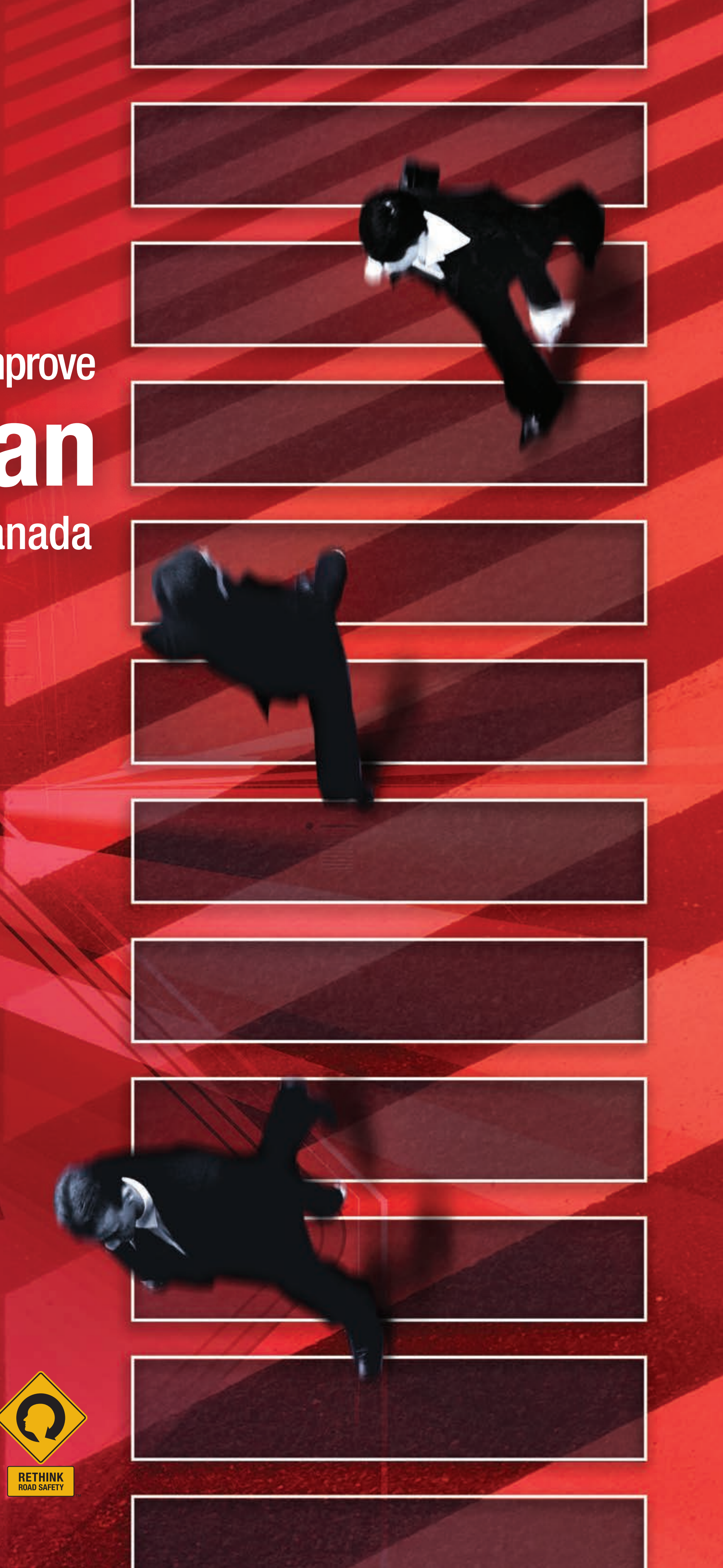
Countermeasures to Improve

# Pedestrian Safety in Canada



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CANADIAN COUNCIL OF MOTOR TRANSPORT ADMINISTRATORS
CONSEIL CANADIEN DES ADMINISTRATEURS EN TRANSPORT MOTORISÉ

RETHINK ROAD SAFETY

## CCMTA Vulnerable Road Users' Expert Working Group on Pedestrians

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## A note about terminology

For the purpose of this report, a vulnerable road user is a pedestrian or cyclist. A pedestrian is defined as any road user outside a motor vehicle and who is not a cyclist or motorcyclist.

In this report, the use of the word "injury" includes all injury severities including fatal injuries. Furthermore, the use of the words "casualties" and "human trauma" have also been used interchangeably.

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# Executive Summary

## INTRODUCTION

Between 1989 and 2009 almost 9,000 pedestrians were killed and hundreds of thousands were injured on Canada's roads. Progress in reducing pedestrian casualties has been much less impressive than for vehicle occupants. The road system has traditionally been designed from the perspective of a motor vehicle driver rather than that of a pedestrian or other type of vulnerable road user. The safe system approach recognizes that the most vulnerable part of the system is comprised of unprotected human beings and that it has to be designed around them. Those jurisdictions that have established road safety as a priority are the same ones that have implemented improvements across all three areas (road user behaviours, roadway design and vehicle safety standards) and have achieved substantial reductions in the numbers of people killed and injured on their roads; this is evidenced by the divergent levels of road safety performance by various countries.[1]

Canada lags behind many top performing countries in the Organization for Economic Cooperation and Development (OECD) when it comes to pedestrian safety. It would not be unreasonable for Canada to, over the near to medium term, reduce its number of pedestrian fatalities to one-third the current level: this would save approximately 2,400 lives in a ten-year period. Research findings and experience of other jurisdictions indicate that vast progress could be made to reduce the number of pedestrians killed and injured in Canada if pedestrian safety were given higher priority and if proven measures were implemented. No longer is it acceptable to assume pedestrian injury is inevitable when motor vehicles share the road system with vulnerable road users. In the modern era of road safety, jurisdictions can assume a safe system approach and include pedestrians and other vulnerable road users as an essential component of the system and one that is given top priority.

Themes of this current report include safer pedestrians, safer drivers, safer road and traffic signal design, and safer vehicles. This report provides an overview of available countermeasures to achieve improved pedestrian safety. It is also hoped that this report will help foster a different way of thinking when it comes to pedestrian safety and the design of the overall system.

## PEDESTRIANS

### Visibility

Many pedestrian fatalities and injuries occur at night or under low-light conditions. Dark clothing is often worn by pedestrians, especially in cold weather, and this, combined with more hours of darkness, greatly increases vulnerability in winter months. Visibility aids have the potential to increase visibility and enable drivers to detect pedestrians earlier. One of the more effective ways of reducing pedestrian collisions at night is the use of retroreflective clothing, patches of material or tags. These materials enhance recognition, in particular when arranged in a 'biomotion' configuration, taking advantage of the motion from the natural movement of a pedestrian's legs, feet, arms and wrists.

### Distraction

A significant source of distraction for road users is the use of hand-held electronic devices such as talking on cell phones, text messaging, Internet use and listening to hand-held music players. Studies show that use of a cell phone while crossing the street interferes with cautious behaviour, reduces situational awareness and poses a threat to pedestrians. While hand-held devices are not the only source of distraction for pedestrians, they remain a major one. There is less information on the role of distraction in collision causation for pedestrians due to a lack of reliable collision data on causal factors.

### Impairment

Pedestrians impaired by alcohol or other drugs pose a grave danger to themselves and are a neglected and challenging problems in traffic safety. In Canada in 2008, among pedestrians tested for alcohol post-mortem, almost 40 percent had been drinking and 27 percent had BACs over 160 mg%. Legal approaches may have little preventative value because of the high proportion of chronic or severe alcohol abusers among pedestrian casualties. Because studies show that impaired pedestrian collisions are often concentrated in circumscribed urban areas, it may be possible to apply localized road engineering, education or public health countermeasures.

## Child Pedestrians

Pedestrian-related injuries contribute to almost 12 percent of all injury-related deaths of children younger than 14 years of age. Lower income neighbourhoods, particularly urban ones, present a higher risk for child pedestrian injuries. Children's overall physical, cognitive, visual and auditory development puts them at a distinct disadvantage as pedestrians. In order to cross a street independently and safely, children need three important skills that are typically not acquired until between 9 and 11 years of age: the ability to determine and use a safe crossing pathway, the capability to realistically assess a vehicle's speed and the cognitive means to judge safe gaps in traffic. Parents and caregivers have a large potential to influence their child's safe pedestrian behaviour. Parents serve as both protectors and educators. When adults accompany children to and from school there is a demonstrated reduction to the risk of injury especially when that adult is well informed. Even then, however, this may not be realistic for all families and in all situations. Schools and community organizations, therefore, can also play a vital role in teaching children to become safe pedestrians but education needs to be matched to the child's developmental level.

## Pedestrians Who are Older

Navigating a traffic environment can be dangerous for older pedestrians due to sometimes limited vision and hearing, slower reaction time and decision making, lower levels of attention, reduced walking speed and other age-related factors. Those over age 70 are more likely to be involved in a serious pedestrian incident than are younger people. Greater injury severity to older pedestrians is due in part to their greater physical fragility including larger impacts from brain injuries and longer recovery times from injury. Accommodating the needs of a rapidly aging Canadian population, many of whom will be transitioning from driving to walking as a primary transportation means, can be made a high priority for governments and community planners. Many of the same countermeasures recommended for pedestrians with special needs would also assist older individuals as there is overlap between many of the characteristics of these populations. Good health and fitness levels among seniors have been correlated with safer pedestrian behaviours. Thus programs that improve the health of seniors may also decrease their risks when using the road system.

## People with Special Needs

Not all pedestrians are equally capable of crossing the road easily and safely. Many people have limitations that require special attention on their part and/or modifications of roadway infrastructure and operations. These special populations include those with physical, sensory and cognitive limitations. Research shows considerably lower walking speeds for various types of mobility restricted pedestrians who rarely ever reach the average speed of 1.2 m/s (4 ft/s), which is the walking speed often assumed in pedestrian crosswalk signal timing. It is recommended that pedestrian signal timing be adjusted to allow safe crossing by those with mobility restrictions. In addition, pedestrian-activated controls should be easily accessible, utilize design-standard curb cuts and gradients for wheel chair access should be provided, as should tactile strips and auditory signals for people with vision loss. Sidewalk markings to warn people with vision loss of hazards should be maximally detectable; pedestrian signs should be designed with the simplest possible messages in order to be understood by people with developmental or cognitive challenges.

## Pedestrians on Wheels

Assisted forms of pedestrian transportation include use of devices such as in-line skates, skateboards, longboards, scooters, Segways™ and assistive mobility devices. There is little research on the risks these devices pose when interacting with motor vehicle traffic, as the injury data often do not distinguish between different causes of injury to users. One controversial issue has been how the use of these various devices should be restricted by location and by age of user. On sidewalks and pedestrian paths, some devices such as Segways™ pose a threat to people on foot; but if permitted on roadways the potential for conflict with regular traffic may be unacceptably high.

## Enforcement of Pedestrian Laws

Enforcement works best when it is part of a comprehensive approach combined with awareness and education. A strategic approach to educating the public is necessary to assist with addressing this public safety issue, as enforcement resources and capabilities are limited. Targeted enforcement strategies require data on collision factors and frequencies to enable agencies to prioritize behaviours. Knowledge of the behaviour and traffic patterns of a community also helps police to develop countermeasures to address specific behaviours. Both driver and pedestrian behaviours may be targeted. Providing professional development opportunities and resource guides for police officers will also assist in successful enforcement of pedestrian laws. Combining education and enforcement with clear legislation would increase the confidence of police officers in their ability to enforce the laws.

## DRIVERS

Motor vehicle-pedestrian crashes occur predominantly in urban settings. Drivers are often at fault. Failing to yield the right of way followed by driver distraction and inattention (including, within this, various visual, dual-task and cognitive processing failures) are the driver actions most frequently implicated in crashes with pedestrians. There are number of ways to address the driver factors that contribute to pedestrian collisions. Most of these approaches are not unique to the prevention of pedestrian crashes but have been identified as ways to improve overall traffic safety. The section on drivers focuses on those factors most relevant to pedestrian safety.

### Vehicle Speed

There is a direct correlation between an increase in vehicle speed and the increase in the risk of injury. It is estimated that a pedestrian struck by a vehicle travelling at 50 km/h is eight times more likely to be killed than a pedestrian struck at 30 km/h.[2] Even small reductions in speed are significant. Reducing vehicle speed has been proven to be one of the most effective ways to prevent pedestrian crashes and reduce the severity of injuries. At a speed of 30 km/h, vehicles and pedestrians are able to co-exist with relative safety because drivers have sufficient time to stop for pedestrians, and pedestrians can make better crossing decisions. The probability of a pedestrian being killed in a vehicle crash increases exponentially with the impact speed.

There are a number of reasons why speed contributes to the risk of a crash. The first is the driver has a narrower field of vision. The visual field of the driver is reduced when the speed of the vehicle increases. Vehicle speed impacts the distance travelled during the time it takes the driver to see a pedestrian, to process that information and then to physically respond by taking actions related to braking and/or steering. Braking distance increases exponentially with increases in speed but also depends on the type of pavement and the condition of the road, as well as the type of vehicle and still other factors. Stopping distances are much higher on wet than on dry roads and can even change depending on the pavement friction coefficient. On the other hand, sunny and dry conditions bring more children and people of all ages outdoors so it is always advisable to have speed reduction strategies wherever pedestrians and motorized traffic mix. The use of automated speed enforcement, or driver feedback, to assist police in enforcing speed limits in pedestrian areas is proven by vast amounts of research and data.

### Driver Education and Training

Drivers could be educated about the needs and vulnerability of pedestrians; in particular they should understand the science and physics related to the difference in pedestrian impact between 50 km/h and 30 km/h. It is important to cultivate an understanding that all road users share the road space especially on residential roads. Training by driver instructors, advice that drivers receive from safety organizations and the police could be oriented to promote attitudes and behaviours based on pedestrian safety priorities. There is an opportunity to foster the social environment that supports pedestrian safety in driver education curricula. Public education and awareness campaigns are likely to be of limited effectiveness on their own and have the greatest potential for success when combined with enforcement programs. For example, one could mount public education and awareness together with enforcement initiatives focused on the problem of speed and the benefits that can be realized through lowered speeds and improved speed management activities.

## ROADWAY DESIGN

Roadway design and intersection signal controls are a fundamental part of a safe system design for pedestrians. In conjunction with implementing an integrated pedestrian strategy, there are many measures that work to improve pedestrian safety. Engineering countermeasures for pedestrians can be classified into broad categories; separation of pedestrians from vehicles through space or time, reducing or eliminating concurrent movements of vehicles and people, reducing pedestrian crossing distances, increasing the visibility of pedestrians including through better lighting, alerting drivers to the location of crosswalks and reducing vehicle speeds. Although the list provided in this report is not exhaustive, it demonstrates that many proven and innovative measures exist and are implementation-ready.

Crosswalk design is a critical component of pedestrian safety. The primary goal of crosswalk design is to provide safe places for pedestrians to cross while encouraging drivers and pedestrians to make safer decisions that will result in reduced levels of human trauma. The installation of a crosswalk is usually determined by the Transportation Association of Canada (TAC) warrants for marked crosswalk installations and for the installation of traffic signals. The design of a crosswalk should consider all possible users, including those with disabilities or using assistive devices. Most accessibility treatments used to enhance crosswalks are outlined in TAC's *Guidelines for Understanding, Use and Implementation of Accessible Pedestrian Signals*.

There are many proven crosswalk treatments available. Marked crosswalk treatments are selected and implemented from a hierarchy starting with the most basic treatment of pavement markings and signs, up to the most complex that involve a pedestrian activated traffic signal. Whether the crosswalk is unmarked or fully signalized, it is essential to apply all crosswalk treatments carefully, ensuring that the type of crosswalk is appropriate for the location and provides maximum pedestrian safety.

In addition to traditional crosswalk designs, there are a number of newer treatments (signs, pavement markings, and signals) that have been tested and show promise. These include: overhead flashing amber beacons, the high intensity activated crosswalk (HAWK), rectangular rapid-flash beacons and pedestrian detection systems.

At signalized intersections, even with pedestrian signals, there is still the possibility of pedestrian trauma resulting from left or right-turning vehicles. Many pedestrian crashes at intersections involve conflicts with turning vehicles. Four relatively simple and low-cost countermeasures that can reduce the potential for such crashes due to turning vehicles are:

- Pedestrian Scramble Operations (PSOs)
- Advanced Green for Pedestrians
- Protected Left-Turning Phase; and
- Prohibition of Right-on-Red

Traffic islands and raised medians are often used on multi-lane roadways where the roadway is too wide for pedestrians to safely cross. The median breaks up the crossing into smaller and more manageable distances. Raised medians or crossing islands have lowered the rate of collisions significantly on multi-lane roads. Painted medians are less effective.

It is important to restrict parking in the vicinity of crosswalks because vehicles restrict the line of sight of both drivers and pedestrians. Bus stops are best located away from crosswalks to deter pedestrians from crossing right in front of the bus. Stopped buses can also create sight line hazards. Ideally, fencing is in place to prevent pedestrians from crossing near the bus stop and that functions to guide them toward the safest crossing location.

The modern roundabout can replace the traditional intersection and has been shown to be safer for pedestrians as well as for vehicle traffic for a number of reasons. European studies have found that modern roundabouts reduce pedestrian-vehicle collisions by 73 to 75 percent.[3] This is especially so when roundabouts are designed with the proven principles related to pedestrian safety and that are covered in this report.

## Traffic Control Devices (TCDs)

As with vehicle traffic, pedestrian traffic needs to be guided, directed, and warned of hazards by TCDs - signs, signals and pavement markings. Signals are found primarily at intersections. Pavement markings indicate the locations of crosswalks and guide pedestrians along a safe path for crossing the road. These TCDs, however, are not all equally effective.[4] For examples, different types of flashing beacons or different types of pavement markings will lead to different rates of compliance by drivers.

Auditory messages and warning signs or displays have been shown to increase pedestrian vigilance at crosswalks. Advance warnings (pavement markings) to motorists of a pedestrian crossing can reduce the danger to crossing pedestrians of multiple-threat situations. Marked crosswalks are not always safer than unmarked crosswalks;[5] on two-lane roads and those with low traffic volume both are equally safe. However, on multi-lane roads with high volumes marked crosswalks have a higher collision risk if they are not enhanced with other treatments such as signals or raised medians.

### Volume Dispersion

Volume control measures are used to reduce the volume of vehicular traffic on local streets in order to increase the safety of vulnerable road users: pedestrians and bicyclists. Most are designed to prevent short-cutting or through-traffic. Diverted traffic should flow on roads where there are other methods deployed to protect pedestrians and cyclists.

### Sidewalks

Separating pedestrians from the roadway reduces crashes between pedestrians and motor vehicles. The presence of a sidewalk reduces pedestrian collisions by 88 percent over no sidewalk. The greater the separation, the better they are protected. Boulevards, streetscaping and fencing are different and effective approaches to separate pedestrians and vehicle traffic. Sidewalks should be at least 1.5 metres in width and maximum safety benefits accrue when sidewalks exist anywhere people travel or move about.

### Rail-Grade Crossings

A common human error is misjudgement of the speed and/or distance of trains. This is partly explained by the "large object illusion" - the perception that large objects are moving more slowly than small ones travelling at the same speed.[6] Not all road users are aware that some crossings have no active warnings (lights, bells, etc.) so they may fail to look for an approaching train. More consistent treatments are needed and some value could be found if pedestrians were better educated about the risks of rail-grade crossings and trains.

### Work Zones

Pedestrians need the appropriate information in order to recognize work areas and potential hazards in order to walk safely through and around work zones. Guiding pedestrians in work zones can present challenges, as these areas may have unexpected or unusual traffic configurations and detours. Signs are typically used for this purpose and these should convey clear and simple directions. Pedestrian detours need to consider the visually impaired and others with disabilities. Guidelines have been developed for the safe transit of pedestrians through work zones.

### Speed Reduction and Calming Measures

In many countries, speed reduction strategies are in place to address issues related to fatality and injury rates for pedestrians and child pedestrians. Setting up 30 km/h zones in residential areas makes sense because at this speed motorists and vulnerable road users can better co-exist and the likelihood of injury is dramatically decreased. Speed calming measures reduce vehicular speeds, promote safe conditions for pedestrians and bicyclists and improve the environment and liveability of neighbourhoods. The key speed calming measures recommended for implementation in Canada are described in this report. They include: rumble strips, speed bumps, humps and tables, chokers, chicanes, mini-roundabouts, landscaping, pavement treatments and still other measures.

## VEHICLES

In North America, less attention has been focused on reducing pedestrian deaths and injuries through vehicle design than is the case for vehicle occupants. Vehicle design has a strong effect on pedestrian injury: softer and more sloping vehicle fronts are effective ways of reducing pedestrian injury and the likelihood of death. Since the majority of vehicle-pedestrian crashes involve the pedestrian being struck by the front of a car, the vehicle's frontal design has the most potential to influence the type and severity of pedestrian injuries. Increasing pedestrian protection in the event of a crash through vehicle design is a key issue and is regulated in Europe and Japan. Influenced by international statistics on pedestrian death and injury rates, these countries pursued their own vehicle standards and regulation in advance of the acceptance of global standards.

Canada regulates new vehicles and imported vehicles under 15 years old, through the *Motor Vehicle Safety Act* (Canada) and has been regulating new and imported vehicles since 1971. It should be noted that the rule-making process is a long one and it usually takes a number of years before a proposed regulation becomes a standard.

Unlike some other countries such as those in the European Union and Japan, Canada does not currently have a regulation for vehicle design for the protection of pedestrians. In 2011 as part of the upgrade of the Motor Vehicle Test Centre in Blainville, Quebec, the federal government constructed a pedestrian laboratory to improve research capacity in this area. Equipment is in the process of being acquired to carry out pedestrian protection research, in conjunction with the U.S. government's National Highway Safety Traffic Administration (NHTSA).

Under the United States (US)-Canada Regulatory Cooperation Council (RCC) that was announced by the two heads of state in February 2011, the two governments are working to harmonize safety standards, including those that would affect pedestrian safety, wherever possible and appropriate to reduce the burden and cost on manufacturers. Accordingly, new regulations in this area will likely be harmonized with the U.S. However, regulations in Canada are also governed by the Cabinet Directive on Regulatory Management (www.regulation.gc.ca) and as part of this regime; the need for regulatory intervention as well as a positive cost benefit assessment is required under the current rules. This is a requirement independent of foreign regulatory actions.

Among the most effective design innovations now available on some vehicles are:

- Improved rear-view requirements to protect children when vehicles are backing up.
- Brake Assist System (BAS), a system that monitors the speed and/or force with which the driver applies the brake pedal, and uses this information to assess the urgency of the action. The BAS then kicks in and generates a high braking power, applying emergency braking and resulting in decreased stopping distance.
- Intelligent Speed Assistance (ISA). These systems can alert drivers to the difference in their speed and the speed limit of the road they are on and can be programmed to prevent vehicles from exceeding the speed limit.
- Adaptive headlights that orient light in the direction the vehicle is turning.
- Pedestrian detection systems that can use a combined camera and radar sensor to monitor any obstacle in front of the vehicle. Such technologies have been developed and are already in production by some vehicle manufacturers.
- Softer vehicle fronts especially those that reduce severity of head and leg injuries to pedestrians.

## Passive Protection

The first impact with the vehicle is often the most significant one and there is scope to mitigate the severity of injuries to pedestrians at speeds below approximately 40 km/h by improving the frontal structures of motor vehicles. In addition to a better frontal shape, new technologies coupled with a greater understanding of pedestrian injury produced by crashes have yielded other solutions which are already in use in some vehicles. One measure now implemented by Volvo Car Company is external pedestrian frontal air bags including air pockets that protect the pedestrian head from the A-pillars and other unforgiving surfaces.

The United Nations has completed the first phase of a global technical regulation on pedestrian safety and light duty vehicle design (UN GTR No. 9) and is currently working on the second phase. This work is being carried out through the United Nations Economic Commission for Europe (UNECE). Because vehicle standards for pedestrian impact are designed to produce safety benefits for pedestrians when vehicles are travelling in the range of 40 km/h or less, speed reduction and traffic calming measures combined with better designed car fronts represents the best possible combination for pedestrian injury and fatality reductions.

## After-market Vehicle Modifications

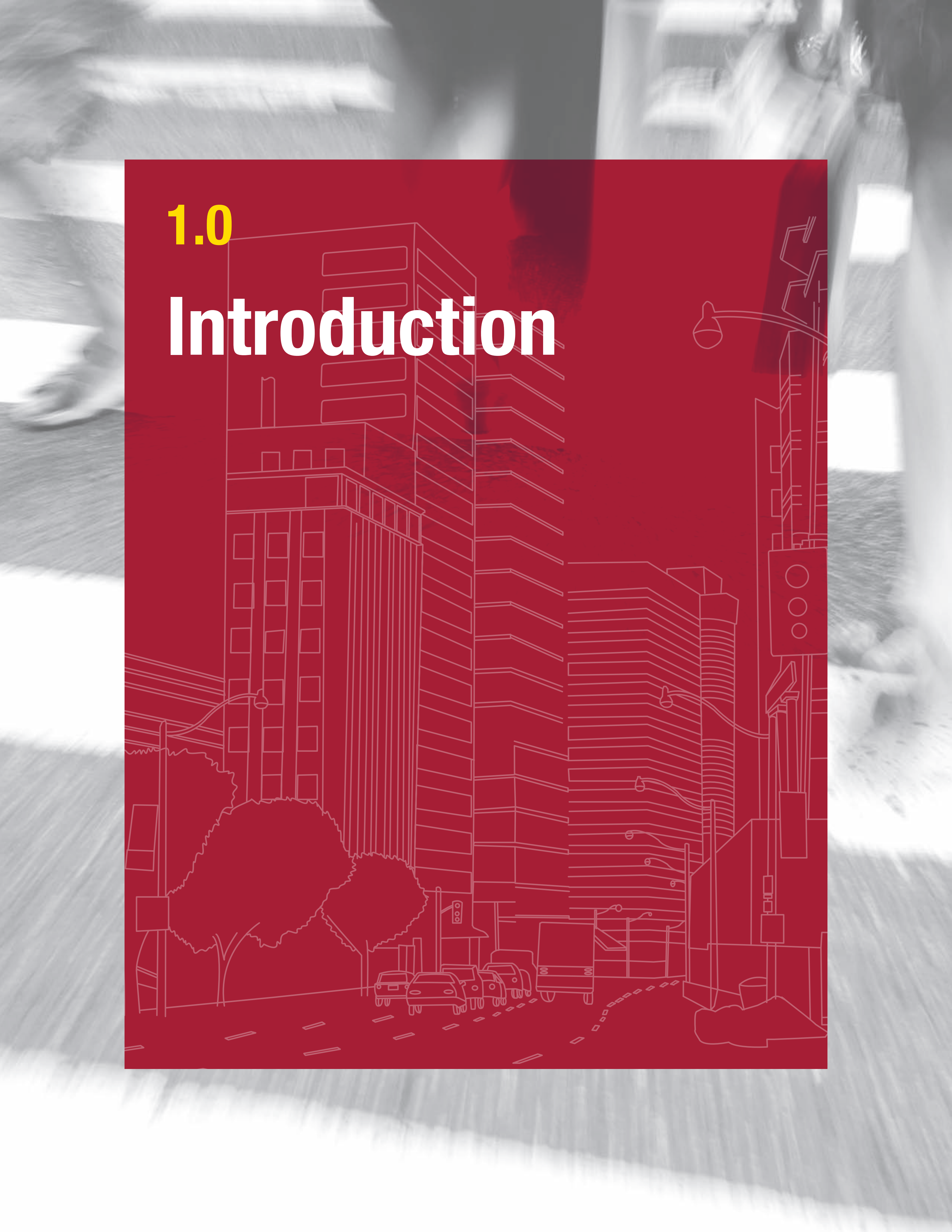
Two of the most pedestrian-unfriendly vehicle modifications identified by the report are raising the vehicle height and adding rigid unforgiving bull bars to the front of the vehicle. Raising the height of a vehicle frame, as an after-market modification, puts other road users at risk; pedestrians are particularly vulnerable. When a vehicle is raised, braking performance and stopping distances can also be significantly affected. Most significantly, the section of the vehicle that comes in contact with the pedestrian is rigid in comparison to the hood, resulting in more severe injury to the struck pedestrian. There is overwhelming evidence that stiff bull-bars (also known as bush bars and grill guards) multiply the injury potential to struck pedestrians for these reasons.

