrian crossing distances. Refer to Situation Sheet 1.7 Corner Radius for additional details.
- Remove obstructions that limit the available intersection sight distance. Refer to Situation Sheet 2.1 Intersection Sight Distance for additional details.
- If warranted, provide an acceleration lane to permit heavy vehicles to increase their speed prior to entering the through lane. Refer to Situation Sheet 1.5 Acceleration Lanes for additional details.
- Increase the left turn storage lane length to accommodate required left turn traffic volumes and vehicle mix.
- Where possible, offset opposing left turn lanes to improve sightlines for opposing vehicles.
- Some jurisdictions such as Alberta have developed intersection design guidelines and configurations to accommodate the longer vehicle dimensions and slower acceleration characteristics of log haul trucks. For additional details, refer to applicable design guidelines in your jurisdiction.
- Illumination warrants should be reviewed for intersections with a history of collisions involving heavy vehicles at night. Also, long trucks crossing rural roads at night should be equipped with side-mounted lights to increase conspicuity of the slow moving truck for other drivers approaching the intersection.

Effectiveness

Solution	Collision Type	Potential Collision Reduction		Cost	Overall Cost Effectiveness
		Range	Most Likely		
Increase the left-turn lane length *[Iowa DOT]*	Total collisions	30%	30%	Medium	Medium
Install proper acceleration lane *[Ogden]*	Lane-change collisions Rear-end collisions Overtaking collisions	40% to 60% 50% to 80% 20% to 40%	45% 55% 25%	Medium	High High Medium
Increase corner radius *[Vermont DOT]*	Total collisions	25%	25%	Medium	Medium
Increase sight lines *[Ogden, TAC (2004), Georgia DOT, Iowa DOT]*	Total collisions	15% to 50%	30%	Low to high	Low to high
Improve offset left-turn condition *[NCHRP 500, Vol 5.]*	The effectiveness of this solution has not been quantified			Low	n/a

Additional Information

This Situation Sheet contains references to topics contained in the following other sections:

1.4 Turning Lanes

1.5 Acceleration Lanes

1.7 Corner Radius

2.1 Intersection Sight Distance

References:

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Appendix and Bibliography

Appendix A - Intersection Safety Checklist

W5 – The Who, What, When, How and Why of Checking

Why and When to Check. Obviously, those intersections that are currently experiencing problems are those that will get the most attention, but the principle of prevention dictates that all intersections should be reviewed from time to time. Intersections should be part of a specific safety audit program that all jurisdictions should follow on a regular basis. If you do not already conduct such a program, one should be initiated. The Canadian Council of Motor Transport Administrators (CCMTA) has adopted a Road Safety Vision which sets specific intersection and other safety targets for 2010. These targets were officially endorsed by all Ministers of Transportation and Highway Safety in the fall of 2000. The targets provide benchmarks against which to develop new strategies and measure your efforts. This handbook is a direct result of the ministers' endorsement.

Who Should Check? Ideally, road safety audits are conducted by highway engineers and planners. However, it is recognized that time and budget limitations may limit the frequency of such reviews; therefore other practitioners including highway maintenance managers may also be required to undertake such work. This handbook is thus written for a wide range of specialist and non-specialist users.

How and What to Check This is the focus of the checklist that follows.

Item	Situation Sheet(s)
Is the route through the intersection as simple and clearly evident to all users as possible?	1.1 1.3 1.5 1.7 1.2 1.4 1.6
Is the presence of the intersection clearly evident at a distance to approaching vehicles from all directions?	2.1 2.2 2.3
Are warning and information signs placed well enough in advance of the intersection for a driver to take appropriate and safe action?	3.2 3.3 4.2
On the approach to the intersection, is the driver clearly made aware of the actions necessary to negotiate the intersection safely?	3.1 3.2 3.3 3.4 4.2
Are the different turning movements sufficiently segregated for capacity and simplicity of action by the driver?	1.4 1.5
Are lane widths and turning radii adequate for the vehicle movements and types that will use the intersection?	1.4 1.7
Do the decisions which need to be made by the driver follow a simple, logical and clear sequence?	5.4
Are the drainage features sufficient to avoid the presence of standing water?	5.1
Is the level of lighting adequate to identify the intersection at night?	2.4
Is the level of lighting adequate to silhouette pedestrian and other movements?	2.4
Are sightlines sufficient and clear of obstructions, including parked and stopped vehicles?	2.1 2.2 2.3
Are accesses prohibited within a specified setback from the intersection?	1.3
Have adequate special features been provided for pedestrians and handicapped users (crosswalks, refuges, ramps)?	1.4 1.5 1.6 1.7 2.4
Have adequate special facilities been provided for cyclists and other non-motorized users?	1.7
Where roads cross, does the design clearly identify right-of-way and priorities?	3.1

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