## POTENTIAL COUNTERMEASURES

This report includes a large number of potential countermeasures covering each of the above areas. This report was developed concurrently with the development of Canada's Road Safety Strategy 2015 – the successor plan to Road Safety Vision 2010. The inventory of approximately 70 initiatives, countermeasures and actions address one of the key targets groups within the strategy matrix – vulnerable road users. It was also developed in keeping with the holistic nature of the new strategy which is based on a road user, infrastructure and vehicle perspective. This report is not only a resource of actions for implementation by governments and the road safety community as a whole but it also provides a broad base of information to interested individuals or organizations on the multifaceted issues and challenges associated with promoting the most basic and fundamental form of travel in Canada: walking.

# 1.0

# Introduction



# 1.0 Introduction

Pedestrians are an important group of road users that often get neglected when it comes to improving road user safety. In North America, walking is increasing in popularity and as a basic means of transportation; almost everyone is a pedestrian some of the time and walking is likely to become more prevalent as a means of improving peoples' physical fitness and in order to reduce carbon emissions and other noxious particulates and pollution from automobiles. Furthermore, as the population ages, an increasing number of senior drivers will be giving up driving and turning to other means of basic human transportation. No matter what, walking is a fundamental form of transportation that every person is entitled to, at every age, and in a safe and secure environment.

While the safety of vehicle occupants in Canada has been steadily improving over the past four decades, the trend is much less pronounced for pedestrians. Figure 1.1 shows the 21-year trend in pedestrian fatalities and injuries, while Figure 1.2 shows these numbers as a percentage of total road user fatalities and injuries. The following highlights show that pedestrian road casualties are a serious and significant road safety problem.

- Between 1989 and 2009 almost 9,000 pedestrians have been killed and hundreds of thousands have been injured in Canada in road traffic collisions.
- About 13 percent of road fatalities and about 6.5 percent of injured victims are pedestrians.[7] On average about 340 pedestrians were killed annually on Canadian roads during the period 2005 – 2009. This included about 44 children (aged 18 and under) each year.
- According to the Canadian Institute for Health Information (CIHI), from 2000 – 2008, there were 6,442 pedestrian trauma cases struck by motor vehicles in Canada.[8] Of these, 854 were children aged 0 – 15.
- The number of pedestrian fatalities and injuries over time has been generally flat over the past two decades.

**Figure 1.1** **Trends in pedestrian fatalities and injuries in Canada, 1989-2009.**
*Source: Transport Canada, National Collision Database (NCDB). Note 2009 figures exclude Newfoundland and Labrador*

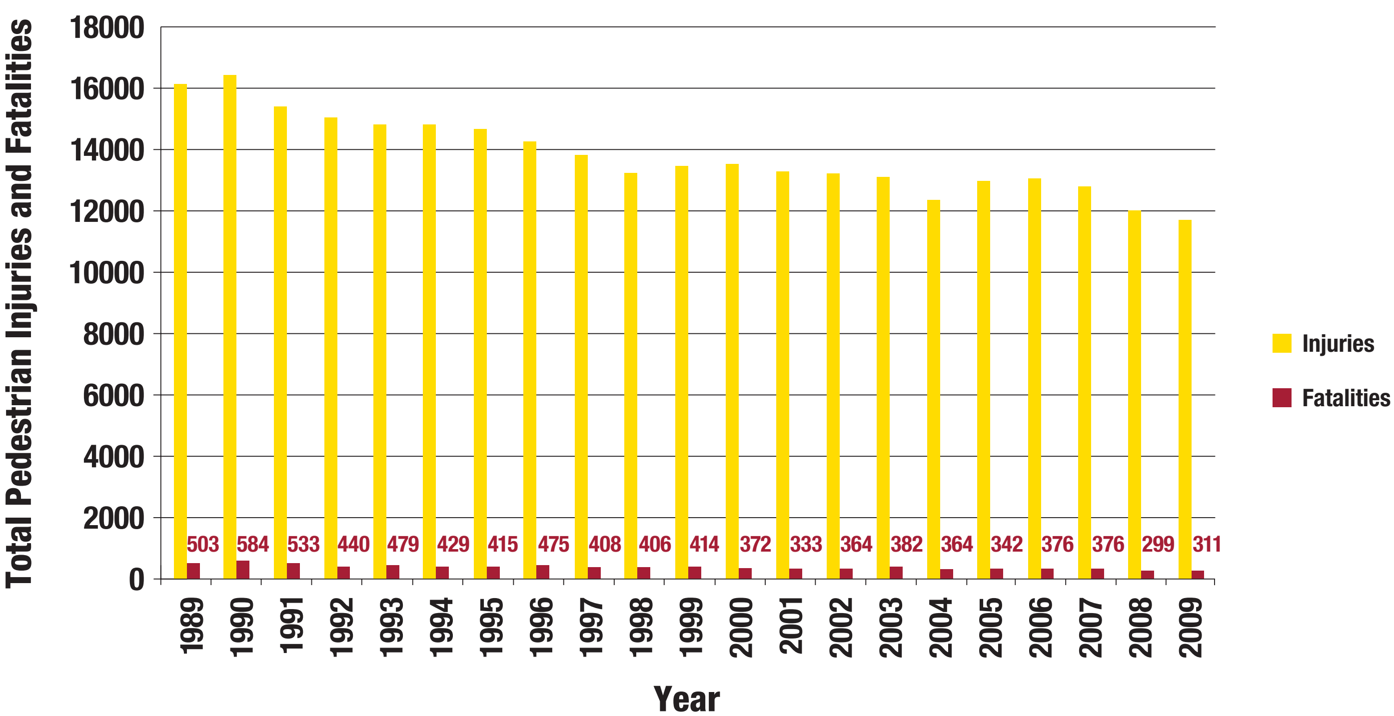
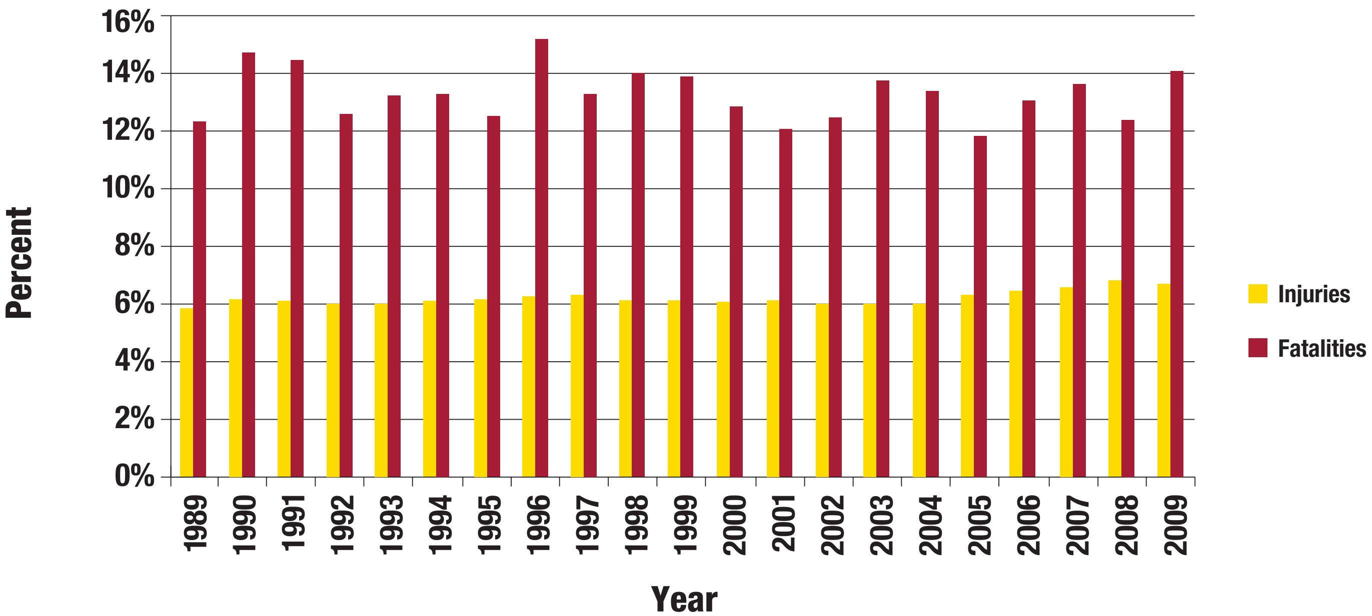


**Figure 1.2 Pedestrian injuries and fatalities as a percentage of total road user fatalities, 1989-2009.**
*Source: Transport Canada, NCDB. Note: Figures for 2009 exclude Newfoundland and Labrador*




A fundamental factor in these statistics is that the road system has traditionally been designed from the perspective of a motor vehicle occupant rather than that of the vulnerable road user. In contrast, international best practice now involves applying multiple strategies aimed at the road user, the roadway and the vehicle and building transport systems that accommodate human error and where the right speed for each type of road has been carefully selected. This is known as the safe system approach.[9] Evidence suggests that international jurisdictions that have made the most progress in reducing human trauma from road crashes have done so by taking a safe system approach. This approach is supported and endorsed by the Organization for Economic Co-operation and Development (OECD) countries as a consensus has been building that embraces this approach bolstered by recent successes.

The safe system approach assumes that the most vulnerable part of the system is that of the unprotected human being, (i.e., the pedestrian) and that the system has to be designed around them. In the last two decades it has become clear that some countries have made considerably more progress in reducing road crash fatalities and injuries than others. Those jurisdictions that established road safety as a priority and implemented improvements across all three of these main areas have achieved substantial reductions in the numbers of people killed and injured on their roads; this is evidenced by the divergent levels of road safety performance by various countries.[10]

In previous decades, road engineering focused on the needs of the motor vehicle occupant as paramount, with the consequence that the needs of other road users, including pedestrians, were more often than not ignored. Priority was often placed on the need to maximize vehicle capacity and vehicle through put. Today, priorities have altered as society's values have shifted toward the equitable use of urban space and human health while recognizing the environmental impacts related to vehicular emissions. Governments in many countries, notably in Europe, have turned priorities around by moving more toward the design of urban transport systems based on a hierarchy that puts pedestrians and cyclists first followed by public transportation and then the private automobile.

Canada lags behind many top performing countries in the OECD. For example, in 2008 the pedestrian fatality rate per 100,000 population was 0.34 in The Netherlands and 0.49 in Sweden compared to 1.1 in Canada.[11 12] In other words, Canada's rate was more than three times higher than that of the Netherlands. The Netherlands had 609 pedestrian deaths in 1970 compared to 56 in 2008, underscoring that the Dutch have not always had low rates, but rather they have achieved low rates by making pedestrian road safety a priority and by implementing pedestrian safety measures. This achievement is all the more impressive considering that walking is a common form of transportation in the Netherlands. It would be reasonable for Canada to reduce its number of pedestrian fatalities to one-third the current level: this would save approximately 2,400 lives in just a ten-year period.

Canada also lags well behind the world's top performer in child pedestrian safety, Sweden. For child pedestrians, Canada's fatality rate (child fatalities per 100,000 child population) was more than double that of Sweden's (0.77 for Canada compared to 0.35 for Sweden).[13]

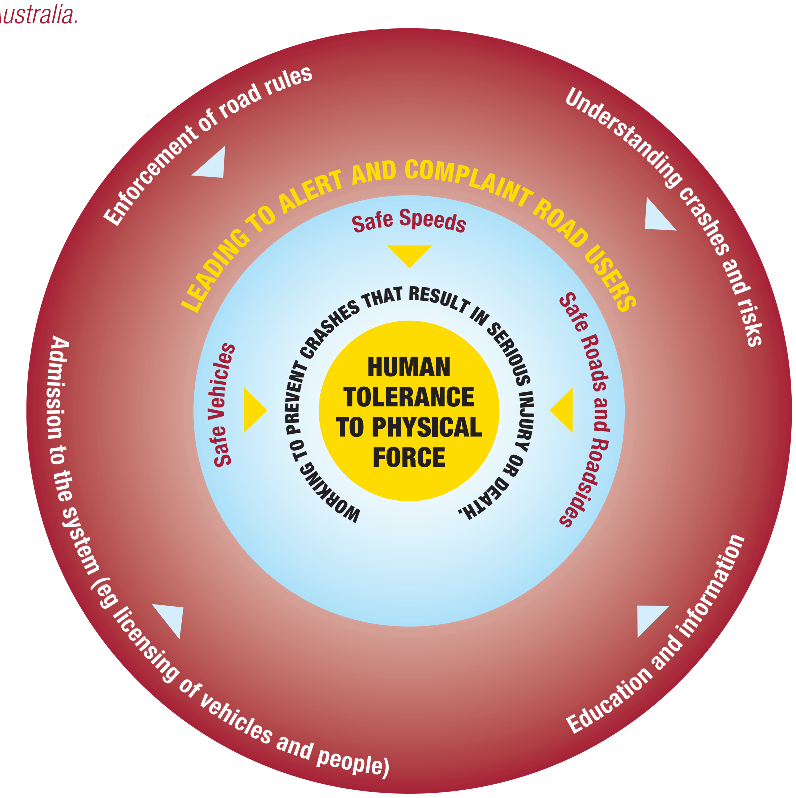
Research findings and experience of other jurisdictions indicate that vast progress could be made to reduce the number of pedestrians killed and injured in Canada if pedestrian safety were given higher priority and if proven measures were implemented. No longer is it acceptable to simply assume pedestrian injury is inevitable. The schematic in Figure 1.3 illustrates the need to recognize human tolerance to physical force as a central tenet in designing a safe system.

There are many proven measures that would generate greater safety benefits for pedestrians and these will be discussed in this report. Themes include safer pedestrians, safer drivers, safer road and traffic signal design, safer speeds and safer vehicles. It is possible, given the appropriate level of priority to significantly reduce the number of pedestrians killed and injured on Canada's roads. It is not unreasonable to adopt and work toward the goal of eventually eliminating pedestrian deaths and serious injuries from traffic systems in Canada. This report provides an overview of available countermeasures and best practices to achieve improved pedestrian safety.

This report is organized around the following four areas:

- The role of the pedestrian;
- The role of the driver;
- The role of roadway system;
- The role of the vehicle.

**Figure 1.3 The safe system approach with safe speeds as one of three primary considerations.**
*Source: This diagram is taken from the 2009 WHO report on the Global Status on Road Safety which was in turn adapted from work commissioned by the Government of Western Australia.*



# 2.0

# The Role of Pedestrians

## 2.1 Background/Context

The term "pedestrian" refers to people travelling outside of a motorized vehicle but who are not pedal cyclists. Pedestrians, quite naturally, are made up of all ages and abilities of people (e.g., children, older adults, persons with disabilities, persons with visual or hearing challenges, as well as those using assistive devices, skateboards, longboards, rollerblades and Segways™). The design and operation of the road system can be designed to take into account the abilities and limitations of all of these vulnerable road users. Both pedestrians and vehicles use public roads, often at the same location and time. However, the design of the roadway system favours the movement of motor vehicles, often at the expense of the safety and needs of pedestrians. With the increase in the numbers of roads, traffic volumes and parked vehicles, pedestrians have been the forgotten road users.

This section describes the tasks and challenges facing all pedestrians, the nature of crashes involving vehicles that strike pedestrians and driver behaviours that put pedestrians at risk (distraction, low visibility and substance impairment) and how these factors contribute to human trauma. In addition, it will analyze the situation for children and older adults as pedestrians, pedestrians with special needs and pedestrians using assistive devices or wheeled forms of transportation. The section also explores the various countermeasures aimed at pedestrians themselves.

## 2.2 The Pedestrian's Task

In order to understand any task or activity carried out by humans, one can conduct a task analysis to identify the main components of the activity and the abilities needed to accomplish it successfully and safely. An analysis of street crossing behaviour reveals four main components - route planning, detection of traffic, judgment and decision making. Crossing the street can be more complex than one might think. For example, a task analysis for child pedestrians undertaken by van der Molen[14] identified 26 subtasks. Behavioural requirements were first determined. Psychological processes such as detection, recognition, identification, and decision making are also involved. There are various factors that impact pedestrian behaviour and safety - environment (road type, width, intersections, crosswalks, surfaces, lighting), traffic (volume, moving and stationary vehicles, communication), personal (physical, psychological, personal characteristics, motivation, experience, psychological state), and social (presence of others, purpose of journey, play).

Before crossing the street, the pedestrian scans the road, perceives traffic and makes judgments about the distance, speed and direction of vehicles. Based on this information, he or she makes a decision as to whether or not to cross the road at that moment. Young children have difficulties, depending on their level of development, with one or more of these subtasks. Likewise, older pedestrians may encounter problems in perception of vehicle traffic and judgment of when to cross the street. Speed estimation can be influenced by the size, colour, and distance of the approaching vehicle. Judgment errors such as these can lead pedestrians to accept unsafe gaps when crossing the road.

## 2.3 Motor Vehicle and Pedestrian Crashes

A problem with much of the research on pedestrian safety is the lack of an index of exposure. That is, there is no control for the amount of pedestrian and vehicle traffic. For example, some age groups may have more crashes because there are more of them walking in locations with high levels of vehicle traffic. A "dangerous" intersection may have a high collision frequency because there are large numbers of pedestrians and vehicles there. If measured as a rate per million miles travelled, walking ranks as the most dangerous mode of transportation, as seen in US data showing fatality rates for public transit, passenger cars and trucks, and pedestrians to be 0.75, 1.3 and 20.1, respectively.[15] However, as pedestrians travel much slower than motorized transport, a still different measure of exposure would be one based on time rather than distance. But such a measure is not readily available.

Motor vehicles that strike pedestrians is a crash pattern made up of two broad types – parallel, where the pedestrian is moving in the same or opposite direction as the traffic, and transverse, where the pedestrian is moving across the path of a vehicle. In the former, the pedestrian may not be aware of the approaching vehicle if moving in the same direction, and may assume that the driver has seen him or her. In addition, the driver may not be able to determine (especially in darkness) whether the pedestrian is moving toward or away from the vehicle, or even whether a pedestrian is present. Vehicle-pedestrian crashes can be classified into several specific types:[16]

- dart out, first half - a pedestrian, not at an intersection, appears suddenly from the roadside
- dart out, second half - same as the first type, except that the pedestrian covers half of the crossing before being struck
- intersection dash - similar to the dart-outs, but occur in or near a crosswalk at an intersection
- multiple threat - the pedestrian is struck by a vehicle after other vehicles have stopped for the pedestrian and are blocking the view of the driver of the striking vehicle
- bus stop related - pedestrian crosses in front of a bus, which is blocking the view of other drivers
- vehicle turn or merge with attention conflict - the driver is turning or merging with traffic, and attention is focussed on looking for a gap instead of on pedestrian crossing the roadway.

The dart out, first half is by far the most common type of pedestrian collision, accounting for 24 percent of pedestrian crash types (based on data from six US states).[17] Figure 2.1 below summarizes pedestrian fatalities and injuries in Canada based on pedestrian action in the ten-year period from 2000-2009.[18] These data reveal that most pedestrians are struck when they have the right-of-way and are not doing anything wrong or illegal.

**Figure 2.1 2000–2009 National Pedestrian Data**

| **PEDESTRIAN ACTION** | Fatal | Injury | Total | % of Total |
|---|---|---|---|---|
| Crossing intersection with traffic control, with right of way | 291 | 32,462 | 32,753 | 22% |
| No traffic control with right-of-way or in crosswalk | 848 | 25,293 | 26,141 | 18% |
| Crossing without right of way | 764 | 28,468 | 29,232 | 20% |
| Pedestrian in roadway | 679 | 11,840 | 12,519 | 8% |
| Pedestrian on sidewalk, median or safety zone | 224 | 6,758 | 6,982 | 5% |
| Enter/Exit vehicle | 45 | 1,803 | 1,848 | 1% |
| Choice is other than the preceding values | 664 | 15,558 | 16,222 | 11% |
| Unknown | 728 | 20,869 | 21,597 | 15% |
| **Total** | **4,243** | **143,051** | **147,294** | **100%** |

# 2.4

# Behaviours and Situational Factors that Increase Pedestrian Risk

Pedestrian visibility obviously involves a relationship between driver and pedestrian. The driver must detect the pedestrian but the pedestrian may also have a role to play in making the driver's task a bit easier. This section focuses on ways pedestrians can make themselves more conspicuous.

Visibility of pedestrians is a particular problem at night; therefore efforts to enhance pedestrian visibility often focus on night-time conditions. However, visibility can also be compromised by weather conditions (e.g., rain, fog, snow) or sunlight glare. Even under ideal environmental conditions, there are ways to enhance pedestrian visibility.

Pedestrians are at greater risk in dark conditions because they have more difficulty assessing the road environment and are much less visible to drivers. Many crashes involving motor vehicle that hit pedestrian occur at night, often on roads where the only light comes from vehicle headlights. Human visual sensitivity declines significantly with decreasing illumination, hence pedestrians become more difficult to detect, as light level decreases. A pedestrian in dark clothing blends in with the dark surroundings and relatively dark road surface. The presence of water on the road surface also reduces visibility at night, especially in the presence of oncoming vehicle headlights or street lights, which create glare in the driver's eyes.

Typically the pedestrian is aware of the presence of a vehicle at night before the driver is aware of the pedestrian. Drivers at night often overdrive their headlights and many think they can see further than they actually can. Allen et al.[19] report that the vast majority of drivers who struck a pedestrian at night claim they had difficulty seeing the person; this claim was made for only about 11 percent of such cases in daytime. About 25 percent of drivers are aware of striking a pedestrian at night only after they hear the impact.

Dark clothing is often worn by pedestrians, especially in cold weather, and this, combined with more hours of darkness, greatly increases vulnerability in winter months. Visibility aids have the potential to increase visibility and enable drivers to detect pedestrians (and cyclists) earlier. Retroreflective materials enhance recognition, in particular when arranged in a 'biomotion' configuration, taking advantage of the motion from a pedestrian's limbs.

### Research Findings

One of the more effective ways of reducing pedestrian crashes at night is the use of retroreflective clothing, patches of material or tags. Light hitting such objects returns to its source, making the object highly visible. The use of lamps attached to the body or carried also enhances conspicuity at night. Blomberg, Hale and Preusser[20] examined various retroreflective materials and lights for their ability to increase pedestrian conspicuity. A flashlight was detected about six times farther away than was a pedestrian wearing a white tee shirt and blue jeans.

Owens, Antonoff and Francis[21] conducted two laboratory experiments comparing visibility of a runner wearing reflectorized vest, stripes, or biomotion stripes (on the hips, arms, legs and shoulders) with a control condition involving no markings. Visibility distances were greater for all reflective marking conditions than for the control condition. Markings on the limbs were more effective than on the torso, and those displaying biological motion were better than a vest or stripes.

In a related study[22] 10 young and 10 older participants drove on a closed road circuit and responded when they could first recognize a pedestrian walking in place on the shoulder of the road ahead. Pedestrian clothing varied - black, white, retroreflective vest, or biomotion. Vehicle headlights were high or low beam, and a glare condition was created by headlights of a vehicle positioned 10.2m in front of the pedestrian. In the worst condition (low beams, black clothing, glare) only five percent of pedestrians were recognized, while recognition was 100 percent in the biomotion condition with no glare. Mean recognition distances, across all conditions, with low beams were 59.4m and with high beam 93.6m. The mean for older drivers was 65m and for young drivers, 97m.

Olson, Dewar, and Farber also explain how a pedestrian could easily be missed at night by a driver with low beam headlights. Photometric measurements reveal that the light from car headlights falls mainly at the feet of pedestrians with little on the middle and upper body until the vehicle is very close.[23] This fact would explain why biomotion placement of retroreflective materials, which typically includes materials around the ankles, is more effective at increasing visibility than vests worn on the upper body. A pedestrian to the left of the vehicle would be illuminated less than would one on the right. This creates an even greater hazard for pedestrians entering the road from the left.

Tyrrell, Wood and Carberry[24] quantified pedestrians' estimates of the ability of drivers to recognize them on the roadside at night. Young and older subjects walked in place on the far shoulder of a closed road circuit and indicated when they were confident that an approaching driver could first recognize that they were present. They wore black, white, or black with a retroreflective panel on their vest. Pedestrians overestimated their own visibility and underestimated the benefits of wearing conspicuous clothing. The actual and estimated recognition distances varied dramatically, depending on the type of clothing worn.

Tyrrell, Patton, and Brooks[25] demonstrated the benefits of educating young adults about the factors that influence pedestrian visibility. Initially the students who participated failed to appreciate the effects of retroreflective clothing and high beam headlight illumination. Those who had received a lecture on these factors several weeks earlier gave estimates that were ten percent shorter than those of a control group.

A second phase of the study found that an intensive lecture with illustrations of these factors led to estimates 56 percent shorter than those of a control group.

Pedestrian conspicuity can also be enhanced in daylight. An extensive review of research on various visibility aids for pedestrians and cyclists revealed that in the daytime fluorescent materials in yellow, red, and orange colors enhanced detection and recognition by drivers.[26] Yellow-green, or lime-yellow, is the most effective non-fluorescent colour in daytime.

## Legislation and Regulation

In 2004, Spain introduced a law requiring all pedestrians on major highways and hard shoulders to wear high visibility garments. In 2008 the French government followed suit and adopted a law requiring drivers to have a high-visibility jacket and a warning triangle in all vehicles in France, including those of tourists. The famous fashion designer, Karl Lagerfeld, was featured in posters (see Figure 2.1 below) to promote compliance with the new legislation. Their slogan translates to: "It's yellow, it's ugly, and it doesn't go with anything, but it could save your life".[27]

In Canada, it is evident that governments recognize the value in increasing pedestrian visibility as demonstrated by the allocation of resources, development and incorporation of visibility standards designed to make individuals who work on the roads safer. There are currently no requirements or standards in Canada for individuals to wear high visibility safety apparel outside of their job requirements.

**Figure 2.2 French campaign poster featuring Karl Lagerfeld promotes legislation on mandatory vest and triangles in vehicles.**
*(Translation: "It's yellow, it's ugly, it doesn't match anything, but it can save lives") Credit: LOWE Paris & Stateus*

## School Programs

In many European countries, schools distribute retroreflective vests at the beginning of every school year as part of an education and awareness campaign. The vests remain the property of the school and get reused year after year. According to an international survey, Norway's investment into a program known as Safe Routes to School contributes to its consistent top performance in road safety. Many school starters (6 year olds) receive caps, vests, or school bags in bright colors and retroreflective materials.[28] In the UK, 12 million reflectors have been distributed to elementary school aged children over the past 30 years through the Cats Eyes for Kids program.[29]

In a study of child injuries in Uganda, pedestrian injuries accounted for one-third of severe injury. This study prompted the development of the "See-Me-Walk" pilot program consisting of education and the distribution of retroreflective arm bands. Over the three month pilot, 2 pedestrian injuries were reported in the 40 schools compared with the same period the year before where 30 pedestrian injuries were reported.[30]

Educational material and booklets have been provided throughout Canada but they have not included the provision of retroreflective clothing or materials.

### POTENTIAL COUNTERMEASURES

- Consideration should be given to having all outwear and shoes for adults and children to have built-in retroreflective materials appropriately placed. Children should be educated on road safety visibility. In addition, they could be provided with tools such as retroreflective materials that can easily be put on and worn on the body.
- Educate drivers about the difficulty in detecting pedestrians at night, stopping distances and the limitations of headlights.
- Educational campaigns that discourage the wearing of dark clothing at night and promote wearing retroreflective materials or a yellow-green colour if non-fluorescent.

## Pedestrian Distraction and Inattention

The issue of driver distraction has received considerable attention in recent years. Distracted driving is any non-driving activity a person engages in that has the potential to distract him or her from the primary task of driving and increase the risk of crashing.[31] Many of the same principles that apply to driver distraction also apply to pedestrian distraction. However pedestrian distraction is much less recognized. A significant source of distraction for road users is the use of electronic hand-held devices such as talking on cell phones, text messaging, Internet use and listening to hand-held music players. Distraction for pedestrians using the roadway may be of one or more of the following types:

- cognitive (e.g., the brain attending to the conversation rather than the traffic; not noticing or taking in information about traffic or other pedestrians; "looking but not seeing.");
- physical (e.g., slowing or awkward movement, if carrying something in one hand);
- visual (e.g., obstruction of the view of traffic on the side such as with an umbrella or looking down at cell phone or texting device);
- auditory (e.g., not hearing approaching traffic due to music or communication devices).

An Australian study of pedestrian distraction from cell phone use while crossing the street has been reported by Hatfield and Murphy.[32] They observed 546 pedestrians either using a cell phone or not while crossing the street at both signalized and unsignalized intersections. More than 20 percent of phone users looked at their phone while crossing (mostly to text message). Cell phone use also influenced speed of crossing and scanning for traffic before crossing, but there were gender differences with respect to these findings.

Bungum, Day and Henry[33] recorded the behaviour of pedestrians crossing the intersection of a busy urban street with a signal and a marked crosswalk. Distracted pedestrians were defined as those wearing headphones, talking on a cell phone, eating, drinking, or smoking while crossing. About 20 percent were distracted as they crossed. Cautious behaviour (looking left and right and entering the street legally) was exhibited by only 13 percent of the distracted pedestrians. There was no comparison group in this study.

Using an experimental approach, Nasar, Hecht and Wener[34] had 60 pedestrians walk along a prescribed route of 92 meters, with half of them talking on a cell phone and the other half holding a phone but not talking or listening. Recall of the objects placed along the route was poorer for those talking on the phone. This suggested reduced situation awareness and higher overload for those using the phone. In a second study Nasar et al. observed the behaviour at crosswalks of pedestrians either using a phone, listening to an I-pod™ or neither of these. Phone users crossed unsafely into oncoming traffic more often than the other two groups - 48 percent of the time, as compared with 16 percent and 25 percent for those with I-pods and neither, respectively.

It is evident from these studies that use of a cell phone while crossing the street interferes with cautious behaviour, reduces situation awareness and poses a threat for pedestrians. While hand-held devices are not the only source of distraction for pedestrians, they appear to be a major one.

## POTENTIAL COUNTERMEASURES

- Educate pedestrians about the dangers of being distracted around traffic.
- Educate pedestrians, especially children, not to use cell phones or other electronic devices while crossing the road taking into account physical and intellectual development.

### Substance-impaired Pedestrians

The alcohol or drug impaired pedestrian is an over-looked and neglected problem in traffic safety. Studies conducted internationally suggest that 30-35 percent of fatally injured adult pedestrians have blood alcohol concentrations (BAC) exceeding 80 mg%.[35] In urban areas this percentage may exceed 40 percent.[36] In Canada, in 2008, among pedestrians tested for alcohol post-mortem, almost 40 percent had been drinking and 27 percent had BACs over 160 mg%.[37] Although testing may be biased towards those most likely to have been drinking, these percentages still indicate a very high prevalence of alcohol intoxication.

Progress in reducing the numbers of motor vehicles that strike impaired pedestrians has not kept pace with the world-wide decline in impaired driving crashes. In any case, legal approaches may have little preventative value because of the high proportion of chronic or severe alcohol abusers among pedestrian casualties.[38] It is likely that the best solutions are ones that involve road design and the motor vehicle.

Wilson and Fang analyzed the characteristics of police-reported collisions involving impaired pedestrians aged 16 and over, as compared to similar aged non-impaired pedestrians in the province of British Columbia.[39] Impaired pedestrians were predominantly male (75 percent) compared to 52 percent of non-impaired pedestrians. Impaired pedestrians tended to be between the ages of 21 and 45, whereas non-impaired pedestrian collisions peaked at age 16 and decreased linearly up to age 55 before levelling off. Impaired pedestrian and vehicle collisions were more than twice as likely to take place in darkness, with 76 percent occurring between 18:00 and 06:00 hours. The impaired pedestrian and vehicle collisions were also much less likely to occur at intersections.

A report from Australia indicates that young people (17-29) are overrepresented in alcohol-related pedestrian crashes.[40] BAC levels of 78 young pedestrians (45 males and 33 females) were measured as they were leaving a licensed drinking establishment and a survey was done. The average number of drinks reported was 8.26 on a typical evening of drinking. More than half of the sample recalled situations in which alcohol had impaired their ability to walk to their destination. The term “drink walking” used in Australia, was known by just under half of those surveyed. Almost half knew someone who had been hurt while drink walking. When asked to rate several risks associated with road users (e.g., drink walking, drunk driving, not wearing a seat belt, speeding, driving when tired), walking in public after drinking was rated lowest. This study showed that young adult pedestrians are often unaware of the dangers associated with walking when impaired. The countermeasures suggested by the authors include fencing at areas near bars to separate pedestrians from vehicle traffic, adequate lighting and education of both pedestrians and drivers about the problem.

The overrepresentation of pedestrians impaired by alcohol could be explained in part by their difficulty in making safe decisions about gaps available to cross the road. Oxley, Lenné and Corben compared intoxicated pedestrians (average BAC levels from 50 to 100 mg%) with sober ones on road-crossing decisions and concluded that those at the higher BAC levels showed a lack of awareness of the impairment, risky crossing behaviour, and difficulty integrating speed and distance information in a timely manner, necessary to select safe gaps in traffic.[41]

There is one example of an intensive multifaceted multidisciplinary countermeasure program targeting alcohol-impaired pedestrians.[42] This program, named Walk Smart Baltimore operated in that city for a one-1/2 year period from 1995 to 1997 and was evaluated by Blomberg and Cleven. A total of 31 different countermeasures were recommended that included the following: traffic engineering (correcting lighting deficiencies, removal of objects that obscured visibility, refreshing crosswalks and mounting special signs and banners to warn drivers of high pedestrian hazards and speed limits); special training to police, public education and awareness through radio, television and print media, inclusion of pedestrian safety as part of server training and mass mailings to liquor licensees. In addition, retroreflective caps were distributed to pedestrians in high crash zones at night.

The majority of countermeasures were implemented in urban zones identified as high crash areas for alcohol-impaired pedestrians. To evaluate the program, a surrogate for impaired pedestrian crashes was defined (male, aged 30-59, from 7:00 pm to 4:00 am, Thursday to Monday). The evaluation found that during the program surrogate crashes declined by 16 percent in all areas, 22 percent in targeted zones and 37 percent on treated roads, while crashes for other similar aged male pedestrians increased. The study demonstrates that impaired pedestrian crashes concentrated in circumscribed areas are sensitive to treatment. Because the countermeasures were implemented as a package, it is not possible to determine which ones were most responsible for the outcome, or if indeed they worked together in some integrated fashion.

### POTENTIAL COUNTERMEASURES

- Server training programs should include mandatory components on pedestrian safety as well as impaired driving.
- Identify urban areas where alcohol and drug-impaired collisions are concentrated and collect information to determine which roadway, signal control, speed reduction, lighting and fencing treatments would be most effective in those areas.
- Apply countermeasures based on knowledge of communities and locations. These could include engineering modifications to separate pedestrians from traffic, traffic calming measures, signs to warn drivers, parking restrictions, distribution of retroreflective clothing or tags etc. as well as education campaigns directed at both pedestrians and drivers.

## 2.5 Child Pedestrians

### Children's Susceptibility to Injury

Children's overall physical, cognitive, visual and auditory development puts them at a distinct disadvantage as pedestrians. They are at an increased risk of injury because crossing the street involves complex processes and behaviours that are not yet adequately developed in children. Crossing involves planning the route, detecting traffic, making assessments about the speed and distance of traffic, and deciding when to cross. Crossing skills require developed motor skills and the ability to continuously process feedback regarding decision-making.[43]

The risk of injury is further exacerbated because children are small in stature and are at a lower eye level than adults, which requires them to look up and over vehicles. Obstructions also frequently limit a child's field of vision, decreasing their perception of and ability to deal with oncoming traffic. Children's small stature also makes them more difficult for drivers to detect, and at close proximity they may be invisible below the height of a vehicle.

### Statistics on Child Pedestrian Collisions

- Child pedestrian injuries are a leading cause of injury-related death for Canadian children aged 14 years or younger.
- On average, 30 child pedestrians younger than 14 years are killed and 2,412 are injured every year.*
- Pedestrian-related injuries contribute to almost 12 percent of all injury-related deaths of children younger than 14 years of age.[44]
- Children aged 10 to 14 years have the highest incidence of

pedestrian-related injuries, but a larger age range of children (5 to 14 years) are at the greatest risk for pedestrian-related fatalities.*

**Transport Canada, National Collision Database (NCDB)*

## Children Under 11 Years of Age

The vision and hearing of children less than 11 years of age is generally not yet fully developed. Even though visual acuity is well developed by six months of age, young children often have tunnel vision which is compounded by their short stature and lower eye level and further limiting their field of view. With regard to colour identification, children 3-6 years of age can often match colours but not necessarily identify them properly and this may be an important consideration when teaching young children about traffic signals. Children also have difficulty identifying the direction of oncoming traffic, because their hearing is not fully developed.[44] Young children in general often favour the most direct route available, rather than seeking the safest place to cross. As a result, they will cross in the middle of the block, at right angles to the curb, or diagonally across an intersection.

In order to cross a street independently and safely, children need at least three important skills that are typically not acquired until between 9 and 11 years of age: the ability to determine and use a safe crossing pathway, the capability to realistically assess a vehicle's speed and the cognitive means to judge safe gaps in traffic.

Before 11 years of age, children have a difficult time judging vehicle speed or even their own walking speed. Children younger than 8 years of age also tend to think that smaller cars travel faster than larger ones. To judge speed, children need to be able to classify and judge a vehicle's size relative to other objects. Detecting traffic requires a search strategy and this is not a reliable skill until children reach approximately 11 years of age. To compound this lack of judgment, both pre-school and school-aged children are often self-absorbed which is a normal state for children but as a result, they find it hard to believe that a driver would not be aware of them.[44]

Young children struggle with recognizing a safe gap in traffic in order to cross the street. Several studies have illustrated that those children younger than six years of age make errors both in identifying too short a gap to cross and in missing appropriate opportunities for crossing. One study demonstrated that 5-year olds missed more chances to cross than adults when they had a comparable number of short gaps. The ability to scan is poorly developed in children younger than 6 years of age. Although children 6-7 years of age can begin to learn planned systematic searches, it is important to note that this function is not well developed until approximately 11 years of age.[44]

Children often become distracted when on or near the road, due in part to difficulties in focusing attention on the traffic. Tabibi and Pfeffer[45] examined the effect of distracters and the role of attention on how children identify safe road crossing sites. Ability to identify safe and dangerous sites was assessed with children aged 6-11 and adults using computer presentations of sites, with and without visual and auditory distractions. Ability to identify safe and dangerous sites improved with age and was related to selective attention in children, but not in adults.

## Children Age 11 to 14 Years

By the time children reach 11 years of age, they engage in greater amounts of abstract thought, which means that they have a much greater ability to combine a number of ideas to form a new concept. This ability is used when one set of rules is applied to multiple and varied situations. It is not obvious to children younger than 11 that the pedestrian safety rules used on one street corner can be applied to all street corners, but older children are capable of understanding and applying this concept. However, it is not unusual for pre-teens and teens to harbour exaggerated beliefs about their abilities and embrace an attitude of invincibility, which can lead to increased risk-taking. For these children, an unhappy ending to their personal story is often inconceivable.[46]

## Role of Parents and Caregivers

Parents and caregivers can guide their children and instil safety awareness and safe pedestrian habits in young children. It is crucial that adults create opportunities for discussion by accompanying children on walks; the simple presence of parents or caregivers may help reduce the risk of injury.[47] Parents and caregivers can initiate discussion of pedestrian safety as soon as they start walking with a child, and continue to do so at least until the early teenage years. However, the success of parental guidance is largely contingent upon adults having the correct knowledge to share with their children.

Parents often view injuries as a natural consequence of childhood and frequently rationalize instances where they put their child at risk, citing convenience, stress, and prioritization of competing interests.[48] Although most parents report teaching their children pedestrian safety, one study found that only 16 percent of parents knew basic pedestrian safety facts.[49]

In addition, parents and caregivers do not generally take advantage of teaching opportunities when they are crossing the road with their child, and neither parents nor children alter their road crossing behaviour as the child gets older.[50] Most parents do not raise the subject of how to cross streets with increased independence, as might be developmentally appropriate and are often unaware of the importance of modeling safe pedestrian behaviour. In addition, adults may unconsciously adjust their own pedestrian behaviour, dependant on the gender of the child they are accompanying. When walking with their daughters, parents more stringently obey pedestrian safety rules.[51]

Parents and caregivers can teach children to:

1. Always look both ways before crossing any street including a marked crosswalk or an intersection with a Walk signal;
2. Continue to look as you cross the street and check every lane of traffic, and any gap, as you walk.
3. Do the same when crossing at intersections but also watch for turning vehicles
4. Never allow a marked crosswalk or WALK signal to allow you to feel safe
5. Always watch out for traffic and do not use electronic devices when walking.
6. Be visible when possible.

In summary, studies demonstrate that even brief teaching moments by parents or caregivers can improve child pedestrian safety and when adults accompany children to and from school there is a demonstrated reduction to the risk of injury.[52 53]

## Environmental Factors

Traffic environments contribute significantly to the frequency and severity of pedestrian-related crashes. Children are predominately hit, as pedestrians, during daylight hours and when road conditions are dry. This should not be surprising as these are the conditions that bring children outdoors. Children are more likely to be struck in areas with heavy traffic volumes, a high density of parked cars, higher speed limits, and limited choices for play, (i.e., lack of green space or lack of suitable recreation areas).

It is well established that lower income neighbourhoods, particularly urban ones, present a higher risk for child pedestrian injuries.[54 55] Growing up in a high density neighbourhood with few safe places to play may result in fewer opportunities to learn or practice safe crossing behaviours.[56] An absence of support networks could also result in children walking to school unaccompanied, before they are fully equipped to do so safely.

A 2008 study reported that children who live in neighbourhoods which they perceive as unsafe are aware of safe traffic behaviours but may not adhere to those practices because of the social environment. Children in such neighbourhoods report adopting distinct walking behaviours in order to avoid social risks. For example, they reported travelling quickly, avoiding eye contact and crossing streets randomly to avoid troubled areas or large groups of people.[57] All of these behaviours and distractions could leave them more susceptible to pedestrian injuries.

Many parents worry about the environment in which their children walk. Areas of concern include: speeding, volume of traffic, drivers not being aware of children playing, children's risk-taking behaviours, increased crime, and unpleasant walking environments. Parents also believe that children resort to playing in the street due to the lack of accessible and affordable alternatives, and that existing public spaces are ill-equipped and poorly maintained.[58 59] In past studies, parents have expressed a willingness to participate in strategies to reduce the risk of child pedestrian injuries. If parents perceive a high risk of injury, they are more likely to attend a meeting or volunteer for a safety program. Neighbourhood solidarity or feeling a sense of connection to the neighbourhood is a good predictor of parents' willingness to make changes to improve child pedestrian safety.[60]

Studies have shown that when there are more people walking, pedestrian injuries are less likely to occur. It appears that motorists adjust their driving behaviour in response to increased numbers of pedestrians.[61] Walkable neighbourhoods also promote health benefits to the community's residents, in addition to reducing environmental pollution from vehicles.[62] See Section 4.0 for ways the safety of streets and neighbourhoods can be improved through roadway design and engineering. Many of these treatments would be beneficial to the safety of child pedestrians.

### Child Pedestrian Education

While the ongoing opportunity for positive, parental influence cannot be underestimated, schools and community organizations can also play a vital role in teaching children to become safe pedestrians. Child pedestrian education should be geared towards children's ongoing development in order to be effective. Because cognitive abilities and perceptions change dramatically from 7 to 14 years of age, educational approaches should also evolve in order to reflect a child's developmental growth. Research indicates that general safety knowledge and safe pedestrian behaviour deteriorate with time, if not followed up and reinforced with continuing education.[63] Of equal importance is that a program be multi-faceted and directly involve parents. Incorporating systematic roadside lessons also increases the likelihood of long-term success.[64]

Many experts recommend institutionalizing ongoing pedestrian safety education within schools, starting at the earliest grades and incorporating both knowledge and skill-based learning. This requires the development of standards and curricula which are flexible enough to accommodate external agencies, neighbourhood groups, and parents, in order to allow for the best possible delivery and implementation within both the schools and the community.[65] Some noteworthy examples of child pedestrian programs are described in Appendix one.

### POTENTIAL COUNTERMEASURES

- Include measures to improve child pedestrian safety as part of a national safety strategy.
- Consider child pedestrian safety in urban communities by implementing area-wide engineering solutions and speed limit reviews to reduce pedestrian risk (including pedestrian facilities, safe play areas and/or traffic calming infrastructure).
- Community-based education/advocacy programs to prevent pedestrian injuries in children 0-14 years, including education for parents and pedestrian skills training to improve child pedestrian road crossing skills.
- Educate parents on the risks children face in traffic and the role of parents in reducing that risk (e.g., through public health facilities, daycare, kindergarten etc.)

# 2.6 Pedestrians Who are Older

The number and proportion of older people in Canada is increasing rapidly, and since many who currently drive will cease driving for various reasons in the coming years, they are likely to travel more by walking. Encouraging physically active transportation modes prior to driving cessation will help older adults to maintain safe pedestrian behaviours and stay healthy and active for longer. Walking in a traffic environment can be dangerous for older pedestrians for several reasons, including limited vision and hearing, slower reaction time and decision making, lower levels of attention, and reduced walking speed. Those over age 70 are more likely to be struck by a motor vehicle. Older pedestrians accounted for about 19 percent of pedestrian road traffic deaths in Canada in 2008.[66] They are more likely to suffer severe or critical trauma as well as mortality if struck as pedestrians than are younger pedestrian victims.[67] Greater injury severity to older pedestrians is due in part to their greater physical fragility, (e.g., more easily broken bones and more vulnerable brain structures) and longer recovery times from injury.

### Research Findings

Davis[68] related severity of injury to struck pedestrians and speed of the striking vehicle. Results showed similar patterns for children up to age 14 and adults 15-59, but pedestrians aged 60 and over had injuries that involved lower impact speeds, and they tended to be more severe than injuries to the other groups.

The abilities and processes known to deteriorate with age that might be relevant to traffic safety have been delineated by Dewar.[69] They include many types of visual functions, hearing loss, physical movement, reduced walking speed, loss of balance and the ability to react to slips and tripping.

Cognitive and attention problems leading to collisions among older pedestrians include misjudging gaps, distraction, watching the traffic signal rather than the traffic, misinterpreting the movement of vehicles, assuming drivers will yield and impatiently crossing a street after waiting, or crossing mid-block.[70]

Walking depends upon visual, proprioceptive (ability to sense body movement and posture without visual cues) and vestibular (balance) functions. Vision is thought to be the most important source of information for balance control and locomotion. Any or all of these functions may deteriorate in older pedestrians resulting in difficulty with balance and postural stability. In order to maintain balance, older pedestrians may walk more slowly and cautiously or use a cane. Decreased foot pickup, toe clearance and stride length result in slower walking speeds and increased chances of tripping.

Pedestrians who are older often have mobility limitations which reduce their walking speed and promote greater attention to their walking than to the traffic due to fear of falling, something seniors fear most. Such preoccupation with falling may reduce attention to the traffic. Avineri and Shinar[71] looked at this issue by videotaping pedestrian crossings at crosswalks and conducting interviews with the pedestrians. Fear of falling was found to increase with age and it was negatively correlated with walking speed at the unsignalized crosswalk. In addition, the proportion of pedestrians who had their heads down while crossing increased with age.

Fear of falling is clearly justified when walking outside in winter conditions. The presence of snow leads to ill-defined curbs and hides potholes and other obstacles, increasing the chances of a slip or fall. Visual difficulties, beyond those typically experienced by older people under non winter conditions, include greater susceptibility to glare from snow and ice and poor contrast due to glare and light conditions,

Errors in judgement of the speed or course of vehicles and unwarranted expectancies about the behaviour of drivers are central factors in collisions involving older pedestrians. The reduction in peripheral visual information processing may be a contributing factor. A study by Sheppard and Pattinson[72] asked older pedestrians involved in collisions about ability to judge speeds of approaching cars. Thirty percent said they could do this “not well at all”, while only 44 percent said they could make this judgement “fairly well” (the best response category). Those who had never driven or who had stopped driving were more likely to report difficulty judging vehicle speed. When queried about difficulties in seeing, hearing or walking many of the participants indicated such problems: 45 percent eyesight, 51 percent hearing and 33 percent walking. However it is not known to what extent these were contributing factors in their collisions.

Studies have shown that pedestrians who are older have difficulty in selecting safe gaps in traffic, as they tend to accept shorter time gaps as vehicle speeds increase. Oxley[72] reports that pedestrians aged 75 and older rely primarily upon the distance of approaching vehicles, as opposed to both distance and speed, when deciding to cross the road. Older pedestrians have difficulty in selecting safe crossing situations in continuously changing complex traffic environments, likely due to deficits in perceptual and cognitive abilities, as well as inefficient visual scanning, limitations in time sharing, inability to ignore irrelevant stimuli and reductions in visual acuity and contrast sensitivity, which are more of a problem at night.

Oxley, Charlton, and Fildes[73] have reviewed the research on the effects of cognitive impairment on older pedestrian safety. The authors conclude that normal age-related cognitive decline has a fairly moderate effect on pedestrian performance and little effect on performance in “less demanding traffic situations”. However, they note that declines in multiple relevant cognitive and executive functions have an effect in demanding traffic situations. Declines in road crossing behaviour include inattention, poor memory, as well as slower information processing and “difficulty in selecting and integrating information, poor decision making and slowed response initiation.” Walking ability was found to be poorer in those suffering from dementia, Parkinson’s disease and cerebrovascular disease.

The health characteristics and problems of 1,249 people aged 72 and older were studied by Langlois et al.[74] They found that 11 percent reported difficulty crossing the street. Those needing help in one or more daily activities were 10 times more likely than others to have problems crossing the street. Fewer than one percent of these latter pedestrians had normal walking speed required to meet the speed standard used for signal timing at intersections and about 7 percent had a walking speed of .92 m/s or slower. This study suggests that improving the health of seniors may also decrease their risk as pedestrians.

### Walking Speed and Design Considerations

An important consideration in intersection design and pedestrian signal timing is the speed at which pedestrians walk. The duration of pedestrian walk signals at intersections is generally based on the assumption that the walking speed of pedestrians is 1.2m/s. However, a significant proportion of pedestrians walk more slowly than that. Estimates suggest that the mean speed is 1.13 m/s and that as many as 35 percent of pedestrians walk more slowly than the design standard.[75] A study in Sweden[76] found that pedestrians aged 70 or older, when asked to cross an intersection very fast, fast, or at normal speed, considered fast to be less than 1.2m/s. The comfortable speed was .67 m/s for 15 percent, well below the standard often used.

A large study of walking speed and start-up time gathered data on 7,123 pedestrians, more than half of whom were over the age of 65.[77] Older pedestrians were significantly slower than those under 65, and they walked more slowly when it was snowing or when the street was snow covered than under other weather conditions. The mean walking speeds were 1.46 m/s and 1.20 m/sec respectively, for pedestrians under 65, and for older pedestrians. Mean start-up time (from the start of the WALK signal to the moment the pedestrian steps off the curb and starts to cross) was longer for older pedestrians (2.48 s) than for younger ones (1.93 s). Oxley, et al.[78] also found that older pedestrians take longer than younger ones to start across the street at unsignalized locations once a gap in the traffic is accepted.

A recent evaluation of walking speed carried out in Winnipeg looked at age, gender, and seasonal differences.[79] Walking speeds for both young and older pedestrians were slower in winter than in summer. It was concluded that nearly 40 percent of older pedestrians and 10 percent of young ones would be excluded using a design value of 1.2 m/s, assuming the speeds found for crossing at an intersection.

A design walking speed of 1.0 m/s has been recommended by Coffin and Morrall[80] at crossings used by large numbers of seniors, on the basis of their observations of speeds of older pedestrians at three types of crossings. Speeds were greater at unsignalized intersections than where there were signals. The older people in their study reported difficulty negotiating curbs and judging speeds of oncoming vehicles, as well as confusion with pedestrian walk signal indications. Mean walking speeds of close to 1.0 m/s have been reported by Bowman and Vecellio,[81] suggesting that a design speed exceeding that may be too high for older pedestrians.

Although the walking speeds reported in the studies cited above vary somewhat, it is clear that a significant proportion of pedestrians will find it difficult or impossible to cross streets at the 1.2 m/s expected of them at most signalized intersections. As mentioned earlier, pedestrians who would normally walk at an average speed for their age can be slowed down through being encumbered with bags of groceries, luggage, etc., as well as by snow and ice on the road. It is evident from these studies that some older pedestrians require much more time than is typically assumed for pedestrian walking speeds.

## POTENTIAL COUNTERMEASURES

- Increase the time allowed for crossing the street at signalized intersections where there is a concentration of senior pedestrians.
- Review speed limits in areas where there is a concentration of senior pedestrians (and, of course, such speed reduction would benefit pedestrians of all ages).

# 2.7 Pedestrians with Special Needs

Not all pedestrians are equally capable of crossing the road easily and safely. Many have limitations that require special attention on their part and/or modifications of roadway infrastructure and operations to accommodate their needs. These special pedestrian populations include those with physical, sensory and cognitive limitations.

A significant percentage of pedestrians have a disability that impairs their ability to walk independently. While the challenges facing a person with restricted mobility may be self-explanatory, a variety of other disabilities pose special needs when travelling on foot. Vision and hearing deficits are a safety challenge as related to the detection of traffic and perception of traffic control devices. Pedestrians with a developmental, learning or other cognitive limitation may experience difficulty with understanding traffic signs and signals, interpreting the movement of traffic and making decisions about crossing streets.

### Pedestrians with Mobility Limitations

Research by Perry[82] shows considerably lower walking speeds for pedestrians with physical limitations, as would be expected. None of these reaches the average speed of 1.2 m/s (4 ft/s), often assumed for design of pedestrian crosswalk signal timing. Some average walking speeds for various medical conditions/assistive devices are shown in Table 2.1.

Those mobility-restricted individuals travelling in wheel chairs should be able to access pedestrian-controlled signals and negotiate curbs. Guidelines for accessible pedestrian signals can be found in the recent NCHRP document addressing this issue.[83]

**Table 2.1 Mean Walking Speeds for Pedestrians with Selected Medical Conditions & Assistive Devices**

| Condition/assistive device* | Walking speed m/s (ft/s) (1 ft./s = .305 m/s) |
|---|---|
| Cane/crutch* | 0.80 (2.62) |
| Walker* | 0.63 (2.07) |
| Wheel chair* | 1.08 (3.55) |
| Immobilized knee | 1.07 (3.50) |
| Below knee amputee | 0.75 (2.46) |
| Above knee amputee | 0.60 (1.97) |
| Hip arthritis | 0.68 to 1.12 (2.24 to 3.66) |
| Rheumatoid arthritis (knee) | 0.75 (2.46) |
| *Limitation of user unspecified | |

### Pedestrians with Vision Loss

In order for pedestrians with vision loss to cross a road alone they need to know the location of the intersection, the direction and speed of traffic, when a traffic signal is indicating that it is safe to cross and, at uncontrolled intersections, when there is a safe gap. Pedestrians who are blind tend to confirm the distance walked by counting steps and numbers of cross streets along the route, but they report that counting steps takes additional attention and can make them less aware of their surroundings. They also depend on the senses of touch and sound to tell them when they have reached an intersection and when it might be safe to cross. Pedestrians who are blind will tend to walk slower than their preferred walking speed when unaccompanied, so some of the same considerations as those for mobility restricted persons also apply.

Roundabouts can pose problems for pedestrians with vision loss. Ashmead, et al.[84] observed the behaviour of six pedestrians who were blind and six who were sighted at a double lane urban roundabout. Pedestrians who were blind waited about three times longer than sighted ones to cross. About 6 percent of their crossings were judged to be dangerous, while none of the sighted pedestrians was found to make dangerous crossings. Drivers yielded frequently on entry lanes but not on exit lanes. Sighted pedestrians accepted drivers' yields, but those who were blind rarely did.

A variety of devices are in use to warn pedestrians with vision loss about hazards and road and sidewalk features. These include signs, pavement and sidewalk markings, and tactile strips on walking surfaces to guide pedestrians. Jenness and Singer[85] studied the detectability of different aids for pedestrians with vision loss by having them view the materials from different distances. The colour of the sidewalk background was important in determining detectability, with greater contrast being better. Yellow and red were the best colours.

A relatively recent problem faced by these pedestrians is the electric vehicle (EV) and hybrid-electric vehicle, which are often quieter than vehicles with an internal combustion engine. See section 5.2 for further discussion.

### Pedestrians with Hearing Loss

Reduced hearing may make vehicle detection and estimation of the speed and distance of approaching traffic more difficult. A New Zealand study[86] examined the relationship between sensory limitations (those related to vision or hearing) and pedestrian injury among children under 15. The study found that children with hearing loss were nearly twice as likely as to be involved in injury-producing collisions, than children with full hearing.

### Pedestrians with Cognitive Limitations

Persons with medical conditions affecting cognitive function (e.g., attention deficit disorder, brain injury, and dementia) may interpret information differently, become easily confused or become anxious in busy road environments. They may lack understanding of traffic hazards and have difficulty with written or symbolic warnings and instructions about street crossing at intersections or become easily distracted in the presence of traffic. From a design perspective, the main issues are consistency in crossing types and waiting times, lack of sufficient crossing time, complexity of intersections and the presence of visual clutter.[87]

### Children with Disabilities

There are few studies of children with learning or cognitive disabilities as pedestrians. A study in Scotland[88] involving a survey of 300 nursery, primary and secondary schools was carried out along with discussions with children and parents. It focussed on children with mild to moderate learning difficulties, those with autistic spectrum disorders (ASD) and attention deficit hyperactivity disorder (ADHD). Since many of these children were driven to school there was limited opportunity for them to learn the basics of road safety. The study concluded that child pedestrians with special needs may lack awareness and have difficulty coping with traffic and with spatial awareness.

## POTENTIAL COUNTERMEASURES

- Adjust pedestrian signal timing to allow those with mobility limitations to cross the street safely.
- Provide easy access to pedestrian activated signal controls.

- Provide curbs and gradients that meet design standards for wheel chair accessibility and reduce physical obstacles near the roadside.
- Use curb cuts, tactile strips and auditory signals to assist the visually impaired.
- Pedestrian signs should be designed with the simplest possible messages in order that they are easily understood by those with cognitive limitations.
- Provide information to persons with hearing loss about the dangers associated with compromised hearing and traffic; educate them to rely on visual cues to judge the speed and distance of approaching vehicles.
- Sidewalk markings to warn of hazards to pedestrians with vision loss should follow design guidelines for maximum detectability.

## 2.8 Pedestrians on Wheels

In addition to a traditional pedestrian (one walking or running) there exist assisted modes of transportation that include: in-line skates, skateboards, longboards, scooters, Heelys™ and Segways™. Most of these are non-motorized. Heelys™ are shoes with small wheels under the heels allowing either normal walking or rolling on the wheels and are most often used by children. Personal mobility devices such as 3-wheeled chairs and motorized scooters for the mobility impaired are also sometimes classified as pedestrian transportation, although some models could be considered as "restricted-use motorcycles" if their output exceeds 100 watts.[89] They are not specifically discussed in this report because they have been the subject of two recent Canadian publications.[89 90] Each type of transportation is popular with different age groups. Younger people tend to use in-line skates, skateboards, longboards, scooters, and Heelys™. Segways™ are used mostly by mature adults; this may be due at least in part to the fact that the recommended operating age of the latter is 16 years and older.

There is a lack of research on the hazards these devices pose when interacting with motor vehicles. The majority of injuries associated with these devices occur through falls, and protective equipment is designed to prevent or mitigate these types of injuries. Nonetheless it is obvious that collisions between pedestrians on wheels and motor vehicles have the potential to be very serious and some of these pedestrians, particularly in-line skaters and skate/long boarders are travelling on roads and at relatively high speeds. One study found the speeds of in-line skaters were particularly high among those under the age of 20. For example, the 50th percentile speed for males aged under 20 was 5.24 m/sec) compared to 3.63 m/sec for 20-39 year old males. There was little difference between the speeds of males and females within the same age group.[91] At these speeds, the risk of entering a roadway or intersection and being unable to react or stop quickly enough appears obvious.

Heelys™ can be very unstable and pose a safety concern, especially for novice users. However, there are no reports that these devices pose a specific danger to children interacting with motor vehicles.

The use of non-motorized scooters has also become popular. These appeal to younger children, as they require less skill and balance than riding a bicycle or in-line skating. A variation on the foot-propelled scooter is the motorized variety. Although the number and use of these is less than the non-motorized ones, the number of serious injuries and deaths is greater, according to the Consumer Product Safety Commission. They can reach speeds in the 24 - 35 km/h range and weigh 18 – 27 kg.

A recent device in use for transportation is the Segway™. This is an electric powered, self-balancing device on which one person stands erect and operates the vehicle by leaning forward or backward and steering. Segways™ weigh 45-90 kg and can reach speeds up to three times faster than a walking pedestrian. There is little research on their safety. Concerns about their use include interference with and frightening pedestrians, lack of operator training and appropriate age and weight requirements. In addition, they may be too fast for use on sidewalks and too slow to be on the road. Some provinces have banned the use of Segways on public roads except when used as a mobility device (i.e., Ontario and Yukon). Their use requires no training or licensing of their users in any Canadian jurisdiction. A recent US study of 41 Segway™ collisions (both motor vehicle and other types) found that the median age of those injured was 50 years, suggesting that these devices are used largely by middle-aged and older adults.[92] The majority of these injuries were caused through falls.

A central question is how best to protect users of assistive pedestrian devices, while balancing their needs with those of other pedestrians. A report for the TAC[93] concluded that in line skating is a viable mode of transportation which should be considered acceptable on certain sidewalks, low speed roadways, and on bicycle and multi use facilities. The report did not cover other devices.

### POTENTIAL COUNTERMEASURES

- Educate users of assistive modes of transportation of the need to wear proper safety equipment and to be aware of the dangers of interacting with traffic.
- Educate parents of young children of the dangers of using non-motorized means of transportation and the need for protective equipment and safe practices.
- Promote familiarity with instructions on the safe use of non-motorized means of transportation.
- Restrict the use of assistive devices on certain roadways, giving consideration to type of road and volume of traffic
- Where allowed, consider requiring licensing and protective equipment for those using Segways™.

# 2.9 Enforcement of Pedestrian Traffic Laws

Enforcing pedestrian laws is difficult. Unlike the laws that govern driver behaviour, pedestrians do not always know or understand the rules, are not required to have certain skills and are of all ages and abilities. Police may find implementing the demand for identification difficult. Whether or not pedestrians know the rules, they may not take traffic laws governing pedestrians seriously or consider the risks of contravening them. This is demonstrated by the frequency at which pedestrians will choose the easiest route over the safest route.[94]

Penalties are a key factor in enforcement. Enforcing traffic laws involves penalties that can range from a warning, to issuing a ticket with varying fine amounts or a more serious charge. Studies have indicated that there may be a larger benefit to issuing warnings for minor offences than monetary penalties.[95] Conversely, some experts suggest that if the level of risk associated with unsafe pedestrian behaviour is not correlated with penalties this will contribute to unsafe pedestrian behaviours. There is more study required to determine if this is indeed the case.[96]

A review of the literature indicates that there are few enforcement countermeasures proven to work in isolation. Therefore, a comprehensive approach that includes targeted enforcement combined with awareness and education is commonly implemented. A comprehensive method requires working within a multi-disciplinary approach that involves partner organizations. The issue of crosswalk and pedestrian safety is an important aspect of traffic enforcement; however, it is challenging to dedicate police resources to using a "focused approach". A strategic approach to educating the public, such as awareness campaigns combined with early education, is necessary to address this public safety issue because enforcement resources and capabilities are usually limited.

## Targeted Enforcement

Effective enforcement measures require skilful planning and resource allocation to maximize the effect of a particular strategy.[97] The objective of using a targeted approach is to address certain behavioural issues related to pedestrian safety and to increase compliance. Both driver and pedestrian behaviours may be targeted. A targeted approach is more than just observing pedestrian and driver behaviours and issuing warnings and tickets. Police agencies and their partners may choose to include public awareness and education campaigns in combination with enforcement. Sustaining a targeted enforcement program is often an issue, because it can be resource intensive. In this section, discussion focuses on how targeted enforcement is established and implemented.[98]

Pedestrian safety enforcement requires the collection of reliable data about pedestrian collisions, injuries, types of pedestrian related violations and culture of the community regarding its inhabitants and "walkability". Getting to know a community is best done through collaborating with other organizations to gather and share information. Working in partnerships enables collective problem solving to address pedestrian safety issues from a variety of angles.[98 99 100] The level of knowledge and providing the appropriate level of staffing are two of the most significant factors to assuring success.[101]

Police agencies need reliable collision data in order to maximize the resources available to them, or sustain an effective strategy. Targeted enforcement strategies require data on collision factors and frequencies to enable agencies to prioritize locations and behaviours. Without this information police and their partner agencies cannot dedicate the resources appropriately.[102] The success of any targeted enforcement strategy is strongly linked to the reliability and accuracy of these data.[103]

Additionally, knowing the behavior and traffic patterns of a community helps police to develop countermeasures to address specific behaviours. For example, police may launch checkpoints based on peak times such as the first week of school. These can encourage children to practise safe walking and crossing habits after the summer break and ensure drivers are using care when entering school zones for drop off and pick up. In some communities, there may be a prevalence of distracted or substance-impaired pedestrians. In these situations, it may be beneficial to work with other organizations such as health promoters or injury prevention groups to discourage these types of behaviours and promote risk awareness.[104] If police identify an enforcement issue that is not pedestrian related, such as speeding or red light running, other countermeasures should be considered for implementation to address the root cause of vehicle-pedestrian collisions.[105]

## Police Training

Compliance with pedestrian laws begins with police officers' understanding of the laws and the method of enforcement. They need to be prepared and provided with the information required to enforce laws and speak with the public on these issues. In such places as Chicago, Miami, North Carolina, and Georgia there has been training specific to pedestrian laws. Guides have also been designed to assist officers on what to look for regarding pedestrian behaviours and how to address issues that may arise related to enforcement.[106] Providing professional development opportunities has assisted in successful enforcement of pedestrian laws.

Jurisdictions in the United States and Australia have developed and provided officers with pedestrian specific training and comprehensive reference manuals. The manuals include information specific to common pedestrian and driver behaviours, related laws, and effective methods for enforcement. When professional development opportunities are provided together with related materials, an understanding of pedestrian safety is more likely. Communication to officers about new methods of enforcement and laws is essential. Recognizing officers as educators is important because they are often the first people who are asked to comment on new laws or pedestrian safety issues.

## Education and Enforcement

The use of verbal warnings and information pamphlets are sometimes identified as ways to educate the public. Engaging with community members encourages the adoption of rules, leading to changed attitudes and behaviours.[107] Education by enforcement officers on its own tends to not be successful. It is "widely understood in road safety that education is most effective when it signals or supports a change in the environment, i.e. the contingencies of behaviour, such as an enforcement campaign".[108]

Combining education and targeted enforcement with clear legislation increases the confidence of police officers in the law and their ability to enforce it. Clear legislation enhances an enforcement officer's ability to interpret the laws accurately.[109]

## POTENTIAL COUNTERMEASURES

- Collect accurate data on pedestrian/vehicle collisions.
- Encourage relationships between police and their communities in order to best understand traffic patterns in their communities.
- Combine targeted enforcement with education, awareness and evaluation.
- Provide officers with pedestrian-specific training and resource materials.

# 3.0

# Drivers

# 3.1 Background/Context

As with all types of road crashes, those involving motor vehicles and pedestrians can result from a combination of environmental, vehicle and behavioural factors. Motor vehicle and pedestrian crashes may involve human error or impairment on the part of the driver. The objective of this section is to explore the driver characteristics and actions associated with drivers who cause pedestrian trauma and to identify the best strategies to address them in order to improve pedestrian safety and reduce harm.

The OECD publication, *Safety of Vulnerable Road Users*, points out that the social environment has an impact on the safety of vulnerable road users. The social environment includes motorists' attitudes towards pedestrians and how they see the needs of pedestrians and their responsibilities towards them. Research done in the UK has shown a lack of sensitivity to pedestrians on the part of motorists because they pose no threat and therefore do not figure in drivers' assessment of risk.[110] Consequently, the protective behavioural patterns of drivers do not account for unexpected and sudden movements of weaker (vulnerable) road users.[111] For this reason, it is important to foster a social environment that recognizes the vulnerability of pedestrians and instils an obligation in drivers to drive in a manner that takes into account the needs of all road users including pedestrians.

# 3.2 Driver Factors in Motor Vehicle and Pedestrian Crashes

Motor vehicle and pedestrian crashes occur predominantly in urban settings; however, rural incidents are particularly severe.[112] Based on Canadian police-reported data for the years 1999-2008, the two driver action factors, "failing to yield the right-of-way" and "distraction and inattention", were more commonly implicated in pedestrian crashes than any other driver action or driver condition factor. Within these factors, various visual, dual-task and cognitive processing failures may have occurred. Considering all vehicle-pedestrian crashes during this time period, failing to yield the right-of-way was identified the most often (28 percent of the collisions), followed by distraction and inattention (20 percent), other driver action (5 percent), improper turning (4 percent), disobeying traffic control device or officer (3 percent), driving under the influence of alcohol (2.5 percent), other driver condition (2 percent), driving too fast for conditions (2 percent), and backing unsafely (2 percent). The other conditions and actions reported in Transport Canada's National Collision Database (NCDB) were identified in less than one percent of crashes. It remains important to remember that police reported data does have limitations and represents only one source of data that can be used to understand crashes involving pedestrians.

An analysis of fatal vehicle-pedestrian crashes in Canada, from 2004 to 2006 revealed that more than one in three fatally injured pedestrians was struck by a driver who committed at least one driving infraction prior to the crash. Pedestrians were struck by drivers failing to yield the right-of-way in approximately 11 percent of fatalities; drinking drivers were implicated in about 9 percent of pedestrian deaths and 7 percent of those killed were struck by speeding drivers.[113]

# 3.3 Vehicle Speed

### Speeding and its Role in Motor Vehicle and Pedestrian Crashes

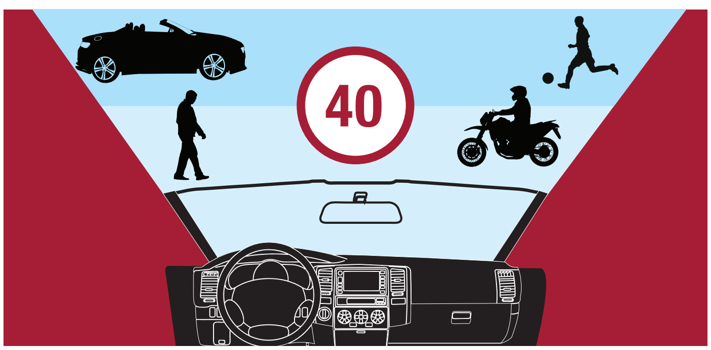
There is a direct correlation between an increase in vehicle speed and the increase in the risk of injury. It is estimated that a pedestrian struck by a vehicle travelling at 50 km/h is 8 times more likely to be killed than a pedestrian struck at 30 km/h.[114] Even small reductions in speed can be significant. For each 1.6 km/h reduction in average speed, collision frequency is reduced by 5 percent.[115] Reducing vehicle speed has been proven to be effective in preventing pedestrian crashes and reducing the severity of injuries.

At speeds greater than 40 km/h, both drivers and pedestrians have an increased potential for making mistakes in judging the time required to stop or cross the street safely, compounded by a driver's tendency to underestimate the speed of the vehicle in which they are travelling. At a speed of 30 km/h, vehicles and pedestrians are able to co-exist with relative safety which means that drivers have sufficient time to stop for pedestrians and pedestrians can make better crossing decisions.

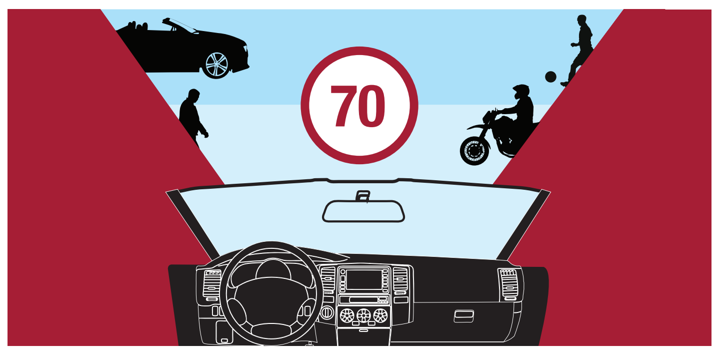
Speeding is common in Canada. According to surveys, about 2.7 million Canadians admit to "habitually driving well over the speed limit."[116] In a Transport Canada study on driver behaviours and attitudes towards speeding, 7 out of 10 drivers admitted to exceeding the speed limit, at least occasionally. The average increase over the speed limit was 12 km/h on highways, 10 km/h on two lane highways and 7 km/h on residential streets. Many people believe that they are not technically speeding at these rates and that they are not endangering themselves or others.[117] The facts, data and research tell a markedly different story.

There are a number of reasons why speed contributes to an increased risk of crashing. The first is the driver has a narrower field of vision. The visual field of the driver is reduced when the speed of the vehicle increases. At 40 km/h, the driver has a field of vision covering 100°, which allows obstacles on the roadside, or other potential hazards, to be seen. At 130 km/h, the field of vision covers around 30°, which reduces considerably the capability of the driver to assess potential danger. A reduced field of vision can contribute to a crash because it can make the difference between seeing and not seeing a potential hazard or other road user. The relationship between speed and field of vision is illustrated in Figure 3.1.

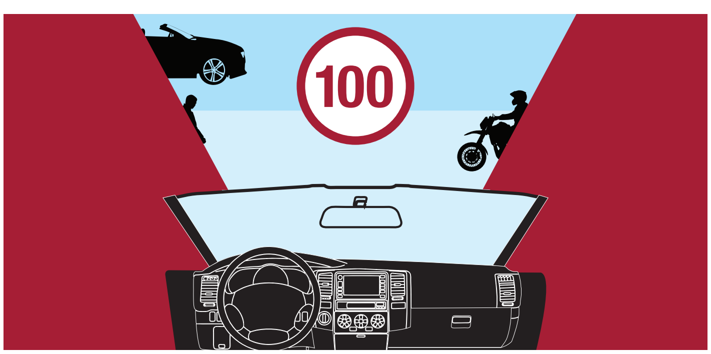
**Figure 3.1** **Speed and field of vision.**
*Source: French Ministry of Transport*



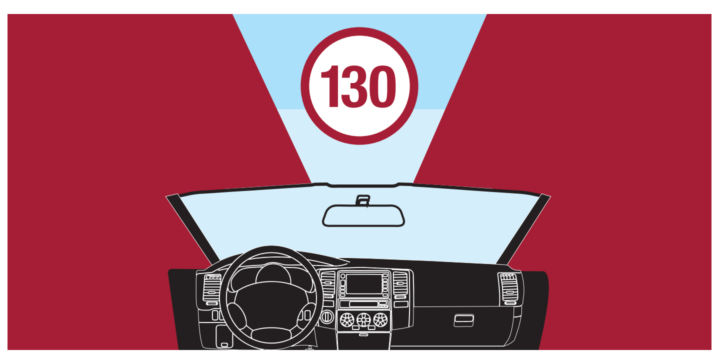

Field of vision of 100°




Field of vision of 75°




Field of vision of 45°




Field of vision of 30°

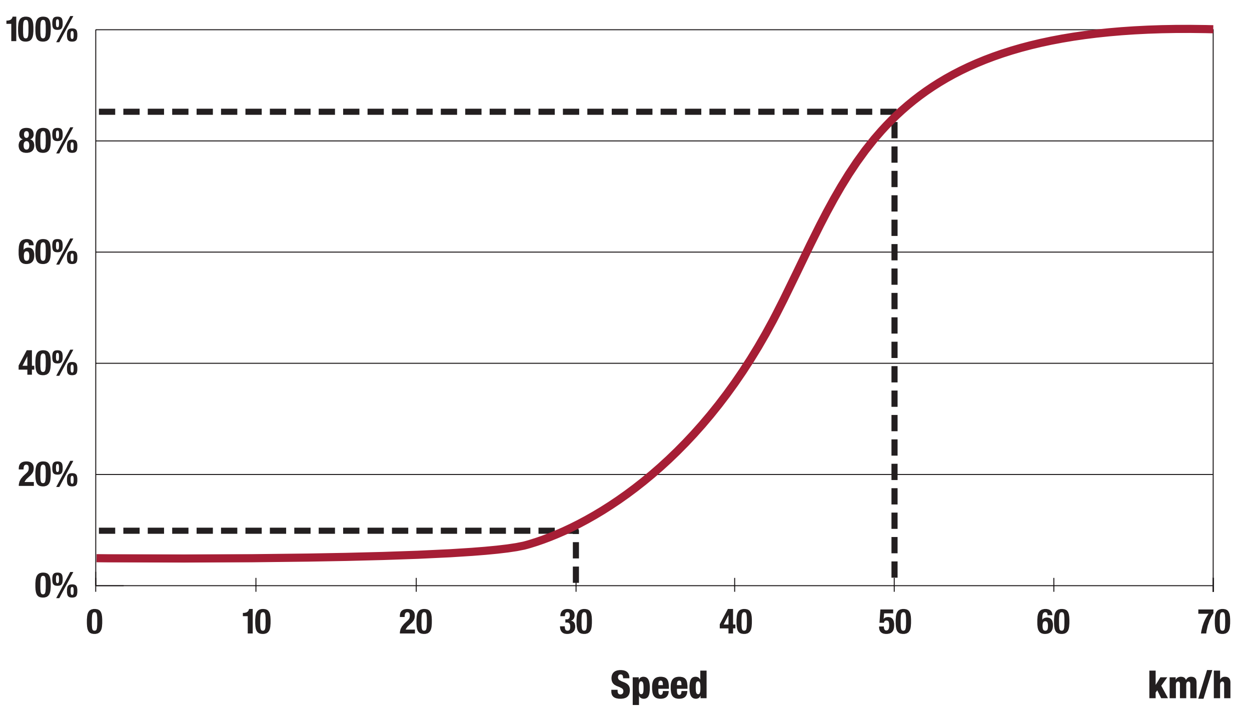
There is an increased risk of getting into any crash at higher speeds. As reported in a recent review by Aarts and Schagen:

> "The results of Kloeden et al. best describe the relationship between individual vehicle speed and crash rate. This means that crash rate rises exponentially for individual vehicles that increase their speed. Further, crash rate increases faster with a particular increase in speed on minor/urban roads than on major/rural roads."[118]

The finding that crash risk rises more steeply with increasing speed on urban roads than on rural roads is significant to pedestrian safety because the vast majority of pedestrians are struck in urban environments and it is in urban environments that we have the greatest obligations to build transport systems that accommodate vulnerable road users like pedestrians and cyclists. The relationship between speed and pedestrian fatal injuries has been well documented with significant increases in likelihood of death with only small increases in speed. Vehicle speed impacts the distance travelled during the time it takes the driver to see a pedestrian, to process that information and then to physically respond by taking actions related to braking and/or steering. Driver reaction time varies from one person to another: one second is the minimum reaction time. In some studies, the average reaction time is estimated to be around 1.5 seconds, but can be much longer, depending on factors such as driver age and condition (e.g., alcohol, fatigue) and environmental conditions such as fog and rain. On top of this, braking distance is proportional to the square of the speed and therefore increases exponentially with increases in speed. In addition, the stopping distance also depends on the type of pavement (its friction coefficient) and the condition of the road as well as the type and weight of the vehicle. Stopping distances are much higher on wet roads than on dry roads.

The probability of a pedestrian being killed in a vehicle collision increases with the impact speed. Results from on-the-scene investigations of collisions involving pedestrians and cars show that 90 percent of pedestrians survive being hit by a vehicle at speeds of 30 km/h; whereas fewer than 20 percent survive at speeds of 50 km/h (see Figure 3.2). The figure also shows that the impact speed at which a pedestrian has a 50 percent chance of surviving a collision is around 40-45 km/h. [119] [120]

**Figure 3.2 Probability of fatal injury to a pedestrian with increases in speed.**
*Source: OECD (2006) Speed Management. http://www.internationaltransportforum.org/Pub/pdf/06Speed.pdf*

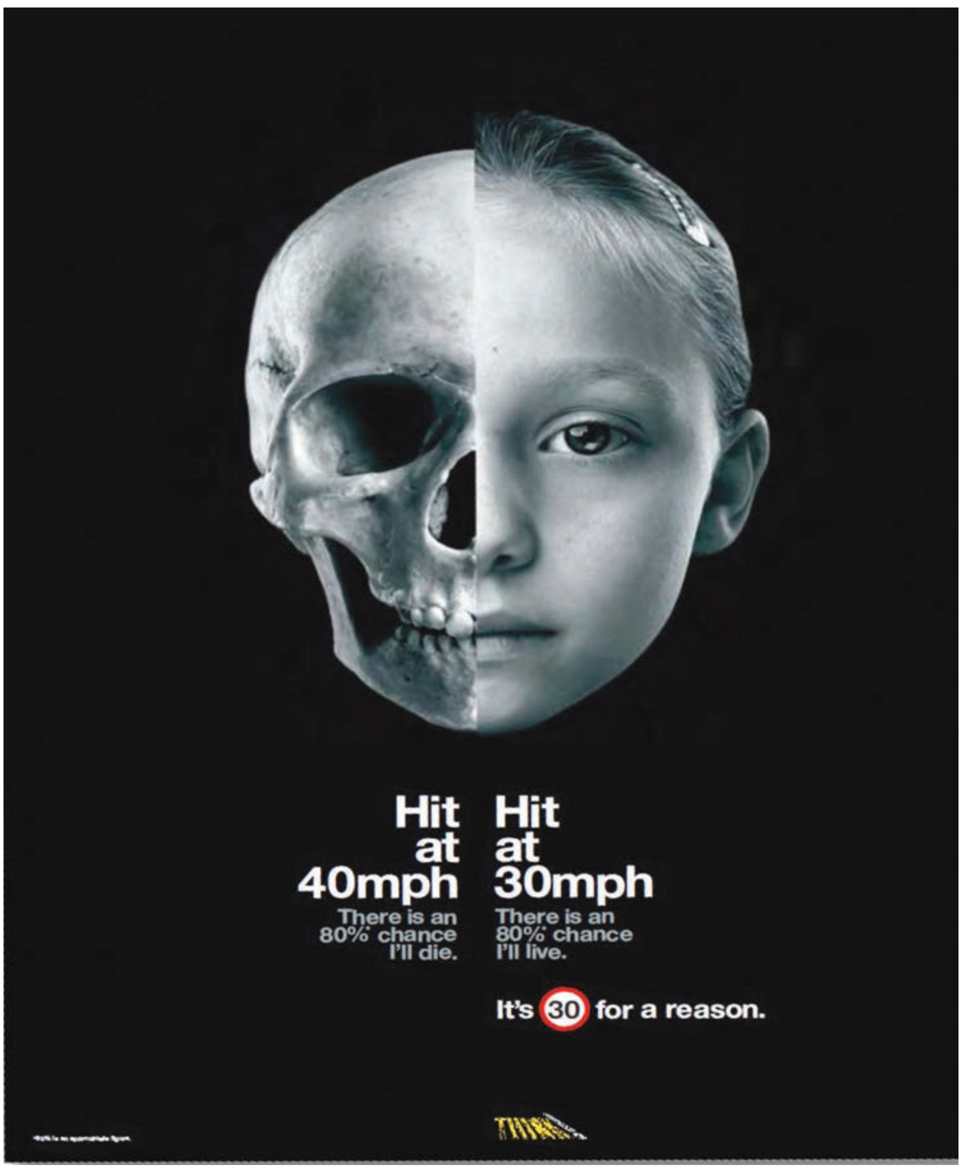


The Government of the UK has vividly conveyed the message to the public of the differential impact of speed on fatality risk to a pedestrian. The poster shown in Figure 3.3 is one way they have done this.

## Electronic Speed Enforcement

Research consistently shows that speed cameras are an effective intervention in reducing road traffic collisions and related casualties. A systematic review examined the impact of fixed or mobile speed cameras and, based on 14 observational studies, found that all but one showed effectiveness of cameras up to 3 years or less after their introduction.[121] Elvik concluded that there are no reasons to doubt the effectiveness of speed cameras as a road safety measure.[122] A Cochrane Review also found consistency of reported positive reductions in speed and crash outcomes across all studies.[123] While the studies have focused on reductions in overall fatalities and injuries, any countermeasure that is effective in reducing vehicle speeds will improve pedestrian injury outcomes.

**Figure 3.3** **Road safety poster from the UK. The below poster image re-printed with the express written permission of the Government of the UK, Department for Transport. (40 mph = 64.37 km/h, 30 mph = 48.28 km/h)**



# 3.4 Distracted Driving

Distracted driving is any non-driving activity a person engages in that has the potential to distract him or her from the primary task of driving and increase the risk of crashing[124]. There are three main sources of distraction: visual (taking your eyes off the road), manual (taking your hands off the wheel), and cognitive (taking your mind off what you are doing).[125] Visual and cognitive distractions are the most common. Interactive electronic devices including texting and wireless conversations with others not also in the vehicle are the worst and most prominent sources of distraction. The use of interactive electronic devices while driving has killed and maimed thousands of Canadians. Other sources of distraction can be inside or outside the vehicle. In general, distractions take the driver's attention away from driving, making the driver less aware of what is happening on the road around them and slow their reaction time.

Most Canadian provinces and territories have legislation banning hand-held communication devices with some also specifying limits on the use or positioning of electronic screens and GPS devices. Prohibitions on hands-free devices for novice drivers currently exist in three jurisdictions. Restrictions on other distracting activities fall under legislation pertaining to careless or imprudent driving in most jurisdictions.

It is feasible to rigorously enforce laws prohibiting use of hand-held devices both routinely and through periodic targeted enforcement campaigns. The New York City Police Department (NYPD) issued over 7,000 summonses on January 21st, 2010 during an announced 24-hour blitz to drivers using hand-held cell phones.[126] On average, in 2009, the NYPD issued 617 summonses a day for this infraction.

A recent poll determined that as many as 75 percent of Canadians are distracted while they drive even though virtually all view it negatively in others and view it as a serious road threat.[127] Educational and awareness efforts could help to modify driver attitudes and behaviour with respect to distracted driving.[128]

# 3.5 Failure to Yield the Right-of Way

Failure to yield the right-of-way to pedestrians can be tied to some of the human factor issues identified in Section 3.2 such as blocked visibility or inadequate search by a driver, or it can be the result of distraction and inattention. It can also be related to the social environment referred to earlier in which pedestrians are not given the same regard as would be granted to other vehicles. Targeted enforcement has been used to deter failure to yield right-of-way. In coordination with the Department of Transportation's education and marketing efforts, the NYPD targets failure-to-yield to pedestrians at prone intersections, as identified through previous crash data.

# 3.6 Driver Training and Public Education

Drivers could be much better educated about the needs and vulnerability of pedestrians. Training by driver instructors, advice that drivers receive from safety organizations and the police should all be oriented to promote attitudes and behaviours based on higher priority for the safety of pedestrians.[129] Raising public awareness and participation is crucial to the success of safety measures and is instrumental to gaining support for the measures being implemented. Many other countries, including the Netherlands, have an extensive focus on the need for motor vehicle drivers to be aware of the presence of pedestrians and cyclists in their driver training curriculum. Unlike in North America, the safety of vulnerable road users is heavily emphasized in many European countries.

## Driver Education

Traditional driver training concentrates on skills acquisition and rules of the road. An integral part of the process however should be to train drivers to share the road and react safely to other road users.[130] There is an opportunity to foster the social environment that supports pedestrian safety in driver education curricula. The driver should feel a responsibility to anticipate pedestrian movements and reduce speeds anytime they are near or approach a pedestrian. This includes when drivers are in residential areas and around schools, play areas, shopping areas and any road used for children and young people to play on or for recreational purposes like street hockey or longboarding. Another component should foster awareness of the high crash risk caused by various types of distractions.[131]

## Public Education and Awareness Programs

These programs provide public education and awareness to promote road safety for all target groups through various channels. They are likely to be of limited effectiveness on their own and have the greatest potential for success when combined with targeted enforcement programs.

The public communication strategy to raise awareness about pedestrian safety issues identified by The New York City Pedestrian Safety Study and Action Plan included the following:[132]

- A broad-based marketing and PR campaign informed by findings, market research and stakeholder feedback;
- Broad-spectrum communication channels including television, and radio with grassroots involvement
- Leveraging additional press coverage of these issues to extend reach of the campaign.
- Targeted tactics to raise motorist awareness - getting campaign materials and messages into the hands of driver education teachers and students; incorporating traffic safety education into classroom curricula; introducing campaign materials at motorist education events

There are examples of successful media campaigns to expand public awareness. One such campaign to enhance pedestrian safety in Victoria, British Columbia featured multimedia campaigns focused on encouraging left-turning drivers to yield to pedestrians. This media campaign produced a long-term effect of increasing drivers' yielding behaviours.[133]

There are number of ways to address the driver characteristics and actions that contribute to motor vehicle and pedestrian crashes. Most of these approaches are not unique to the prevention of pedestrian trauma as they prevent many different types of crashes. For this reason these approaches are mentioned only briefly here. The focus of this report is on countermeasures specifically designed to improve pedestrian safety.

## POTENTIAL COUNTERMEASURES

- Consider countermeasures to reduce all forms of distracted driving to increase drivers' situational awareness;
- Selective Traffic Enforcement Programs (STEP) that combine intensive enforcement of a specific traffic safety law with extensive communication, education, and outreach informing the public about the enforcement activity;
- Public education and awareness initiatives on vehicle speeds and the impact to safety for pedestrians
- Consider automated enforcement (speed and intersection safety cameras) in urban areas and introduce where appropriate;
- Consider initiatives that require and promote the need for drivers to slow down in areas where pedestrians frequent.

# 4.0

# Roadway Design

## Roadway Design, Engineering & Traffic Control Devices

# 4.1 Background/Context

The following is a scan of existing measures that may be considered to increase pedestrian safety; however it is not an exhaustive literature review or guideline. Many jurisdictions have their own guidelines and best practices that they use for the implementation of specific measures. TAC publications may also be used.

Roadway design and intersection traffic control devices are a fundamental part of a safe system design for pedestrians. In addition, many of the measures identified in this section also have the very positive by-product of reducing speeds particularly in pedestrian locations.

It is important to note that the best way to protect pedestrians is through strengthening measures directed at all of the following: the pedestrian, the driver, the vehicle and the roadway system, all of which can be complementary to one another. For example, pedestrian-friendly car fronts only produce benefits at a maximum speed of about 40 km/h so it is important to reduce vehicle speeds at least to this level wherever there is vehicle/pedestrian mix and of course 30 km/h or less is even better. Wherever speeds exceed this amount, it is important to separate pedestrians from vehicles. For both situations, road design, intersection design, and improved measures for drivers each remain complementary in supporting reduced pedestrian trauma outcomes.

In Canada responsibility for road safety is divided between three levels of government. Most pedestrian fatalities and injuries in Canada occur in urban environments where local governments have responsibility for roadway and intersection design. Road engineers rely on guides such as the *Manual of Uniform Traffic Control Devices for Canada (MUTCDC)* (1998), published and maintained by the TAC. Other common guides used are TACs *Pedestrian Crossing Control Guide* (to be published in 2012), and TACs *Geometric Design Guide for Canadian Roads* (1999).

A list of roadway engineering and traffic control guides published by the Transportation of Canada and often referred to in this report are as follows:

1. Loane, R. and Stewart, R. (2008). Guidelines for Understanding, Use & Implementation of Accessible Pedestrian Signals.
2. National Committee on Uniform Traffic Control (1998). Manual of Uniform Traffic Control Devices for Canada.
3. Zein, S. (2006). School and Playground Areas & Zones: Guidelines for Application and Implementation.
4. Guebert, A. (2005). Canadian Traffic Signal Warrant Matrix Procedure.
5. Pedestrian Countdown Signal Project Steering Committee (2008). Informational Report on Pedestrian Countdown Signals. Traffic Operations and Management Standing Committee
6. McLean, D., Lutkevich, P., Lewin, I. et al. (2006). Guide for the Design of Roadway Lighting.
7. Bahar G, Parkhill M (2005). Synthesis of Practices for the Implementation of Centreline Rumble Strips
8. National Committee on Uniform Traffic Control (1998). Pedestrian Crossing Control Manual.
9. Montufar J, Regehr J, Bahar J, Patmore K & Zegeer, C. (2012). Pedestrian Crossing Control Guide.

These guides provide uniform technical information and design principles to engineers and local governments. At the same time, it should be kept in mind that most of these guides are amended, revised or republished from time to time to reflect new data, research, practices and ideas.

In conjunction with implementing an integrated pedestrian strategy, there are many measures that work to improve pedestrian safety involving roadway and intersection design. A study published in the *American Journal of Public Health* found that one of the general engineering principles for better protecting pedestrians involves separation of pedestrians from vehicles through space and time.[134] Countermeasures that separate pedestrians from vehicles, through space or time, or provide other engineering/traffic control safety benefits to pedestrians is the subject of this section.

There exists a long and growing list of pedestrian fatality and injury countermeasures. This section will show some major examples of proven and emerging practices. It should be noted, however, that this list is not exhaustive but rather intended to capture and convey information about some of the most effective measures while also demonstrating that many measures exist and are implementation-ready.

# 4.2 Crosswalk Design

Pedestrian safety can be made a high priority on Canadian roads. Engineering countermeasures for pedestrians can be classified into broad categories; separation of pedestrians from vehicles through space or time, reducing or eliminating concurrent movements of vehicles and people, reducing crossing distances, increasing the visibility of pedestrians including through better lighting, alerting drivers to the location of crosswalks and reducing vehicle speeds. If a countermeasure can address one of these key areas it will have good chance of playing a positive role in pedestrian safety. At the same time, other measures also exist to support pedestrian safety and these can perform this role in many different ways. One example is through the use of measures that provide good access to safe crossings like the simple use of curb cuts and tactile markings for people who use wheelchairs and people who are visually impaired.

Crosswalk design is a critical component of pedestrian safety. One of the primary goals of crosswalk design is to provide safe places for pedestrians to cross while enabling drivers and pedestrians to make safer decisions while minimizing the likelihood of a crash. Crosswalks are also used by forward-thinking jurisdictions to signal greater priority to pedestrian travel.

In Canada, the TAC develops national guidelines for traffic control, including crosswalks, traffic signs and signals, and pavement markings. Provinces and territories that agree with the guidelines and best practices are free to adopt them in whole or in part and to integrate them into the regulations and standards in their respective jurisdictions. A municipality seeking to adopt a particular treatment would need to ensure it meets with any provincial regulation or work to have that regulation updated.

In Canada, each province and territory has a definition of a crosswalk in its highway, traffic or motor vehicle act. The definition generally includes both marked and unmarked crosswalks. Unmarked crosswalks exist at most intersections and drivers must yield to pedestrians in these locations.[135] Despite the legislative provision that crosswalks exist at every intersection, there are areas where additional devices and markings will improve the safety of the crossing by both drawing driver attention to the crosswalk, reducing vehicle speeds, distances that pedestrians must cross, number of lanes they must cross as well as other features that improve safety and encourage pedestrians to cross at a preferred location.

In addition, lighting and accessibility are key elements of crosswalk design. For specific Canadian Guidelines one may refer to TACs *Guide for the Design of Roadway Lighting (2006)*. Street lighting is essential in areas where there are a lot of pedestrians walking at night. Lighting not only makes pedestrians more visible to drivers but creates a safer environment for walking at night. The effectiveness of street lighting was analysed by Siddiqui, Chu, and Guttenplan[136] who indicate that, compared to dark conditions without street lighting, daylight lowers the odds of a fatal injury by 75 percent at mid-block locations and 83 percent at intersections, while street lighting reduces these by 42 and 54 percent, respectively at mid-block and intersection locations.

The design of a crosswalk should consider all possible users and take an inclusionary approach. Curb cuts make crosswalks accessible to pedestrians using wheelchairs, scooters, strollers and other walking devices. Furthermore, the alignment of curb cuts with crosswalks enables the pedestrian to face the crosswalk, which is an important signal to approaching drivers.

Most other accessibility treatments used to enhance crosswalks are outlined in TAC's *Guidelines for Understanding, Use and Implementation of Accessible Pedestrian Signals (2008)*. The Guidelines provide agencies with practical and uniform information on audible pedestrian signals (APS) prioritization, design, installation, operations and maintenance. They recommend standardizing the locations of the button on the pole by using pole locator tones to assist pedestrians with visual impairments to cross safely.

The installation of a crosswalk is based on individual jurisdictional warrants set in place or can be determined by TAC warrants based on their publications *Canadian Traffic Signal Warrant Matrix Procedure (2005), MUTCDC (1998), and Pedestrian Crossing Control Manual (1998)*. In order for traffic and pedestrian control devices to be effective they should be monitored and upgraded to conform to these standards, including all new signal installations and rehabilitation projects.[137]

## Common Marked Crosswalk Treatments

The following discussion is meant to provide an overview of some common crosswalk designs and treatments.

The decision to install a crosswalk can be based on a number of considerations. When a crosswalk is installed, there are a number of factors considered to identify the correct type of crosswalk design and treatments. Professional engineers use TAC's *Pedestrian Crossing Control Guide, Pedestrian Crossing Control Guide: Technical Knowledge Base, and MUTCD* to at least help inform their decisions. At the same time, road user mixes, research, best practices and societal priorities are not static and fixed and so all forms of guidance must be reviewed and amended over time.

If the crosswalk is going to be installed in a school zone the determination is made based on similar criteria, but crosswalk components are different.

Generally, more complex road systems (i.e., higher speed limits, more lanes, and existence of refuges) have more complex crosswalk treatments. This creates a hierarchy of marked crosswalk treatments that are chosen based on the factors above.

The following is a simplified example of a hierarchy of marked crosswalk treatments, for more detailed information regarding the sites in which to implement a specific crosswalk treatment please refer to the aforementioned TAC *Pedestrian Crossing Control Guide and Pedestrian Crossing Control Guide: Technical Knowledge Base*.

Once an engineer has assessed and determined that a marked crosswalk is required there are a number of signs, markings, and devices that can be used. Marked crosswalk treatments are selected and implemented from a hierarchy starting with the most basic treatment of pavement markings and signs up to the most complex that involves a pedestrian activated traffic signal.

### Basic Marked Crosswalk

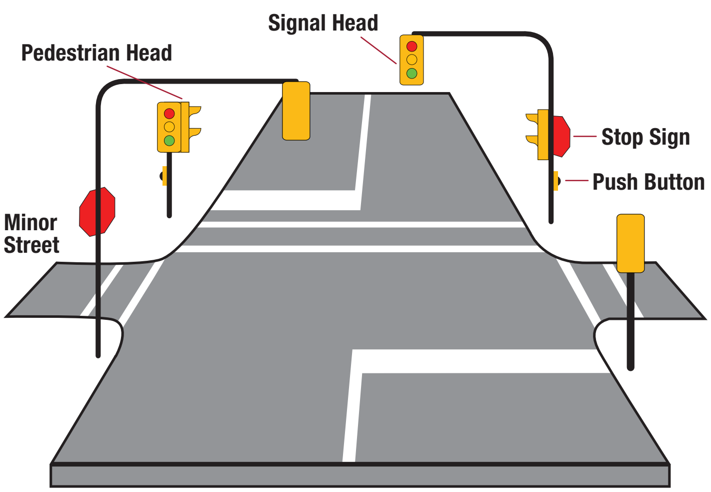
The most basic marked crosswalk consists of twin parallel line crosswalk markings across the surface of the road with a basic crosswalk sign (see sign above). The signs are side mounted on either side of the street in both directions. The signs are often referred to as an RA-4 - one for the left side (RA-4L) and one for the right side (RA-4R). An example of where these may be used is in low traffic volume areas, low speeds (50 km/hr), and few lanes (one-two lanes). In a school zone/area, the crosswalk treatments could include, zebra crosswalk markings, school zone crosswalk signs, and in some cases a crossing guard.[137]

### Marked Crosswalk with Overhead Sign

The next type of crosswalk is a basic crosswalk supplemented by pedestrian crosswalk overhead signs (see sign above). These may be seen in areas where there are higher volumes of traffic, at higher speeds (e.g., 60 km/hr), and where there is no raised pedestrian refuges. One factor that may also be considered is if the crosswalk is frequently used at night. This type of crosswalk signage may be used in locations where there are many pedestrians using a crosswalk at night and there are high vehicle approach speeds.[137]

## Marked Crosswalk with Overhead Lighting and Pedestrian-activated Flashing Amber Beacons

In situations where this device is warranted, roadway designers may consider using a Marked Crosswalk with Overhead Lighting. The installation involves the addition of pedestrian-activated amber beacons installed alongside of the RA-5 signs above the crosswalk. Each sign has two flashing lights, facing each direction of oncoming traffic. Engineers need to ensure that the beacon lights flash long enough for pedestrians to clear the crosswalk; approaching traffic must yield to the pedestrian for the entire width of the road to assist the pedestrian to cross safely.[137] These may be used in areas where there are greater speeds (e.g., 70 km/hr) and in places where there is a pedestrian refuge (raised or not).




PEDESTRIAN HALF-SIGNAL

## Marked Crosswalk with Pedestrian-activated Traffic Signal or Half- Signal

If the location does not have enough gaps in traffic to let pedestrians cross safely sometimes a pedestrian-activated traffic signal or half signal may be used (see sign above). TAC recommends that the crosswalk be within 100 to 200 metres from an adjacent traffic control signal or pedestrian-activated beacon equipped crosswalk; however each jurisdiction may decide using another distance based on their individual circumstances. Where this type of crosswalk is located at an intersection, the traffic volumes should be low enough not to warrant full traffic control signals. A pedestrian-activated traffic signal uses a standard traffic signal display to control vehicle and pedestrian traffic at a crosswalk. When this type of a crosswalk crosses a major road at an intersection, it is often called a half-signal, because only the major roadway is signalized. The side street (or minor street) is controlled by a stop sign. The half-signal only changes the traffic and pedestrian signals when activated.[137] The time required for this change to happen will vary. If the half-signal is coordinated with other signals in the area, then the controller communicates with other controllers to synchronize the displays of the signals, thereby enabling traffic to flow smoothly and efficiently.[137]

## Fully Signalized Intersections

A fully signalized intersection may be installed after a determination of need is calculated based on the vehicle traffic volume at the intersection in combination with the pedestrian traffic volume. One example of a warrant procedure that may be used would be TACs *Canadian Traffic Signal Warrant Matrix Procedure (2005)*. The procedure is a mathematical process used by engineers to determine the need for a signalised intersection.[137]

A fully signalized intersection often has marked crosswalks on all four legs. The crosswalk will either have pedestrian signals that are connected to the traffic signals or pedestrian activated signals. If the pedestrian signals are connected to the traffic signals, the pedestrian waits until the walk signal is displayed going in the direction they are crossing. At the same time, the opposing traffic signal displays a red light, stopping the traffic from crossing over the crosswalk. If the pedestrian signal is not connected to the traffic signals the pedestrian has to push the button for the walk signal to be displayed.[138] While this represents a basic signalized intersection, the discussion to follow will examine ways to improve this basic intersection design through the use of relatively simply signal timing measures like pedestrian scramble operations, leading pedestrian intervals and restricting vehicle turning – all measures of which are designed to reduce or eliminate dangerous concurrent movements that often lead to motor vehicles striking pedestrians even when pedestrians are legally crossing at an intersection.

*Figure 4.1: Signalized Intersection Control, Photo – David Coburn, Neil Arason*

## Pedestrian Detection

And even more innovative measure, however, are pedestrian detection systems which increase the time a pedestrian needs to cross and, in some cases, will only activate if there is a pedestrian in the crossing. The PUFFIN crossing (Pedestrian User-Friendly Intelligent Crossing) works on a unique non-timed system, which uses detectors and sensors to monitor the presence of crossing pedestrians and adjusts light signal durations according to walking speeds. While there is a pedestrian presence detected in the crossing area, the walk signal will remain. The walk signal is cancelled as soon as the crossing area is clear, thus eliminating any delays to traffic. The benefit of the PUFFIN system is that it encourages pedestrians to stay within the crosswalk, otherwise the walk signal will end. Often zigzag lines are painted in the vehicle lanes leading up to this type of crossing in order to warn drivers that they are approaching a pedestrian crossing and to reduce their speed.[139] This type of pedestrian detection system is widely used in the UK.

## Treatments that Eliminate Left and Right-hand Turn Conflicts

At traditionally signalized intersections, even with pedestrian signals, there is still the possibility of a conflict between a motor vehicle and a vulnerable pedestrian. The conflict comes in part from allowing left-and right-hand turns during pedestrian walk phases. Most pedestrian trauma incidents at intersections involve a left or right-hand turning motor vehicle. Four countermeasures that can reduce the potential for collisions due to turning vehicles are:

- Pedestrian Scramble Operations (PSOs)
- Advanced Green for Pedestrians
- Protected Left-Turning Phase; and
- Prohibition of Right-on-Red

## Pedestrian Scramble Operations

This countermeasure also referred to as "all exclusive pedestrian phasing", stops traffic in all four directions and provides exclusive walk phases to pedestrians, where they are able to cross diagonally, or laterally, at any leg of the intersection. During the pedestrian walk phase, drivers cannot turn right or left, eliminating common points of conflict with pedestrians. The US DoT has reported a 34 percent decrease in pedestrian collisions at intersections that were converted into PSOs.[140] Currently pedestrian scrambles exist in Calgary, Montreal and Toronto. Pedestrian scrambles reduce conflict between vehicles and pedestrians at signalized intersections and thus respond to one of the most dangerous threats to people who across intersections in urban places. Pedestrian scrambles signal a new priority in the use of urban travel space by putting people at the heart of design.

Alberta conducted a pilot test on the effects of implementing PSOs at two intersections in the downtown area, and found that they significantly reduced the number of pedestrian-vehicle conflicts. This study of scramble operations in Calgary[141] made observations of pedestrian-vehicle conflicts and violations. The most important measure, conflicts, decreased. Of the total pedestrian violations 13 percent were "safe side" crossings (concurrent with vehicle movement). About 40 percent of the violations were at the beginning of the "Don't Walk" phase. A survey showed that public attitudes to the new signal operation were positive. In addition, a survey found that the majority of the pedestrians using those intersections took full advantage of the ability to cross diagonally, a maneuver they were not able to perform on conventional signalized intersections.

*Figure 4.2: Pedestrian Scramble, Photo – Courtesy of City of Calgary*

## Advanced Green for Pedestrians (or Leading Pedestrian Intervals)

At a typical intersection, the pedestrian signal works simultaneously with the traffic signal and many pedestrians are struck just after leaving the curb and with a WALK signal in their favour typically by a right-turning vehicle and at other times by a left-turning one. The answer to this common problem is the leading pedestrian interval which is a low-cost countermeasure that allows pedestrians to get a head start (3-6 seconds or more) before the vehicles are given a green light. This accomplishes a number of things including that it puts pedestrians well into the crosswalk, and hence makes them more visible to drivers, before drivers begin to turn. More than that, as pedestrians get used to this advanced signal measure, many are able to get across a good portion of their crossing during this protected pedestrian period. The longer times are especially helpful in areas where there are multiple lanes to cross.[142 143 144]

A study by Van Houton et al.[145] has examined a three-second leading pedestrian interval (LPI) whereby the WALK signal comes on three seconds before vehicles can proceed. The treatment was found to reduce conflicts for pedestrians starting across at the beginning of the walk interval by 95 percent. The introduction of the LPI reduced the odds of a pedestrian having to yield to a vehicle by approximately 60 percent. Use of the LPI would not only make it safer for pedestrians, but may also give them an increased sense of comfort and safety. The distance traversed by pedestrians during the LPI would be sufficient for them to assert their right-of-way over vehicles. The need for an absolute minimum three second LPI is underscored by the fact that older pedestrians delay for about 2.5s before starting to cross.[146]

## Protected Left-Turn Phasing

Some jurisdictions have increased the number of intersections with protected left-turn phasing and those where drivers are prohibited from turning right on a red light. This is because most intersections make it difficult for drivers to make safe turning choices. To reduce the potential for conflicts, protected left-turn phases can be included into a signal sequences. In this scenario, the pedestrian is held at the curb by a "Do Not Walk" phase and through traffic is held by a red light. The driver is able to make a turn without conflicting with pedestrians.


*Figure 4.3: Channelized Left Turn, Photo – David Coburn, Neil Arason*

## Prohibition of Right-on-Red

As mentioned already, one of the conditions leading to motor vehicles hitting pedestrians is the conflict created when vehicles turn right at an intersection, especially when the light is red in their direction and pedestrians have the right of way. The right turn on red (RTOR) rule is a major source of concern for pedestrian safety. Drivers are supposed to stop and yield to crossing pedestrians in this situation but they often fail to do so. This issue was examined in a study by Preusser et al.,[147] who found a significant increase in pedestrian and bicyclist trauma after the introduction of the RTOR at signalized intersections. These increases of pedestrian collisions in four jurisdictions ranged from 43 to 107 percent. Analysis of the police reports suggested that drivers stop for a red light, look left for a gap in the traffic and fail to see pedestrians and cyclists coming from their right as they turn. Prohibiting right turns on red effectively removes the potential for a conflict between drivers and pedestrians, as long as drivers comply with the rule.[148]

***Figure 4.4:*** *Prohibition on Right-Turn-on-Red, Photo – David Coburn, Neil Arason*

## Reducing Crossing Distances

### *Traffic Islands and Raised Medians*

The use of traffic islands and raised medians is an excellent practice especially on multi-lane roadways where the roadway is too wide for most pedestrians to cross safely. The median breaks up the crossing into smaller more manageable distances. Installing a median can be especially helpful for pedestrians who need more time to cross, such as children, older adults and persons with mobility challenges.[149] Nonetheless, they serve all pedestrians well by improving their safety and security.

Raised medians or crossing islands have lowered the rate of collisions significantly on multi-lane roads, regardless of whether the crosswalk is marked or unmarked.[150] The US DoT found that using a raised median has resulted in a 46 percent reduction in pedestrian crashes at unsignalised locations.[151] Painted (unraised) medians were not found to have the same benefits. Additionally, Fitzpatrick et al.[152] found that medians and refuge islands lead to higher driver compliance rates on lower-speed roadways.


***Figure 4.5:*** *Pedestrian Median, Photo – David Coburn, Neil Arason*

***Figure 4.6:*** *Pedestrian Median, Photo – David Coburn, Neil Arason*

### *Offset Crosswalks (Danish Offset)*

An offset crosswalk, or Danish Offset, is a somewhat simple but brilliant crosswalk design. This crosswalk application uses an offset median that breaks up the crossing distance and prevents the pedestrian from walking straight across the road and instead guides them so that they face and are looking directly at the next half of the oncoming traffic. The offset is created by using a fence or barrier system such as number of closely spaced bollards. The median provides a safe place for pedestrians to wait for a break in the traffic prior to crossing.[153] The length of the offset can be shorter or longer depending on pedestrian volumes. A longer offset can create a large holding area for pedestrians especially useful in locations where there is heavy pedestrian traffic. The Danish Offset pictured here, left, connects a high school to a mall where many students cross at once during lunch time.

***Figure 4.7:*** *Danish Offset Crossing, Photo – David Coburn, Neil Arason*

***Figure 4.8:*** *Danish Offset Crossing, Photo – David Coburn, Neil Arason*

## Parking Restrictions and Bus Stop Placement

In many cases, pedestrian trauma occurs because there are parked vehicles obstructing drivers' views as they approach an intersection or marked crosswalk. Parked vehicles also hinder a pedestrian's ability to see oncoming traffic from the safety of the curb. To reduce the potential for collisions, many jurisdictions have prohibited parking near intersections and crosswalks and moved bus stops from these same locations.[154] European Transport Ministers have passed resolutions banning parking near crosswalks in school zones.[155] Ideally, fencing is in place to deter people from crossing near the bus stop location and instead guides them to the safest crossing location.

Bus stops near crosswalks and intersections add another complication, because when a bus is stopped and passengers are disembarking, some drivers may attempt to overtake the bus. This is especially dangerous because the bus obstructs drivers' vision so they cannot see pedestrians crossing from in front of the bus; and similarly pedestrians cannot see the passing vehicle.[156] It was noted in the US Department of Transportation's Toolbox of Countermeasures that moving a bus stop location away from crosswalks deterred pedestrians from crossing right in front of the bus.

## Other Best Practices

### *Roundabouts*

A roundabout is an effective intersection design that involves traffic flowing in a counter clockwise circle around a centre island. Although an old idea, modern roundabouts have been re-gaining their popularity since the 1990s due to their immense safety benefits, the marvelous quality of reduced speeds that this design brings about and their ability to control traffic flows without the use of traffic signals and concomitant reductions in greenhouse gas emissions. Roundabouts significantly reduce road user injuries due to the slower speeds and the lesser conflict points outlined in Figure 4.3. Roundabouts reduce vehicle-pedestrian conflict points from 24 to 8. With such a decrease in possible conflict points, and the average maximum speed in a roundabout much less, they have proven to greatly decrease the severity and likelihood of an injury collision.

There are many provinces and municipalities that have made significant progress towards the implementation of the roundabout. Many have installed numerous single and multi-lane roundabouts in various locations. The region of Waterloo has made significant progress in the area of roundabout installation and has been named the roundabout capital of Canada. They have installed 13 roundabouts on major commuter roads, as well as other roundabouts on smaller streets. Roundabouts are gaining so much popularity amongst Canadian jurisdictions that several policies have been created that outline that a roundabout should be considered as the default option for intersection designs. There are three reasons why pedestrians are safer at roundabouts: Pedestrian crossing distances are often shorter because extra lanes are not needed on an approach, and where splitter islands are present the crossing is done in two-stages; pedestrians only have to look in one direction for oncoming traffic; lower vehicle speeds -

roundabouts are designed to reduce vehicle speeds by up to 85 percent, thus there is more time to make eye contact with a motorist and avoid a crash, and if a crash does occur it will be less severe. Well designed roundabouts that take into account pedestrian safety consider factors such as the roundabout's cross-distance (typically the more compact the better in order to reduce speeds), the need for the fewest number of lanes, measures that make navigating the roundabout as simple as possible for drivers as well as pedestrians, additional speed reduction measures if necessary and the use of pedestrian crossing features such as use of a median, good lighting and many other general crosswalk features discussed in this report.

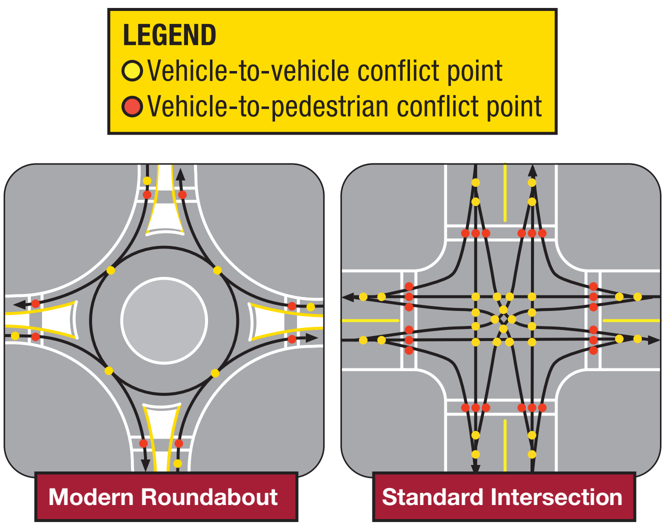



***Figure 4.9:*** *Vehicle-vehicle and vehicle-pedestrian conflict points*

***Figure 4.10:*** *Roundabout, Photo – David Coburn, Neil Arason*

### *Pedestrian Overpasses and Underpasses*

In some situations, it may be clear that a traditional crosswalk is not an option because the roadway to be crossed is unsafe. It may be because of higher speeds or it may be that many people cross at a particular location that is unsafe for any number of different reasons. Underpasses or overpasses are commonly used where there are high volumes of traffic at high speeds and where pedestrians would be especially vulnerable. Common locations include near schools, universities, parks, shopping areas, recreation facilities, multi-use paths, or any long stretch of higher speed road without alternate locations for pedestrians to cross. Moreover, to be most effective these overpasses (or underpasses) should be accessible so ramps or even an elevator may need to be included in the design. In addition, underpasses should be well lit at night and consider what can be done to prevent other types of safety issues from arising such as crimes involving assault. Also, if crossings appear to be an inconvenience they will be not be used.[157] A Japanese study of 31 overpasses in urban areas found that the number of pedestrian collisions decreased 91 percent within 100 meters of an overpass.[158]

***Figure 4.11:*** *Pedestrian Overpass, Photo – Courtesy of BC Ministry of Transportation and Infrastructure*

## POTENTIAL COUNTERMEASURES

- Consider pedestrians in the planning and design phase of new or refurbishing projects.
- Crosswalk treatments should consider all types of pedestrians and pedestrian abilities.
- Consider pedestrian collision information (i.e., minor, moderate, major and fatal injuries) and neighborhood characteristics (i.e., older adults, school zones, commercial districts, etc.) in order to determine treatment types.
- Install crosswalks and appropriate treatments where warranted and according to engineering standards and practice.
- The use of the half-signal where appropriate.
- The use of sensors at signalized crossing and that detect the presence of pedestrians and that provide sufficient time for each individual pedestrian to cross safely.
- The use of mechanisms that separate pedestrians from traffic through time: Pedestrian Scramble Operations, Leading Pedestrian Intervals, Prohibition on Right-Turn-on-Red and more channelized turning at signalized intersections.
- The use mechanisms that physically separate pedestrians from traffic: the use of mid-block crossing medians, curb extensions and the use of variations on the Danish Offset
- Effective bus stop location, use of fencing and parking restrictions
- Greater use of the roundabout especially when designed to take into account best practices that apply to pedestrian safety, and that create safe crossing locations and features, and that are found in this report
- The use of overpasses or underpasses that physically separate pedestrians from traffic flows.

# 4.3

# Traffic Control - Signs, Signals and Markings

This section is about the traffic control devices (TCDs) used to warn motorists of the presence of pedestrians and to guide and alert pedestrians in the safe crossing or roads. Signs are the most commonly used TCD to warn motorists of the presence of pedestrian crosswalks, to promote safe behaviour on the part of drivers and to indicate playground and school zones. As with vehicle traffic, pedestrian traffic needs to be guided, directed, and warned of hazards by TCDs - signs, signals and pavement markings. Signals are found at intersections and occasionally at mid-block crosswalks. Pavement markings indicate the locations of crosswalks and guide pedestrians along a safe path for crossing the road. These TCDs, however, are not all equally effective.[159] The following section of research findings related to pedestrian traffic control devices highlights some of the issues with and the differences in the effectiveness of the various signs, signals and markings.

### Pedestrian Signs at Crosswalks

Signs or pavement marking directed at pedestrians have been used in the UK and other jurisdictions. Pedestrian signs are generally used at signalized intersections to remind pedestrians about dangerous road and vehicle threats. The signs below are more of an educational technique than an engineering design; however, they can be used in combination with other crosswalk treatments to instruct pedestrians on the use of signal push buttons and to encourage pedestrians to be cautious at signalized intersections. Sometimes at signalized intersections, pedestrians can be over-confident and forget to look for turning vehicles or ensure the pedestrian signal is activated.[160]

**Figures 4.12** **Examples of pedestrian warning signs at crosswalks. Source: Crosswalk Safety Task Force Final Report, 2007.**

## Signs to Warn Drivers and Pedestrians

A variety of signs have been used to warn drivers of the possible presence of pedestrians and to warn pedestrians to watch for vehicles. The relation of driver age and comprehension of a pedestrian right-of way sign, "TURNING TRAFFIC MUST YIELD TO PEDESTRIANS" was examined by Abdulsattar and McCoy[161] who found that this message was well understood in a right turn scenario. However, in a left turn situation drivers below age 56 understood or paid more attention to the sign than did older ones. The authors suggest that the difference may be due to different perceptions of right-of-way in the two situations, whereby pedestrians are considered by left turning drivers not to have the right-of-way, since left turns are often protected for vehicle traffic.

In a study by Retting et al.[162] special signs which read, "LOOK FOR TURNING VEHICLES" with an accompanying pictograph of the crosswalk, and pavement markings which read, "WATCH TURNING VEHICLES", were installed at three signalized intersections. Pedestrian-vehicle conflicts were recorded and crossing behaviour of pedestrians was observed before, immediately after, and one year after these prompts were introduced. The percentage of pedestrians who did not look for any threats from vehicles, as well as the number of conflicts, dropped dramatically from the before to the after periods for both the sign only and the sign plus markings conditions. The one year follow-up showed no conflicts, as compared to about 2.7 percent pedestrians in the baseline condition.

A similar study[163] looked at the impact of a sign to remind drivers to yield to pedestrians at 12 marked crosswalks. A before-and-after study showed that conflicts between pedestrians and turning drivers reduced 20 to 65 percent for left turns and 15 to 30 percent for right turns. In spite of these improvements, the occurrence of conflicts was still quite high after the sign installation – 35 percent for left turns and 38 percent for right turns.

### *Advance Yield Markings and Crosswalk Prompt Signs*

The use of an advance X on the pavement was used in Canada in the past to indicate a crosswalk was near. Currently the advance "X" pavement markings are only used on an approach to a railway crossing. However, there is research that other advance pavement markings are effective in increasing yielding distance at crosswalks.[164]

The multiple-threat collision involves one vehicle stopping to allow a pedestrian to cross while another moving in the same direction fails to stop and strikes the pedestrian. Vehicles stopped too near the crosswalk can obscure the visibility of the crossing pedestrian. The effects of a sign, "YIELD HERE TO PEDESTRIANS" and advance yield pavement markings were examined as they influence motor vehicle-pedestrian conflicts at multilane crosswalks at T-intersections.[165] The advanced pavement markings were a combination known as "shark's teeth" or "saw-tooth markings". The study found that the sign alone reduced conflicts and increased the distance at which drivers yielded to pedestrians. The addition of pavement markings further increased yielding distances and reduced conflicts. The countermeasure is best suited for places where there are multilane roads, because with the extra distance, pedestrians and drivers can see each other better.

The effect of advance yield markings and crosswalk prompt signs (placed 10 metres upstream of a stop-controlled intersection) in multiple-threat scenarios was studied by Fisher and Garay in a simulation experiment.[166] Driver eye fixations and yielding behaviour at marked mid-block crosswalks were examined as drivers approached the intersection. Subjects in the control group encountered traditional road markings with stop bars 3 metres before the intersection while subjects in the experimental group experienced advance yield markings and prompt signs group. Subjects in the experimental group looked for pedestrians 69 percent of the time, while those in the control group looked 47 percent of the time and began to look sooner. Sixty-one percent of the advanced yield group yielded or stopped when a pedestrian emerged behind the stopped vehicle while none of the control group drivers yielded or stopped. It was evident that the advance warnings of a pedestrian crossing greatly reduced the danger to crossing pedestrians in this multiple-threat simulated driving situation.

The use of advance stop lines and sign prompts has been found to reduce pedestrian-vehicle conflicts by almost 80 percent at a crosswalk on a six-lane urban street.[167] On a street with a 50 km/h speed limit conflicts were observed before and after stop lines were painted on the pavement and signs with the message "STOP HERE FOR PEDESTRIANS", accompanied by an arrow pointing down at 45 degrees to the road, were installed 15 m before the crosswalk. The proportion of drivers yielding to pedestrians increased only slightly with the stop lines and signs, however, yielding drivers were found to stop much further from the crosswalk under the experimental conditions, which increased the likelihood that drivers and pedestrians would see each other. The pavement markings alone were found to be as effective as the sign and markings combined, suggesting that the essential component in improving pedestrian safety were the markings.

It should not be assumed that the use of pavement markings for uncontrolled crosswalks always leads to greater pedestrian safety.[168] A study of marked and unmarked crosswalks gathered data at 1,000 marked and 1,000 unmarked pedestrian crosswalks in 30 US cities.[169] On two-lane roads no differences were found between marked and unmarked crosswalks. Similarly, on multi-lane roads with an average daily traffic (ADT) of 12,000 or less the presence of markings made no difference in crash rate. However, the presence of a marked crosswalk alone (without other substantial treatments) was associated with higher pedestrian crashes when compared to an unmarked crosswalk on multi-lane roads having high traffic volumes (greater than about 12,000 ADT). Even with raised medians those locations with an ADT of more than 15,000 had higher crash rates with marked crosswalks. Use of marked crosswalks may induce more pedestrians to cross there and may give them a false sense of security and reduce vigilance. For these higher-volume, multi-lane road crossings, the authors recommend installing more substantial improvements than marked crosswalks alone, such as raised median islands, traffic and pedestrian signals (if warranted), enhanced night-time lighting, and reducing the number of lanes.[170]

A recent study by Fitzpatrick et al.[171] examined the visibility of three types of crosswalk markings: bar pairs, continental and transverse. Visibility distances of the first two were similar but greater than for the transverse markings. Using a rating measure, transverse markings were also preferred by drivers over the continental marking. It was recommended that bar pairs be used for crosswalks.

A variety of markings have been used at crosswalks. The most basic involves a solid white line extending entirely across the pavement. Where appropriate a stop line will be painted across approaching lanes to indicate the place where vehicles should stop. Other types of markings are “zebra” (longitudinal stripes parallel to the flow of traffic), as well as the word SCHOOL painted on the pavement in advance of crossings near schools. In addition to the standard school zone and advance school zone signs, school zones have also used crossing guards to control vehicle traffic as well as in-street school crossing signs when schools are in session.

## In-roadway Warning Lights and Other New Technologies

In-roadway warning lights are similar to those seen on airport runways. The warning lights are installed along the road in front of the crosswalk facing approaching traffic and are activated when a pedestrian pushes a button similar to the ones found on other pedestrian activated devices. In-roadway lights display different colours such as white or red, to encourage drivers to stop.

Studies suggest that these types of treatments are effective in increasing driver compliance, reducing driver-pedestrian conflicts and reducing speeds. The devices are most effective at night as they are not as visible during the day.[172] Carson et al. conducted a review of the applications of these devices in the US[173] (only a few of which apply to pedestrian crossings). They point out that these devices increase driver awareness and vehicle yielding while reducing vehicle approach speeds, vehicle-pedestrian conflicts and pedestrian wait times at crossings. Similar findings of reduced vehicle speeds, reduced conflicts, increased stopping distances and greater compliance were found by a number of studies.[174] [175] [176] [177] One of the biggest challenges with in-roadway lights is their maintenance when exposed to winter conditions and snow plow damage. While these types of devices show promise in increasing pedestrian awareness and driver compliance, the maintenance issues may need to be considered for northern climates, at least until new advances in technology occur.[178]

### *Overhead Flashing Amber Beacons*

Overhead flashing beacons are amber coloured beacons that are installed on traffic signal poles that increase driver awareness that pedestrians are crossing the road. These beacons may be programmed to be continuously lit or they can only become lit when a pedestrian wishes to cross the crosswalk. An overhead beacon near a school crossing is shown in the following photo. It was found that vehicles generally complied with these types of beacons, but compliance was higher when some form of pedestrian actuation was used in conjunction with the overhead flashing beacon installation.[179]

### *High Intensity Activated Crosswalk*

A signal known as a High intensity Activated crossWalK or "HAWK" was developed in the 1990s and has been tested in a number of US jurisdictions. The HAWK is meant to increase driver compliance at crosswalks to enable pedestrians to cross the roadway. The unique design of the HAWK not only encourages drivers to stop for pedestrians, it also permits drivers to proceed immediately after the pedestrian has passed. The HAWK is a combination of beacon flasher and a traffic control signal - similar to a half-signal. It is meant to be installed in areas where a pedestrian crossing is needed, but does so without having a signal control for a side street.[180]

The lights on the beacon remain dark until it is activated by a pedestrian.[181] The signal uses a configuration of lights that includes an amber signal on the bottom and two red signals (side-by-side) at the top. Pedestrians approaching the crosswalk see a solid "don't walk" symbol. When the pedestrian pushes the button to cross, the HAWK beacon begins to flash amber, alerting drivers the signal is about to change. The signal then changes to a solid amber and then to a single solid red. At this time, the pedestrian signal displays a walk signal, allowing the pedestrian to begin crossing. When the pedestrian signal begins to flash to the "don't walk" signal the traffic signal also begins to flash the two red lights alternately to indicate to stopped drivers that they may proceed as long as the pedestrian has crossed safely. The drivers that follow must stop and then proceed only when it is safe to do and until the flashing red lights stop. It is thought that using red lights can increase driver compliance at crosswalks and there is some evidence that supports this.[182]

After installation of the HAWK signals there was a reduction of 69 percent in vehicle-pedestrian crashes. Changes at control intersections showed either very slight reduction or a significant increase.[183] One concern in Canada is the fact that the signals remain dark until activated and in most jurisdictions an unlit signal requires drivers to stop in case the light is not working. Therefore, the half-signal is considered a better crosswalk treatment in cases where there is a multi-lane major road connected to a minor unsignalized road.[184] The Hawk is now recognized by the U.S. Manual of Uniform Traffic Control Devices[185] but at this time is not included in TACs Pedestrian Crossing Control Guide.


***Figure 4.13:*** *Pedestrian Hawk, Source www.pedbikeimages.org, Photo – Sree Gajula*

### *Countdown Signals*

The length of a pedestrian signal is important for determining a pedestrian's safety. The goal is to give pedestrians enough time to cross without unduly delaying traffic. One way of doing this is to demonstrate to pedestrians the length of time remaining to cross. Many jurisdictions have moved to install pedestrian countdown signals that indicate the remaining time a pedestrian has to cross once the flashing "don't walk" signal begins. TAC has an *Informational Report on Pedestrian Countdown Signals (2008)* that can provide additional information on countdown signals. The countdowns are also helpful for drivers to indicate the length of time remaining in the walk phase of the signal. The use of countdown signals for pedestrian crossings has become widespread in recent years. Their effectiveness has been evaluated in Germany by Schlabbach[186] in a before-and-after study. A total of 45,000 cars and 71,000 pedestrians were recorded and questionnaires completed by 760 pedestrians. Red-light violations by pedestrians reduced from 21 percent to 16.7 percent after the signals were installed. About a quarter of those surveyed indicated that their behaviour was changed by the new signals.

At intersections with pedestrian countdown signals there is the possibility that drivers' speeds may increase when they see a countdown signal near the end of the pedestrian crossing period. This was investigated by Nambisan and Karkee[187] who measured vehicle speeds immediately upstream of the stop bar and during different indications of the pedestrian signal head, with the times remaining for pedestrians to cross at 15 sec., 15-10 sec., 10-5 sec. and less than 5 sec. Speeds were greater during the countdown and "don't walk" displays than when the "walk" display and countdown time were displayed.

Other recent technologies include skid resistant polymer surfaces and coloured crosswalks with retroreflective beads for greater night-time visibility.[188]

### *Illuminated Signals at Crosswalks*

Fitzpatrick et al.[189] found that treatments with red signal or beacon devices led to high driver compliance (more than 95 percent) while pedestrian crossing flags and in-street signs were less effective (65 and 87 percent compliance, respectively).

Shurbutt et al.[190] compared the effects of different types of beacons on drivers' yielding to pedestrians in multi-lane crosswalks. LED rectangular rapid-flash yellow beacons (RRFBs) were found to be much more effective in causing drivers to yield to pedestrians than were traditional overhead or side mounted flashing yellow beacons. RRFBs resulted in a change in yielding from 2 to 86 percent at the sites examined in Florida, and the yielding level remained at the 85 percent two years later. These effects were even greater at night, with yielding reaching more than 90 percent.

***Figure 4.14:*** *Rectangular Rapid-flashing Beacon (RRFBs), Source www.pedbikeimages.org, Photo – Michael Frederick*

### *Signs and Marking to Warn*

Because pedestrians often fail to scan the traffic environment they are vulnerable to being struck by turning vehicles. Van Houton et al.[191] have demonstrated the effectiveness of a novel manner of communicating to pedestrians at signalized crosswalks to look for vehicles. At two intersections in Florida an "EYES" display was used for the pedestrian crossing signal. It consisted of blue LEDs – two eyes with blue eyeballs that scanned left and right at a rate of one cycle/sec. The eyes were positioned one above the standard symbol of a hand (for wait) and one above the walking person (for walk), which were also LED configurations.

In the baseline condition standard pedestrian signals were used, while the experimental conditions included the" EYES" display either immediately before the "WALK" signal for 2.5s, concurrent with the beginning of the "WALK" signal for 2.5s or concurrent, then repeated every 9.5s during the "WALK" signal. The percentage of pedestrians not looking for turning vehicles reduced dramatically under all conditions. Conflicts between pedestrians and turning vehicles were also greatly reduced by using the "EYES" display.

### *Auditory Messages*

In a US study[192] the influence of three verbal messages for pedestrians was studied to see if they would reduce pedestrian/vehicle conflicts at intersections. The messages, spoken by either a woman or a child just before the walk signal was illuminated, indicated that pedestrians should wait for the walk signal or watch for turning vehicles. During the baseline condition 16.3 percent of pedestrians did not look for threats (vehicles) and there was an average of one conflict per session. The auditory signal reduced the number of those not looking to 4.2 percent and the conflicts to 0.25 per session. The use of a child's voice was more effective than an adult's in promoting the search for threats.

Auditory indications of when it is safe for pedestrians who are blind or with low vision to cross at a signalised intersection (when the WALK signal is on) are provided with sounds such as a cuckoo or chirp. However, it is not always possible to hear these properly at a busy intersection due to vehicle noise.

### Newer Tested Crosswalk Treatments

There are a number of more recent treatments (signs, pavement markings, and signals) used in various jurisdictions that have studies to support their benefits. They are presented here for consideration and to encourage engineers and planners to monitor the outcomes of installing these devices. The purpose of this section is to provide broad examples of current practices. It is not by any means exhaustive. The TAC *Pedestrian Crossing Control Guide* will be accompanied by a Technical Knowledge Base Report, which includes an exhaustive literature review of various crossing control treatments.

### POTENTIAL COUNTERMEASURES

*Signs and Signals:*

- At intersections install signs warning drivers to watch for pedestrians and signs to prompt pedestrians to watch for turning vehicles.
- At intersections install signs indicating “YIELD TO PEDESTRIANS” or “STOP HERE FOR PEDESTRIANS”.
- Place placards at signalised crosswalks with instructions on how to use pedestrian-activated signals and the meaning of pedestrian signal indications where there are frequent pedestrian violations.
- Introduce innovative applications such as the “HAWK” pedestrian signals and voice messages indicating when it is safe to cross. Install count-down pedestrian signals.
- Use Rectangular Rapid Flash Beacons particularly in multi-lane crosswalks.

*For Pavement Markings:*

- Install advance stop bar markings at least 15 metres in advance intersections.
- Install markings warning pedestrians of turning vehicles.
- Install within-pavement flashing lights at appropriate locations.
- Limit the use of markings for crosswalks to roads with an ADT of less than 12,000 vehicles.
- Maintain crosswalk markings to ensure high visibility.

# 4.4
# Volume Dispersion

Volume control measures are used to reduce the volume of vehicular traffic on local streets in order to return their use to people and increase the safety of pedestrians and bicyclists. Most are designed to prevent short-cutting or through traffic. The following section describes key countermeasures used for volume control and recommended for use in Canada. Almost all have been shown to be effective in substantially reducing traffic volumes on affected streets. Volume control measures increase pedestrian safety by reducing the exposure of pedestrians to motor vehicles in areas where these countermeasures are implemented.

Most of these countermeasures often restrict residential access and may divert traffic to other streets[193] therefore it is necessary consider these effects.

### Directional Closure

A directional closure, as shown on page 58, is a curb extension or vertical barrier extending to approximately the centreline of a roadway effectively obstructing one direction of traffic. When combined with other measures elsewhere in a neighbourhood, directional closures obstruct short-cutting or through traffic routes. Bicycles are typically permitted to travel through a directional closure in both directions. In some cases, gaps or a contra-flow bicycle lane are used to provide bicycle access.[194] Directional closures have been shown to substantially reduce vehicle volume to affected residential streets.[195]

### Diverter

A diverter, as shown on page 58, is a raised barrier placed diagonally across an intersection, blocking through traffic movements. A number of diverters are usually staggered to create circuitous routes through neighbourhoods to reduce traffic volumes.[196] Diverters can incorporate gaps for pedestrians, wheelchairs and bicycles and can be designed to permit passage by emergency vehicles. One study in Regina found a reduction from 3,050 vehicles per day to 500 vehicles per day on a street with two diverters spaced five blocks apart.[197] Also, in another study from Vancouver, a 20 to 70 percent reduction in area-wide traffic volumes was found, depending on the extent of the diverters used.

## Full Closure

A full closure is a barrier extending the entire width of a roadway that obstructs all motor vehicle traffic from continuing along the roadway. A closure can change a 4-way intersection to a 3-way intersection, or a 3-way intersection to a non-intersection. Gaps can be provided for cyclists and pedestrians and it can be designed to be mountable by emergency vehicles.

## Intersection Channelization

Intersection channelization is the use of raised islands located in an intersection to obstruct specific traffic movements and physically direct traffic through an intersection. Intersection channelization can improve pedestrian crossing safety by reducing crossing distances and providing refuge areas. As a result, it may reduce vehicle pedestrian conflict. Gaps in channelization islands may be used to accommodate bicycles.

## Raised Median through Intersection

A raised median through an intersection, is an elevated median located on the centreline of a two-way roadway through an intersection, which prevents left turns and through movements to and from the intersecting roadways. The purpose of a raised median through an intersection is to obstruct motor vehicle short-cutting and reduce the crossing distance for pedestrians. It can create a refuge for pedestrians and cyclists, enabling them to cross one direction of travel at a time, thereby reducing waiting times for gaps when crossing the roadway.

## Right-In/Right-Out Island

A right-in/right-out island, is a raised triangular island at an intersection approach which obstructs left turns and through movements to and from the intersection, street or driveway. Bicycles are typically permitted to make left turns and through movements from the side street, either through gaps or depressions in the right-in/right-out island, or by travelling around the island.


*Figure 4.15: Directional Closure, Source www.pedbikeimages.org, Photo – Dan Burden*


*Figure 4.16: Diverter, Source www.pedbikeimages.org, Photo – Adam Fukushima*

### POTENTIAL COUNTERMEASURES

- The following measures may be considered as volume control measures: direction closure; diverter, full closure, intersection channelization, raised median through an intersection, right-in/right-out island. More information on the aforementioned countermeasures please refer to the TAC *Canadian Guide to Neighbourhood Traffic Calming*.

# 4.5 Sidewalks and Sidewalk Design

As defined by the Geometric Design Guide for Canadian Roads, a sidewalk is “a travelled way intended for pedestrian use, following an alignment generally parallel to that of the adjacent roadway”. Sidewalks provide pedestrians with a means of travelling within the public right-of-way but separate from vehicles on the road. Research has shown that separating pedestrians from the roadway reduces pedestrian trauma from motor vehicles. Generally, the further that sidewalks are separated from the roadway the better the safety benefits for pedestrians. The US DoT, in their Toolbox of Countermeasures, for pedestrian crashes, has recognized the safety benefits of sidewalks and concluded they provide an 88 percent reduction in pedestrian collisions.[198] A US cross-sectional study of urban streets with and without sidewalks found that pedestrian collisions were more than two times as likely to occur at locations without sidewalks based on equal exposure.[199]

Sidewalks are typically made of concrete but increasingly are built using other materials including brick, stone and even rubber. Regardless of materials used, all sidewalks must be in good shape, adequately maintained and cleared and have a high enough friction coefficient to ensure that people do not easily slip on them. Most streets in urban areas have a sidewalk installed with the exception of controlled access facilities such as freeways, expressways, and some higher-speed arterials. Pedestrians are usually discouraged from being in areas with controlled access facilities because of the high speed of vehicles and safety risks. Sidewalks are desirable on both sides of the street especially in residential areas.

The width of a sidewalk depends on the volume and type of road users. Since pedestrians may desire opportunities to pass stopped or slower moving pedestrians and sometimes walk in pairs, it is desirable to have a clear sidewalk width of 1.8 m; however 1.5 m is the minimum design width. Each additional lane of pedestrian travel requires a minimum of approximately 0.7 m of clear sidewalk width.[200] This width is free from any obstructions such as lighting poles, fire hydrants, traffic signs, etc. In commercial areas where there is a higher volume of pedestrians, sidewalk widths are usually 2.4m.[201] At bus stops, there should be sufficient space to accommodate waiting passengers and also those pedestrians wanting to walk past. This is typically 3.0 m of width.[202] A special consideration should be given to areas where there are hospitals and assisted care homes, as persons who use wheelchairs need a wider sidewalk. Persons who use wheelchairs need about 1.2 m of clear sidewalk width for unimpeded travel; therefore, typically 2.0 m is used for the full sidewalk width.[203]

***Figure 4.17:*** *Separated Sidewalk, Photo – David Coburn, Neil Arason*

***Figure 4.18:*** *Separated Sidewalk, Photo – David Coburn, Neil Arason*

## Ramps and Curb Cuts

Curbs, raised medians and channelizing islands can cause difficulty to persons with disabilities when they are improperly designed and this is especially so for people who use wheelchairs. In order to provide accommodation for this, curb cuts and ramps are installed in a continuous fashion across medians, islands and opposite curb on either side of a crosswalk. However, sidewalk ramps and curb cuts make it difficult for visually impaired pedestrians to determine where the sidewalk ends and the road starts. Texturing the ramp addresses this issue and also provides a non-skid surface. It is important for the use of ramps, curb cuts, and texturing to be uniform locally for design consistency and pedestrian expectation.

***Figure 4.19:*** *Curb Cut, Photo – David Coburn, Neil Arason*

***Figure 4.20:*** *Tactile Markings, Photo – David Coburn, Neil Arason*

## Boulevards

Since a separation between the sidewalk and roadway traffic provides increased safety for pedestrians and children at play, an extra space is often provided between the sidewalk and the curb. This is referred to as the boulevard. Boulevards are usually 3.0 m wide for arterial streets and 2.0 m wide for collector or local streets. In areas where there is limited space available or where sidewalks need to be wider to accommodate a high volume of pedestrian traffic, boulevards may be decreased.[204] It is also used as an area to store snow ploughed or shovelled from the road and sidewalk, while serving as a barrier between pedestrian and vehicle traffic.

## Streetscaping

Streetscaping design is very focused on safety and primarily considers the pedestrian and cyclist, with secondary considerations given to the vehicular traffic.[205] There are several ways to provide adequate space for pedestrians and streetscaping elements which include:

- Widening the sidewalk by reducing or eliminating boulevard and border widths;
- Changing streets from two-way to one-way traffic operation to allow conversion of a traffic lane to pedestrian and/or bicycle use;
- Using the setback space (private property) between the right of way and the building face, if available, as additional pedestrian space;
- Narrowing traffic and/or parking lanes to dimensions at the lower end of the design domain;
- Reducing the number of traffic lanes or the width of those lanes;
- Closing a street to private vehicular traffic altogether, to create a transit or a pedestrian mall.[206]

In many streetscaping projects, it is typical to widen the existing roadside area to ensure proper pedestrian accommodation as well as provide space for the streetscaping elements and other street hardware. Vegetation is often planted adjacent to the curb as a buffer between pedestrian spaces and the vehicular traffic area, provided that it does not create a hazard to vehicular traffic.[207] Clear sidewalk widths in the range of 2.0 m to 3.5 m are typical of most urban commercial areas where streetscaping projects are implemented.[208] However, where a significant number of seniors or wheelchairs are expected, a greater clear width should be provided.[209]

***Figure 4.21:*** *Streetscaping, Photo – David Coburn, Neil Arason*

### Fencing

Fencing is used to provide an added protection between roadway vehicular traffic and pedestrians. It can be used as a barrier and to direct pedestrians along a safe route. Often fencing consists of bollards or posts linked together by chains or ropes. Some examples of fencing are shown below. It is important to note that some fencing and bollards that are used in pedestrian areas may be strong enough to provide physical protection from errant motor vehicles while others are not and provide only a barrier to prevent pedestrians from crossing where they should not, to prevent people from falling onto a roadway or simply as visual cues that provide guidance to road users.

***Figure 4.22:*** *Bollards, Photo – David Coburn, Neil Arason*

### POTENTIAL COUNTERMEASURES

- The following measures will improve pedestrian safety: boulevards, sidewalks, ramps, streetscaping and fencing. For more information on the aforementioned countermeasures, please refer to the TAC *Geometric Design Guide for Canadian Roads*.

# 4.6 Speed Reduction and Traffic Calming

Reduced speeds play a fundamental role with respect to making the system safer for pedestrians. Speed reduction is a unique road safety measure with dual positive benefits as it, a) reduces the likelihood of a crash in the first place; and b) it reduces the amount of human injury even when a crash occurs. And it accomplishes both of these things at an exponential rate for every kilometre per hour that speed is reduced. Road transport systems are complex systems that will always benefit from lowered speeds since we will simply never eliminate human error and crashes. It is simple physics: turn down overall speed in the system and the amount of human trauma will be lessened.

Pedestrians are disproportionately impacted by speed because they have no protection against the immense forces of a moving motor vehicle. Pedestrians are usually struck in urban areas and at speeds which are often above the limits of human tolerance.

In general, the relationship between speed and crash risk is very clear: the faster the speed the greater the probability of a crash due to a reduced field of vision, increased vehicle travel during reaction time and increased stopping distance during the time that the vehicle's brakes are being applied (see Section 3.3).

Even when speeding is not the decisive cause of a collision, the severity of injury is highly correlated with the vehicle speed at the moment of impact. The effects follow the rules of physics regarding the change in raw kinetic energy that is released in an instant. The energy released and absorbed in a collision is linked to the impact speed in a collision, and most of the kinetic energy is absorbed by the lighter crash "opponent" – often the vulnerable road user.[210]

## International Context

The OECD has stated that reduced speeding will immediately reduce the number of fatalities and injuries on the roads and is one guaranteed way to make real progress towards road safety targets.[210] With respect to pedestrian safety, the need for speed reduction is largely centred on urban environments where speed management is especially compatible with mobility and economic needs. Moreover, the effects of speed in reducing travel time are generally overestimated by drivers especially in urban areas: time savings are often small or negligible because of delays at intersections, at traffic lights, turning locations and in many other places. Reducing the average speed of the traffic flow does not necessarily reduce the throughput capacity of the road.[210] Reducing speeds is also compatible with improved quality of life goals: noise reduction, reduced fuel consumption and reduced pollutants including carbon monoxide, hydrocarbons, oxides of nitrogen and particulate matter – the lessening of discharges that improve air quality.

In many parts of the world, speed reduction strategies are in place to address issues related to fatality and injury rates for all pedestrians including child pedestrians. Many leading international jurisdictions have placed speed reduction as one of their major road safety policy priorities including, for example, the Netherlands and the UK. According to Sustainable Safety principles in the Netherlands, residential areas have a speed limit of 30 km/h because collisions at speeds lower than 30 km/h seldom result in fatal crashes. Slow traffic (pedestrians, cyclists, and light moped riders) and motor vehicles can mix safely at this speed limit. Since 1983 it has been legally possible to set up a 30 km/h zone in the Netherlands.[211] The UK also has a Traffic Calming Act and embraces the need for reduced speed for public health reasons. Also in that country there has been a major movement underway since 2007 called "20's Plenty for Us" which has been working to reduce urban speeds to 20 miles per hour or just 32 km/h.

## Speed Calming Measures

Speed calming measures reduce vehicular speeds, promote safe and pleasant conditions for pedestrians, bicyclists, and motorists, improve the environment and liveability of neighbourhood streets, and discourage use of residential streets by through vehicular traffic. The following describes the key speed calming measures recommended for implementation in Canada.

### *Rumble Strips*

Rumble strips are a series of raised strips across a road or along its edge, changing the noise a vehicle's tires make on the surface and so warning drivers through both sound and vibration of an intersection ahead, speed restrictions or of the edge of the road. Edge rumble strips help prevent single-vehicle run-off-road crashes. The noise and vibrations generated by horizontal rumble strips warn drivers on a high speed road that there is an intersection ahead. They are usually coloured white for visual identification.

### *Sidewalk Extension*

A sidewalk extension is a sidewalk continued across a local street intersection. A raised sidewalk extension is continued at its original elevation, with the local roadway raised to the level of the sidewalk at the intersection. An unraised sidewalk extension is lowered to the level of the roadway. With a sidewalk extension, the continuation of the surface improves visual identification of the crosswalk area and emphasizes pedestrian priority, the roadway approaches to and departures from the raised sidewalk extension are appropriately ramped in consideration of vehicle types and desired speeds.[212]

***Figure 4.23:*** *Sidewalk Bulge, Photo – David Coburn, Neil Arason*

***Raised Crosswalks and Speed bumps in Advance of Crosswalks***

Speed bumps or raised crosswalks are often only useful on low-speed local streets, parking lots, or driveways, and areas that are not used as emergency routes. Their use is limited to these areas because of the potential damage they can cause to vehicles. The tactile treatments are generally used more for traffic calming than as a crosswalk treatment alone.[213] A raised crosswalk or speed bump makes the crosswalk more noticeable in addition to slowing drivers down.

***Speed Hump***

A speed hump is a raised area of a roadway. It is used primarily to reduce vehicle speeds. With speed humps, the vertical deflection of vehicle wheels produces an uncomfortable sensation for vehicle occupants travelling at speeds higher than the design speed.

**Figure 4.24:** *Speed Hump, Photo – David Coburn, Neil Arason*

***Speed Table***

A speed table is a term used to describe a very long and broad speed hump, or a flat-topped speed hump. Sometimes a pedestrian crossing is provided in the flat portion of the speed table. The speed table can either be parabolic, making it more like a speed hump, or trapezoidal, which is used more frequently in Europe. Speed tables can be used in combination with curb extensions where parking exists.

***Raised Intersection***

A raised intersection is an intersection constructed at a higher elevation than the adjacent roadways. The purpose of a raised intersection is to reduce vehicle speeds, better define crosswalk areas, and reduce pedestrian-vehicle conflicts. With a raised intersection, the vertical deflection of vehicle wheels produces an uncomfortable sensation for vehicle occupants travelling at higher speeds and the raised roadway surface emphasizes pedestrian priority at intersections. The roadway approaches to the departures from the raised intersection are appropriately ramped in consideration of vehicle types and desired speed.[214]

***Textured Crosswalk***

A textured crosswalk incorporates a textured and/or patterned surface which contrasts with the adjacent roadway. Its purpose is to better define the crossing location for pedestrians and reduce pedestrian-vehicle conflicts. The enhanced visual and tactile identification of the crosswalk area emphasizes pedestrian priority. Also, rough or pronounced texturing may create additional noise from vehicle wheels, which functions in a similar way to rumble strips to slow traffic. Interlocking paving stones or coloured reinforced stamped concrete and asphalt are often used. A disadvantage is that they may create traction and/or stability problems for seniors, the disabled, wheelchairs, bicycles and motorcycles if there are rough or pronounced grooves parallel to the direction of travel.[215]

**Figure 4.25:** *Textured Crosswalk, Photo – David Coburn, Neil Arason*

### *Chicanes and Curb Extensions*

A chicane is a series of curb extensions on alternating sides of a roadway, which narrow the roadway and require drivers to steer from one side to the other to travel through the chicane. Typically, a series of at least three curb extensions is used. The purpose of a chicane is to discourage shortcutting or through traffic and reduce vehicle speeds.

***Figure 4.26:*** *Traffic Calming Chicane, Photo – David Coburn, Neil Arason*

A curb extension is a horizontal intrusion of the curb into the roadway resulting in a narrow section of roadway. The curb is extended on one or both sides of the roadway to reduce its width to as little as 6.0m for two-way traffic. The purpose of a curb extension is to reduce vehicle speeds, reduce crossing distance for pedestrians, increase pedestrian visibility, and prevent parking close to an intersection.[216]

### *Curb Radius Reduction*

A curb radius reduction is the reconstruction of an intersection corner with a smaller radius, usually in the 3.0 m to 5.0 m range. The purpose of a reduced curb radius is to slow right-turning vehicles, reduce crossing distance for pedestrians and improve pedestrian visibility.[217]

### *Mini Roundabouts*

Mini roundabouts are raised circular islands constructed in the centre of residential street intersections, which requires vehicles to travel through the intersection in a counter-clockwise direction around the island. Mini roundabouts reduce vehicle speeds and this, in turn, reduces road user injuries at intersections.

***Figure 4.27:*** *Mini Roundabout, Source www.pedbikeimages.org, Photo – Carl Sundstrom*

### *Chokers*

Chokers are curb extensions that narrow a street by widening the sidewalks or planting strips, creating a pinch point along the street. They slow vehicles at a mid-point along the street, create a clear transition between a commercial and a residential area, narrow overly wide intersections and midblock areas of streets, and add room along the sidewalk or planting strip for landscaping or street furniture.[218]

***Figure 4.28:*** *Choker, Photo – David Coburn, Neil Arason*

***Gateways***

A gateway is a physical or geometric landmark that creates an expectation for motorists to drive more slowly and watch for pedestrians when entering a commercial business, or residential district from a higher speed roadway. They are frequently used to identify neighbourhood and commercial areas within a larger urban setting. Gateways may be a combination of street narrowing, medians, signing, archways, roundabouts, or other identifiable feature. Gateways should send a clear message to motorists that they have reached a transition point and must reduce speeds. Gateways are only an introduction and slower speeds are not likely to be maintained unless the entire area has been redesigned or other traffic-calming features are used.[218]

***Landscaping***

The use of landscaping along a street can provide separation between motorists and pedestrians, reduce the visual width of the roadway (which can help to reduce vehicle speeds), and provide a more appealing street environment. This can include a variety of vegetation which can be planted in the buffer area between the sidewalk and the street or within the central island of a mini roundabout. Landscaping enhances the street environment and calms traffic by creating a visual narrowing of the roadway.[218]

***Paving Treatments***

Paving materials can act as a traffic-calming device (e.g., when the street is paved in brick or cobblestone). These send a visual cue about the function of a street, create an aesthetic enhancement of a street, and delineate separate space for pedestrians or bicyclists. However, some of these materials may be noisy and unfriendly to bicyclists, pedestrians, wheelchairs, or snowploughs blades. In particular, cobblestones should not be used in the expected pedestrian or bicycle path, although they may be used as aesthetic elements in a streetscape design.[219]

***Serpentine Design***

A serpentine design refers to the use of a winding street pattern with built-in visual enhancements which allows for through movement while forcing vehicles to slow. The opportunities for landscaping can be used to create a park-like atmosphere. Such designs are usually implemented with construction of a new neighbourhood street or during reconstruction of an existing street corridor. This type of design can be more expensive than other traffic-calming options and needs to be coordinated with driveway access.[218]

***Woonerf***

A Woonerf is a Dutch term for a common space created to be shared by pedestrians, bicyclists, and low-speed motor vehicles. It is typically a narrow street without curbs and sidewalks. Vehicles are slowed by placing parking areas and other obstacles in the street. Motorists become the intruders and must travel at speeds below 16 km/h. A Woonerf identification sign is placed at each street entrance. Consideration should be given to providing access by fire trucks and service vehicles, if needed. Woonerfs create a very low automobile volume, primarily on local access streets. They also create a public space for social and commercial activities.

***Roadway Narrowing***

Roadway narrowing can reduce vehicle speeds along a roadway section and enhance movement and safety for pedestrians. Bicycle travel will also be enhanced and bicyclist safety improved when bicycle lanes are added.[218]

***Reduced speed limits***

Research on speed limit reductions in countries such as South Africa, Belgium, Finland, France, Germany, New Zealand, United Kingdom and the United States, have demonstrated that when a speed limit was reduced, travel speeds and road crashes decreased from between 8 to 40 percent.[220] A recent 20 year time-series showed that in London, 20 mph zones (32 km/h) are effective measures for reducing road injuries and deaths and their introduction was associated with a 41.9 percent reduction in road casualties.[221] The current speed limit of 50 km/h on most residential streets is not congruent with research findings and best practices related to speed management and risk reduction, particularly in relation to children. Please refer to the TAC Guidelines for *Establishing Posted Speed Limits (2009)* report and that TAC *School and Playground Areas and Zones: Guidelines for Application and Implementation (2006)*.

### POTENTIAL COUNTERMEASURES

- Establish community safety zones and reduced speed limits. Create 30 km/h, or 40 km/h, speed zones in areas where there exists a pedestrian/vehicle mix. Reduce the speed limit on residential streets to 30 km/h or 40 km/h. This can also be accomplished, in part, by providing local governments with the legal authority to reduce urban speed limits to less than 50 km/h in blanket geographic zones.
- Establish a three-tiered default speed limit: 30 km/h in areas where there are no pavement markings; 50 km/h in other urban areas and 80 km/h in rural areas.
- Introduce traffic calming and other engineering measures that generally slow traffic
- Extend school speed zones to all schools from Kindergarten to Grade 12.
- The following measures are known to reduce speed of motor vehicles and increase pedestrian safety in general: rumble strips; sidewalk extension; raised crosswalk and speed bump; speed hump; speed table, raised intersection, textured crosswalk, chicanes and curb extensions; curb radius reduction, mini roundabouts, chokers, gateways; landscaping, paving treatments; serpentine design; woonerf; roadway narrowing; reduced speed limits. More information is available from the TAC *Canadian Guide to Neighbourhood Traffic Calming*.

# 4.7 Rail-grade Crossings

While pedestrian collisions with trains at railway crossings are rare, they are often fatal. Between 1995 and 2002 there were 181 such collisions in Canada.

The main objective in promoting pedestrian safety at crossings is to modify pedestrian behaviour as well as to reduce the potential for pedestrian error.

Pedestrians are often unaware of the restrictive nature of a railroad right-of-way. Since railroads may present barriers to the shortest path to a destination (e.g., school, store, train platform) pedestrians are motivated to cross tracks where and when they should not. It is not unusual to find pedestrians not expecting or not paying attention to trains when crossing railroad tracks. Those who are listening to headsets at crossings may sometimes miss detecting the sounds coming from trains.

### Human Perceptual Limitations in Relation to Approaching Trains

A common human error is misjudgement of the speed and/or distance of trains.[222] One type of collision between trains and pedestrians or drivers involves trying to "beat the train" across the tracks. Velocity estimation of an approaching train is influenced by a number of factors - visual cues available (e.g., the presence of visual information in the background), darkness, whether the train is coming straight on or crossing in front and actual train speed. The perception of trains presents some unique problems. One is the "large object illusion" - the perception that large objects are moving more slowly than small ones travelling at the same speed.[222] In addition, there is virtually no lateral motion (an important cue to speed) in the perception of an approaching train when a pedestrian is close to the tracks. Pedestrians often fail to take speed of trains into account, relying primarily on an estimate of their distance. Older pedestrians (aged 65+) show less sensitivity to changes in velocity than do younger ones.

The reason humans have difficulty judging the approach speed of a train when it is seen nearly head on is because the rate of change of the size of the image on the eye is very gradual until the train is close.[223] When an approaching train gets quite close the visual image size increases rapidly and we suddenly realize just how close it is and how fast it is travelling. By then it is often too late to avoid a collision.

These visual phenomena (large object illusion and perception of movement in depth) combine to produce errors in judgement of the speed and distance of approaching trains, and may well explain why so many people think they can beat the train across the track.

### Warning Devices

While the most commonly used warning devices at railroad crossings are warning signs, it has been found that road users often miss or ignore these warnings. Because the appearance of a train when crossing tracks is a rare event in their experience, people tend to perceive the danger to be minimal. In addition, some road users assume that all crossings have active warnings (lights, bells, etc.), which is not the case, so may believe that no train is coming unless an active device is warning them. Richards and Heatherington[224] reported that about 20 percent of drivers think all crossings are active, so they interpret the absence of a signal as indicating no train. The same may apply to pedestrians.

Road users may become impatient while waiting for a train to reach the crossing and cross the tracks when it is unsafe to do so, in spite of warnings. They generally expect a train to arrive within 20 seconds of the activation of a signal, and they begin to lose confidence in the warning if warning times exceed 40 seconds for flashing lights and 60 seconds for gates.[225]

An additional human factor contributing to some pedestrian collisions at crossings is the sudden appearance of a second train, where there are two or more tracks, just after the first train has passed. This is a rare and unexpected event, so pedestrians will often begin crossing as soon as the first train has cleared. Unexpected events on the road require a longer than usual response time to detect and react to a hazard.[226] Railway tracks present a particularly hazardous situation for in-line skaters and skate boarders due to the risk of catching a wheel in the space between the rails or tripping on an uneven surface.[227]

It can be seen from this brief review of relevant human factors that pedestrian behaviour and limitations can play a significant role in pedestrian collisions at railroad grade crossings.

## POTENTIAL COUNTERMEASURES

- Provide adequate warning of approaching trains. Pedestrian-focused solutions include:
  - Signs prompting pedestrians to take a particular action (look both ways for trains or do not cross here) may increase safe behaviour.
  - Pavement markings that delineate the pathway up to and across the crossing and to indicate the desirable location to stop while waiting for approaching train/s.
  - Barrier treatments such as fencing and "Z"/maze barriers which encourage pedestrians to look both ways.
  - Surface treatments such as visually contrasting materials, raised truncated domes, directional surfaces, and flangeway gap treatments to provide a smooth and continuous crossing surface across the tracks.
  - Install active systems that activate auditory/visual signals when a train is approaching or crossing. Systems which also activate pedestrian gates should be considered at locations and at crossings with more than one track.
- Reduce risky pedestrian behaviour at crossings through enforcement of trespassing laws and warning signal/sign violations.
- Educate pedestrians concerning the dangers of crossing railway tracks without paying attention to train traffic.
- Young people in particular need to be made aware of the need to pay attention at crossings when they are using entertainment and communication devices.

# 4.8
# Work Zones

Work zone traffic control has historically been centered on providing a safe vehicular path. However, the right of pedestrians to access properties abutting work areas is of no less importance than the right of safe passage accorded to motorists. Work zones safety issues relate to both the pedestrian who needs a safe path past a work area and the pedestrian worker within a work zone. Many of those working in work zones are pedestrians. They are exposed to danger from passing motorists as well as from construction vehicles during much of their time on the job. However, the scope of this report does not extend to workplace safety because these special pedestrians are governed by workplace laws and regulations and it is not the intention of the current report to comment on those rules and policies. For this reason they are required by law to wear bright clothing in order to be easily seen by drivers. The requirements for workplace clothing are a provincial responsibility, including the adoption of visibility standards.

The “visual noise” associated with work zones can confuse and distract pedestrians. In addition, since work zone activity can also be a distraction to drivers, they may be less likely to notice a pedestrian walking along or crossing the road. The pedestrian’s path is a critical issue to be considered in planning, design and installation of traffic control for work areas. This is especially the case in areas of high pedestrian flow.

## Review of Available Resources

Pedestrians need the appropriate information in order to recognize work areas and potential hazards in order to walk safely through and around work zones. Guiding pedestrians in work zones can present challenges, as these areas may have unexpected or unusual traffic configurations and detours. Signs are typically used for this purpose. When directing pedestrians Ullman and Ullman[228] report that the action phrase “Use other side” was better understood than “Cross here”. They recommend that distance information be included in advance of closures to pedestrian traffic.

A challenge for pedestrians with visual impairments is walking through and near work zones. Ullman and Trout[229] studied how best to communicate to these pedestrians in work zones through the use of auditory messages. Based on a laboratory study and field tests of auditory messages in a mock work zone the authors made a number of recommendations including that an alternate route leading to the sidewalk on the opposite side of the street be clearly indicated, with turning and crossing instructions and the distance needed to continue on that path.

In many instances, the use of work area delineation is adequate to alert pedestrians to potential danger. In more cognitively demanding circumstances, e.g., in which pedestrians are required to use bypasses and detours, there is a need to provide traffic control devices that are responsive to specific information needs.

Pedestrians need to know well in advance of encountering the work site that the normal path may be disrupted and that additional caution is required. Chadda and McGee[230] described advance information as information placed at appropriate distances from the work zone which allows pedestrians to make timely decisions regarding alternative paths. They further pointed out that situations requiring pedestrian pathway blockage or detours are ideal locations for advance information strategically placed at decision points.[230] Transition information should be provided to guide pedestrians to a safe path through and around work zones.

*Figure 4.29: Construction areas, Source www.pedbikeimages.org, Photo – Dan Burden*

This type of information is particularly important when work activity restricts the width of pathways or requires a pedestrian bypass or detour. The following guidelines are recommended for transition areas:

Suggested guidelines for work zones are the following:[230]

- Transition to redefined or relocated pathways should be clearly delineated by markings, tapes, tubes, cones, signs, wooden railing, barricades, portable concrete barriers, or other devices to provide positive guidance.
- Physical barriers may be necessary to restrain pedestrians from using unsafe pathways and wandering into construction areas.
- If the pathway is used at night, illumination or delineation with steady burn lights should be used.
- All temporary crosswalks should be clearly delineated by signs and markings.

Other strategies for safe pedestrian movement include:

- Pedestrians should not be led into conflicts with work site vehicles, equipment, and operations.
- A pedestrian route should not be severed and/or moved for non-construction activities such as parking for vehicles and equipment
- When pedestrian and vehicle paths are rerouted to a closer proximity to each other, consideration should be given to separating them by a temporary traffic barrier.

## POTENTIAL COUNTERMEASURES

- The guidelines for work zone safety of pedestrians, as outlined by Chadda and McGee[230] in their report entitled "Pedestrian Safety Through Workzones: Guidelines" should be adopted as the "gold standard" when designing transition areas around work zones.

# 5.0

# Vehicles

## Improving the Safety of Motor Vehicles for Pedestrian Protection

# 5.1 Background/Context

The role of the vehicle in a safe system approach cannot be overlooked. Motor vehicle standards and vehicle design improve crash avoidance and can provide protection to all road users in the event of crash. In Canada and the United States, resulted in vehicles becoming safer in terms of features like air bags, seat belts, seat belt reminder sounds and indicators, crumple zones and many other changes have helped to create better trauma outcomes for vehicle occupants. High income countries around the world have experienced similar trends of decreasing motor vehicle fatalities over the last few decades.[231] Much of this progress is the result of improved motor vehicle design.[232 233] A NHTSA study estimated the number of lives saved in the United States from 1960 to 2002 due to vehicle safety standards was approximately 328,551.[234]

Less progress, however, has been aimed at reducing injuries and deaths to pedestrians from motor vehicles that strike them. Unlike other countries such as those in the European Union and Japan, Canada and the U.S. do not currently have a regulation for vehicle design that specifically promotes the protection of pedestrians. The same can be found in Australia. A study by the University of Adelaide concluded that an Australian Design Rule conforming to the proposed United Nations Global Technical Regulation No. 9, with the addition of Brake Assist, would reduce, in Australia, pedestrian fatalities by approximately 28, serious injuries by approximately 947 and slight injuries by approximately 1,247 each year, with associated savings in crash costs of approximately $385 million per year.[235]

This section will examine the role of the vehicle in reducing human trauma from crashes involving vehicles that hit pedestrians.

Compared to vehicle occupants, much less attention is focused on reducing pedestrian deaths and injuries through vehicle design.[236] Since the majority of pedestrian vehicle collisions involve the pedestrian being struck by the front of a car, the vehicle's frontal design has the most potential to influence the type and severity of pedestrian injuries.[236]

Vehicles that offer increased pedestrian protection in the event of a collision are a key issue in Europe and Japan.[237] Scientific studies demonstrate that vehicle design has a strong effect on pedestrian injury; more specifically they indicate that the heavier the vehicle, the stiffer the bumper and the less deflection offered by the hood, the more likely severe injury or death will result.[238 239]

Canada regulates new and imported vehicles less than 15 years old, through the Motor Vehicle Safety Act (Canada) and has been regulating new and imported vehicles since 1971. This means any improved vehicle standards introduced, in Canada, will have no effect on existing vehicles but will result in changes to approximately 1.5 million motor vehicles sold in Canada each year. Furthermore, motor vehicles 15 years and older that enter Canada as imports, including right hand drive vehicles, are exempt from Canadian standards, and those that are less than 15 years old only need to meet the federal regulations as of the date of manufacture. Nonetheless, there are over 40 different safety standards that must be met by a typical new passenger vehicle that involve performance-based standards which are verified via component and vehicle testing.

Canada's current position and policy on regulation of motor vehicles is that it is committed to the harmonization of North American and global vehicle safety regulations. As a result, Canada strives to harmonize motor vehicle safety standards with the U.S. except in cases where there is a demonstrated net benefit to Canadians in pursuing a non-harmonized approach. Canada has also signed a United Nations Economic Commission for Europe (UNECE) treaty entitled "the 1998 Agreement", committing to work together with other regulatory bodies to develop global vehicle safety regulations. Work under this agreement has led to multiple globally harmonized standards including a standard for pedestrian safety. Under the United States (US)-Canada Regulatory Cooperation Council (RCC), the two governments are working to harmonize safety standards, including those that would affect pedestrian safety, wherever possible and appropriate to reduce the burden and cost on manufacturers.

Nonetheless, Canada is an independent country and can regulate consumer products to the extent that it deems necessary, and as permissible under the requirements of the Cabinet Directive on regulatory Management, including the need to achieve a positive cost:benefit test (regulation.gc.ca). In 2011, as part of the upgrade of the Motor Vehicle Test Centre in Blainville Quebec, the federal government constructed a pedestrian safety laboratory to improve research capacity in this area. It is in the process of being instrumented to test protection of head forms and leg forms.

# 5.2 Potential for Improving Pedestrian Protection on Canadian Vehicles

### Active Pedestrian Safety

The best solutions relate to preventing collisions in the first place and there is no greater need than to prevent collisions with unprotected pedestrians and cyclists. Active detection systems may eventually make the most significant contribution in lowering overall levels of human trauma from road crashes.

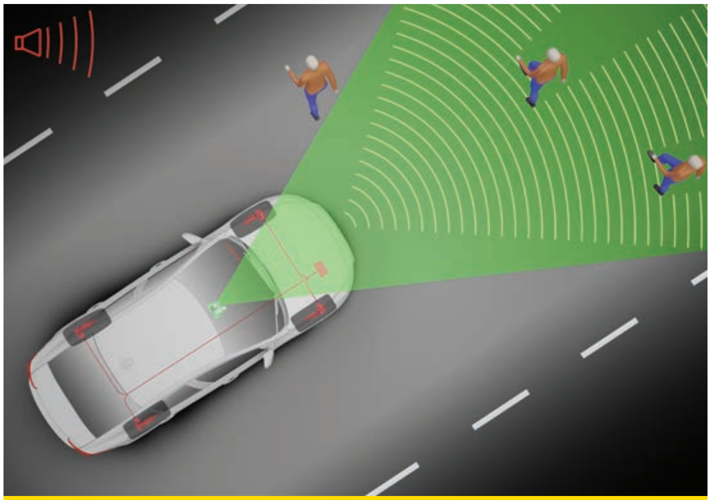
Back-over incidents involving pedestrians occur too frequently in Canada and most could be avoided through improved vehicle design. A 2009 Canadian study found that of 4,295 child pedestrian injury collisions in the 12-year period from 1993 to 2004, 148 were injured in a back-over collision with 49 of these collisions involving a vehicle backing out of a driveway.[240] The US intends to improve rear view requirements under its vehicle safety standards as a result of the *Cameron Gulbransen Kids Transportation Safety Act of 2007*.[241] NHTSA introduced a proposed rule-making on this issue and is assessing the comments it has received. Canada could provide the same new protections to children by replicating this requirement should it proceed to a final rule in the U.S., and should one of the current criteria for change; the cost:benefit assessment, prove to be positive. These costs and benefits are being assessed in the Canadian context.

Another vehicle safety feature not regulated in Canada is the Brake Assist System (BAS); this is a system that monitors the driver's use of the brake pedal and based on the speed and/or force with which the driver applies the brake pedal, uses this information to assess the urgency of the action. If the brake application supports a panic situation, the BAS kicks in and generates a high braking power, applying emergency braking and resulting in decreased stopping distances. A report by DaimlerChrysler states that test track results showed BAS contributes to a significant reduction in stopping distance by up to 45 percent on a dry road surface.[242] BAS is also subject to new European Union regulations with a particular focus on its benefits to pedestrians and other vulnerable road users.[243] A study commissioned by the European Commission shows that BAS combined with changes to passive safety requirements would significantly increase the level of pedestrian protection. Mandating the installation of BAS in new motor vehicles is therefore appropriate. However, this should not replace, but rather complement, high-level passive safety systems.

Other potential areas for safety improvements include Intelligent Speed Adaptation (ISA) which is the most promising type of Advanced Driver Assistance System, and from a technical point of view, large scale deployment is possible in the short term.[244] These systems can alert drivers to the difference in their speed and the speed limit of the road they are on. Alternatively, these systems can also be programmed to physically prevent the vehicle from travelling faster than the speed limit of the road being travelled on. Even relatively simple features, already in mass production in some cars, like adaptive headlights that orient light in the direction the vehicle is turning rather than simply straight ahead, has good benefits for a number of road safety situations including better illumination of pedestrians during turns. The existence of such technologies today indicates that they are technically and economically feasible. A fuller assessment is needed to assess whether they can be regulated and if so, in what timeframe.

#### *Pedestrian Detection Systems*

Pedestrian detection systems can, for example, use a combined camera and radar sensor to monitor any obstacle in front of the vehicle. The radar measures how far away it is, while images from the camera are analyzed by image-recognition software to determine what the object actually is. If the analysis determines the object to be a pedestrian, the vehicle's brakes are automatically applied on the vehicle. The 2011 Volvo S60, which entered the market in September 2010, was the first vehicle to come equipped with such a system.[245]



Pedestrian Detection with full auto brake consists of a radar unit integrated into the car's grille, a camera fitted in front of the interior rear-view mirror and a central control unit. The radar's task is to detect objects in front of the car and to determine the distance to them. The camera determines what type of object it is. In an emergency situation, the driver receives an audible warning combined with a flashing light in the windscreen's head-up display. At the same time, the car's brakes are pre-charged. If the driver does not react to the warning and an accident is imminent, full braking is automatically applied.

***Figure 5.1:*** *Active Pedestrian Safety, Image – Volvo Car Company*

### *Auditory Detection of Vehicles*

Visually impaired pedestrians face a potential problem in detecting the electric vehicle (EV) and hybrid-electric vehicle (HEV), which are somewhat quieter than those with an internal combustion engine (ICE). Garay-Vega et al.[246] examined this issue by measuring the sound levels produced by HEVs and ICE vehicles. Sound levels from some hybrids were too low to be recorded. The HEVs were quieter than the ICEs at 9.6 km/h and 16 km/h and when backing, but not at speeds of 32 km/h and above. For vehicles slowing and accelerating from a stop the differences were small. Additional tests included having blind pedestrians detect these vehicles based on audio recordings of them approaching, backing and moving parallel to the pedestrian. Detection level was generally good, ranging from 83.3 percent for vehicles slowing from 32 to 16 km/h to 95.8 percent for vehicles approaching at 9.6 km/h. However, ten percent never detected one or more of the HEVs backing and one-sixth never detected slowing vehicles. Since this study was conducted in a quiet area, one might expect poorer performance in the average road environment. This study indicates that noise threshold standards may need to be developed for these vehicles when travelling at lower speeds in order to increase detectability. The U.S. and Canadian Governments have jointly studied means of increasing minimum noise levels for EV and HEV. In January 2013, the U.S. Government published a Notice of Proposed Rulemaking and invited comments.

## Passive Pedestrian Safety

There is now overwhelming evidence that pedestrian survival rates and injury levels can be markedly impacted by vehicle design particularly at lower urban speeds. Research suggests that two-thirds of all fatally-injured pedestrians are hit by the front of a car. There are usually two phases in car-to-pedes¬trian collisions. The first and most severe phase consists of multiple impacts with different parts of the car front. The second phase is contact with the road surface, where injuries are usually less severe.[247] The most frequent causes of serious and fatal pedestrian injuries in collisions with cars stem from impacts between the head of the pedestrian and the whole area of the car hood and windshield/frame; the pelvis or the abdomen of adults and the hood edge; the abdomen or chest of children or the head of small children and the hood edge and the legs and the car bumper.[248 249]

In general, lower-limb trauma is the most com¬mon form of pedestrian injury, while head injury is responsible for most pedestrian fatalities.[250 251]

Consequences for the human body when struck by a motor vehicle have been examined and described as far back as the 1960s. Today, more than sufficient amounts of data exist and the properties of the front of a car that would mitigate injuries when it strikes a pedestrian are well understood.[252] In addition a better frontal shape, new technologies coupled with a greater understanding of pedestrian injury produced by crashes have produced even more solutions including a minimum 10 cm clearance between the engine block and the hood; pyrotechnic devices or hoods that pop up when the vehicle strikes a pedestrian, improved bumper height and geometry and energy absorbing bodywork designed to lessen decelerations.[253 254]

Regulations adopted in the EU and Japan in 2005 contain a number of dynamic tests that must be performed and passed and that help to determine the degree to which kinetic forces are reduced on the pedestrian upon impact at certain contact points in order to reduce, for the most part, head (child and adult) and leg injuries. All pedestrian safety standards are aimed at pedestrians struck on the side of their bodies and by a vehicle at speeds up to 40 km/h, since this was judged to be the upper limit at which pedestrian protection could reasonably be provided.

The vehicle manufacturer is left to make decisions on exactly how they will achieve the stated testing values set out in regulation. One of the most significant tests is called the Head Performance Criteria (HPC) and it is used in most pedestrian regulations, including those in UN GTR No. 9. It remains important to note that passive pedestrian safety does have limitations: the human body will still come off of the vehicle and land on the road, or onto another vehicle, and the effects of this secondary impact may not be possible to mitigate. In any single and specific crash, there are many variables that are uncontrolled, unknown or have random effects. Nonetheless, the evidence is clear that the first impact with the vehicle is often the most significant one and there is scope to mitigate the severity of injuries to pedestrians at speeds below approximately 40 km/h by improving the frontal structures of light duty motor vehicles.[255]

### *Pedestrian Air Bags*

Beginning with the 2013 Volvo V40, these cars will have external pedestrian air bags – these are yet another effective measure that involves frontal air bags including air pockets that protect the head from the A-pillars and other unforgiving surfaces. Since they are now going into mass production, it is important to consider when these could be regulated and required in all vehicles. The passive protection afforded to the human body and head will be unprecedented. Once government regulators have enough data to assess the performance and cost:benefit of this technology, a decision can be taken on whether they could be mandated for the entire light duty vehicle fleet.

*Figure 5.2: Test vehicle with pedestrian air bag and advanced vehicle design (Photo copyright and re-printed with the express permission of Fiat Research Center: an APROSYS research project sponsored by the European Commission: www.aprosys.com)*

## Vehicle Regulation in the European Union and Japan

The European Parliament adopted binding regulations known as directives involving a series of dynamic tests related to pedestrian vehicle safety. The first directive took effect in 2005 and the third and current one, Regulation (EC) No. 78/2009 of the European Parliament and of the Council contains a number of phases. It has been called Phase Two as it includes modified test parameters and a new time schedule. The different phases of the regulation will come into effect in a total of eight stages, depending on vehicle categories and masses. The scope of this regulation will gradually increase to the year 2019. Whereas these regulations become effective in the future, the Phase One has been in effect since 2005, covered by the EC directives 2003/102 and 2004/90. Pedestrian protection has also received additional attention within the new Euro NCAP rating scheme. The new overall rating, which includes pedestrian protection, forces automobile manufacturers to improve pedestrian protection, in order to receive four or five star ratings in the future. [256] Japan has had similar pedestrian regulations also in effect since 2005.

## United Nations (UN) Global Technical Regulation (GTR) on Pedestrian Safety

In 2009, work on the UN GTR No. 9 was completed by the United Nations Economic Commission for Europe (UNECE) which has members from 56 countries located in the EU, non-EU Western and Eastern Europe, South-east Europe and Commonwealth of Independent States (CIS) and North America. The global technical regulation is available on the world-wide web.[257]

The stimulus for these changes comes from a review of international injury outcomes: data from Australia, Japan, the United States of America, Germany, Italy, Spain, Canada, the Netherlands, Sweden, and Korea indicate that, annually: in the European Union about 8,000 pedestrians and cyclists are killed and about 300,000 injured; in North America approximately 5,000 pedestrians are killed and 85,000 injured; in Japan approximately 3,300 pedestrians and cyclists are killed and 27,000 seriously injured; and in Korea around 3,600 pedestrians are killed and 90,000 injured.[258]

The global technical regulation was developed primarily on the basis of data showing that a crash speed of up to 40 km/h would account for more than 75 percent of total pedestrian injuries.[258] Thus, if a speed on impact of up to 40 km/h is considered, it will significantly reduce the levels of injury sustained by pedestrians involved in frontal impacts with motor vehicles.[258]

The maximum benefit of a pedestrian vehicle regulation would be generated if all types of vehicles were covered, however it was recognized that such a regulation would likely not be possible to apply to heavy vehicles and therefore the regulation focused on passenger vehicles, light commercial vehicles and other light trucks. At the same time, these types of vehicle categories represent the vast majority of vehicles. Canadian data suggest that a very high percentage of pedestrian fatalities involve light duty vehicles.

### UN GTR No. 9 on Pedestrian Safety

The frequency of fatal and serious injuries (Abbreviated Injury Scale, AIS 2-6), with respect to body regions, has been found to be highest for the child and adult heads and the adult leg.[258] On the vehicles themselves it has been seen that the hood top, the windshield and the A-pillars (the two support posts that run in a vertical/sloping direction at the ends of the windshield) are the vehicle regions mostly identified with a high potential for pedestrian contact. The shape of the vehicle is also considered to be important as it can have an influence on the injury levels.[258] The UN GTR No. 9 therefore focuses the testing procedures on these body regions and vehicle contact areas and relies on separate testing, i.e., separate head and leg impactors are used. The specifications of the impactors and the application of the tests are detailed in this global technical regulation.

The GTR No. 9 consists of two sets of performance criteria applying to: (a) the hood top and (b) the front bumper. Test procedures have been developed for each region using sub-system impacts for adult and child head protection and adult leg protection. A second phase to the UN GTR No. 9 is currently underway. This work is aimed at improving the lower leg test to increase the injury assessment ability. A new lower leg impactor is being developed that will have better biofidelity. Japan is leading the research work with support from Canada.

It should also be noted that improving vehicle design and standards together with a road design strategy represents significant potential for reducing pedestrian road crash trauma. Because vehicle standards for pedestrian impact can only produce safety benefits for pedestrians when vehicles are travelling in the range of 40 km/h or less, speed reduction and traffic calming measures combined with better designed car front represents great potential for pedestrian injury and fatality reductions.

## 5.3 After-Market Vehicle Modifications

### Raised and Altered Vehicles

What happens to pedestrians when they are struck by vehicles with raised frames or those altered in other ways? It is well known that even the difference between a pedestrian being struck by a passenger car and a light truck is significant[259] (trucks are generally higher and heavier). The impact on the pedestrian of being struck by a vehicle that has been raised, through an after-market modification, will almost always be worse as a result of that vehicle modification, often catastrophically.

Once a vehicle is lifted or lowered outside of the Original Equipment Manufacturers (OEM) operating tolerances, the vehicle may not comply with test requirements of the Canadian Motor Vehicle Safety Standards. If the vehicle is registered in a jurisdiction and then modified, it is the responsibility of the licensing authority. In the case of vehicle importation, such changes would prevent the vehicle from being legally imported into Canada, under Transport Canada regulations. When a vehicle is raised braking performance and stopping distances can be significantly affected. Most significantly the section of the vehicle that comes in contact with the pedestrian is rigid in comparison to the hood, which may result in more severe injury to the struck pedestrian. In addition, the higher the vehicle the more likely that that the pedestrian is knocked over and subsequently run over rather than being "scooped up" and landing on a more forgiving vehicle hood.

## Bull Bars

Bull bars are predominantly rigid metal bars fixed to the front of a car, truck or sports utility vehicle (SUV), originally designed to prevent damage on contact with animals in rural areas. There has also been much debate about their use in densely populated urban areas with vulnerable road users.[260]

Bull bars have been subject to extensive debate in the last decade regarding their safety with respect to pedestrians and other vulnerable road users and their suitability in mixed traffic use areas in urban settings. Bull bars without deformable padding are very stiff and have the effect of concentrating crash forces in a smaller area with a greater likelihood of injuring pedestrians and cyclists in a collision than if the vehicle were not fitted with a bull bar.[261 262 263]

As early as 1970s it was recognized that bull bars altered the profile of a vehicle front end making it potentially more aggressive in pedestrian collisions.[264] A numbers of crash simulation studies have been conducted using pedestrian dummies and vehicles equipped with and without bull bars in order to investigate the altered injury mechanisms and kinematics involved. These simulation studies repeatedly show greater injury severity to head, pelvis, abdomen, femur as well as greater injury to head, neck and thorax injuries in children. Injury risk for bull bars increases more rapidly with speed than the injury risk for the vehicle without bull bars. There is additional danger of being run over by the vehicle after initial impact.

The impact surface of a bull bar is rigid and much stiffer than a vehicle body, deforming less on impact and consequently absorbing less energy. This obviously increases the impact force on the pedestrians with more serious consequences for injury severity. Suggestions have been offered for re-designing the bull bars with softer materials like plastics to make them more pedestrian friendly. According to limited available literature bull bars present an additional risk to pedestrians and other vulnerable road users, and possibly to occupants in other vehicles as well.

Higgins proposed that in addition to the intended function of bull bars, image and fashion are also powerful motivators for using them.[265] This latter point is consistent with a much earlier report by Page et al. on a survey of large number of drivers. The three major reasons given for fitting bull bars to sedans were to protect against parking collisions, to make the vehicle more visually attractive and to allow more aggressive driving in peak hours.[266]

Research has shown that pedestrians are typically thrown violently when struck by a vehicle with a bull bar. Due to this effect even a low speed collision is more likely to be fatal if a bull bar is attached to the vehicle. In Australia, the Madymo simulation proved that the bars changed the direction of the fall of pedestrians who were hit and consequently increased the danger of fatal head injuries.

In an early report, Chiam and Tomas examined the effect of bull bars on the vehicle pedestrian collision dynamics.[267] The experiments reproduced collisions between an adult male dummy and cars with and without bull bars and at impact speeds of 20 km/h. The results show that impacts with bull bars result in a higher incidence of knee or ankle fractures and higher severity head injury than impacts with the front of the vehicle. It was concluded that this is due to higher and more concentrated impact points in the case of bull bars.[268]

The Transport Research Laboratory (TRL) in Britain examined 1994 crashes and found that there were 2 to 3 additional fatalities and about 40 additional serious injury casualties as a result of vehicles being fitted with bull bars.[269] In Australia, bull-bars were involved in up to 12 percent of fatal pedestrian crashes.[270] Zellmer and Otte reported on crash tests conducted in Germany at the Federal Highway Research Institute (BASt). They concluded that bull bars strongly increase the risk of injury in vehicle crash with pedestrians or bicyclists.[271] They stated that injury risk for a child in an impact with a bull bar at 20 km/h is similar to an impact with an off road vehicle at 30 km/h and a regular car at 40 km/h. They also conclude that hip and lower limb fracture risk for an adult impacting a bull bar at 25 km/h is similar to impacting a car hood at 40 km/h.[272]

Recent tests by the University of Adelaide found that, in a test simulating a pedestrian's head striking the front of SUV with a steel bull bar produced head decelerations typically 249 percent greater than the vehicle with no bull bars, and leads to a much higher fatality risk. The aluminum bull bar was not much better than the steel one.[273]

Mizuno et al. conducted a child pedestrian headform impact tests and found that the head injury criteria is higher when struck by a SUV with steel bull bars and leads to higher injury risk.[274] The study further found that the geometrical incompatibility (e.g., the steel bull bars, the higher hood height) of SUVs is the major cause of a higher mortality rate.

Other related studies have shown that steel or aluminum bull bars can produce extremely high impact loads.[275 276 277 278] These studies also indicated that bull bars might have other effects in pedestrian crashes and they alter the front geometry of the vehicle and therefore alter the kinematics of the struck pedestrian, either onto the upper surface of the vehicle, or onto the road. The computer simulation results show that the addition of a bull bar to the front of a vehicle increases the speed of the head impact with the hood.[279]

***Figure 5.3:*** *Vehicle with Bull Bars, Photo – David Coburn, Neil Arason*

***Figure 5.4:*** *Vehicle with Bull Bars, Photo – David Coburn, Neil Arason*

In conclusion, there is evidence that bull-bars multiply the injury potential to struck pedestrians and other road users, while providing questionable benefit to those whose vehicles are fitted with them, especially in an urban environment.

## Harmonization and the Regulatory Cooperation Council

At this time, the motor vehicle industry in Canada is closely linked to that of other countries, chiefly the United States. As a result of economic and manufacturing related challenges, Canada takes the position that there continues to be significant benefit to harmonize motor vehicle standards and regulations between the two countries. Under current rules, vehicles built to the specifications of one country are generally importable into the other. There is also a free flow of vehicles across the border for tourism and commercial purposes.

The US-Canadian Regulatory Cooperation Council was announced in February 2011. The goal is to harmonize regulations between the two countries where appropriate. Under the RCC, while each country will maintain its own sovereign regulatory system to protect consumers' health, safety and security as well as the environment, to the extent possible, new regulatory systems will be designed to be aligned between the two countries. Ultimately, the goal is to increase the regulatory harmonization between Canada and the United States to improve safety, reduce the financial and resource burden on businesses, and thereby to consumers.

These principles will require federal departments to fully consult with other governments, businesses and all Canadians in the development of regulation.

In practical terms, the Government of Canada has taken the position that Canadian Motor Vehicle Regulations will, where possible, be in harmony with those of the US. It is therefore incumbent on both countries to work together to develop safety standards and regulation to improve the efficiency and/or safety of motor vehicles. That cooperation has already begun on new safety standards, as evidenced by the proposed regulation for minimum noise levels for naturally quiet vehicles.

## POTENTIAL COUNTERMEASURES

- Consider development of regulations related to passive pedestrian protection including the introduction of requirements based on the United Nations Global Technical Regulation No. 9 (GTR No. 9), in the context of the U.S.-Canada Regulatory Cooperation Council.
- Consider a regulation requiring new vehicles sold in Canada to have advanced braking systems including the Brake Assist System and other available systems that assist the driver in the event of a panic or emergency braking situation.
- Consider a regulation to require new vehicles sold in Canada to have adaptive headlights that orient light in the direction the vehicle is turning rather than simply straight ahead.
- Consider a regulation to require new vehicles sold in Canada to have advanced speed assistance technologies to help drivers manage their speed, warn them if they are exceeding the speed limit and thereby assist with speed limit compliance.
- Consider a regulation to require new vehicles sold in Canada to have improved systems to protect those outside vehicles, including children, when vehicles are backing up. A proposed rule-making for improved rear view requirements has been introduced by NHTSA in the US and Canada could adopt similar regulations, if warranted under Canadian regulatory directives.
- Consider a regulation to require new vehicles sold in Canada to have radar-brake pedestrian detection systems that would detect the presence of a pedestrian and automatically apply the vehicle's brakes in order to prevent the vehicle from striking a pedestrian.
- Consider a regulation requiring electric (and other) vehicles to meet a minimum auditory detection threshold in order to increase safety for pedestrians, particularly those with visual impairments
- Consider the need for a provincial/territorial regulation to prohibit or set limits on raising a vehicle's height at the wheel-base because this brings a pedestrian into contact with the rigid vehicle frame rather than the vehicle hood.
- Consider the need for a provincial/territorial regulation prohibiting the installation of rigid bull bars on vehicles as these concentrate blunt force and increase injury severity to pedestrians when struck by motor vehicles.

# 6.0

# Summary of Potential Countermeasures

## Pedestrian Visibility

- Consideration should be given to having all outwear and shoes for adults and children to have built-in retroreflective materials appropriately placed. Children should be educated on road safety visibility. In addition, they could be provided with tools such as retroreflective materials that can easily be put on and worn on the body.
- Educate drivers about the difficulty in detecting pedestrians at night, stopping distances and the limitations of headlights.
- Educational campaigns that discourage the wearing of dark clothing at night and promote wearing retroreflective materials or a yellow-green colour if non-fluorescent.

## Pedestrian Distraction and Inattention

- Educate pedestrians about the dangers of being distracted around traffic.
- Educate pedestrians, especially children, not to use cell phones or other electronic devices while crossing the road taking into account physical and intellectual development.

## Substance-impaired Pedestrians

- Server training programs should include mandatory components on pedestrian safety as well as impaired driving.
- Identify urban areas where alcohol and drug-impaired collisions are concentrated and collect information to determine which treatments would be most effective in those areas.
- Apply countermeasures based on knowledge of communities and locations. These could include engineering modifications to separate pedestrians from traffic, traffic calming measures, signs to warn drivers, parking restrictions, distribution of retroreflective clothing or tags etc. as well as education campaigns directed at both pedestrians and drivers.

## Child Pedestrians

- Include measures to improve child pedestrian safety as part of a national safety strategy.
- Consider child pedestrian safety in urban communities by implementing area wide engineering solutions and speed limit review to reduce pedestrian risk (including pedestrian facilities, safe play areas and/or traffic calming infrastructure).
- Community-based education/advocacy programs to prevent pedestrian injuries in children 0-14 years, including education for parents and pedestrian skills training to improve child pedestrian road crossing skills.
- Educate parents on the risks children face in traffic and the role of parents in reducing that risk (e.g., through public health facilities, daycare, kindergarten etc.)

## Pedestrians who are Older

- Increase the time allowed for crossing the street at signalized intersections where there is a concentration of senior pedestrians.
- Review speed limits in areas where there is a concentration of senior pedestrians

## Pedestrians with Special Needs

- Adjust pedestrian signal timing to allow those with mobility limitations to cross the street safely.
- Provide easy access to pedestrian activated signal controls.
- Provide curbs and gradients that meet design standards for wheel chair accessibility and reduce physical obstacles near the roadside.
- Use curb cuts, tactile strips and auditory signals to assist the visually impaired.
- Pedestrian signs should be designed with the simplest possible messages in order that they are easily understood by those with cognitive limitations.
- Provide information to persons with hearing loss about the dangers associated with compromised hearing and traffic; educate them to rely on visual cues to judge the speed and distance of approaching vehicles.

- Sidewalk markings to warn of hazards to pedestrians with vision loss should follow design guidelines for maximum detectability.

## Pedestrians on Wheels

- Educate users of assistive modes of transportation of the need to wear proper safety equipment and to be aware of the dangers of interacting with traffic.
- Educate parents of young children on the dangers of using non-motorized means of transportation and the need for protective equipment and safe practices.
- Promote familiarity with instructions on the safe use of non-motorized means of transportation.
- Restrict the use of assistive devices on certain roadways, giving consideration to type of road and volume of traffic
- Where allowed, consider requiring licensing and protective equipment for those using Segways™

## Enforcement of Pedestrian Traffic Laws

- Collect accurate data on pedestrian/vehicle collisions.
- Encourage relationships between police and their communities in order to best understand traffic patterns in their communities.
- Combine targeted enforcement with education, awareness and evaluation.
- Provide officers with pedestrian-specific training and resource materials.

## Drivers

- Consider countermeasures to reduce all forms of distracted driving to increase drivers' situational awareness.
- Selective Traffic Enforcement Programs (STEP) that combine intensive enforcement of a specific traffic safety law with extensive communication, education, and outreach informing the public about the enforcement activity.
- Public education and awareness initiatives on vehicle speeds and the impact to safety for pedestrians.
- Consider automated enforcement (speed and intersection safety cameras) in urban areas and introduce where appropriate.
- Consider initiatives that require and promote the need for drivers to slow down in areas where pedestrians frequent.

## Crosswalk Design

- Consider pedestrians in the planning and design phase of new or refurbishing projects.
- Crosswalk treatments should consider all types of pedestrians' and pedestrian abilities, and for longer crossing distances consider curb extensions or media refuge islands.
- Consider pedestrian collision information (i.e. minor, moderate, major, and fatal injuries) and neighbourhood characteristics (i.e. older adults, school zone, commercial district etc.) in order to determine the types of treatments.
- Install crosswalks and appropriate treatments where warranted and according to engineering standards and practice.
- Mitigate interaction with turning vehicles at intersections through such treatments as pedestrian scramble operations, advance green for pedestrians, protected left turn and prohibiting right turn on red by vehicles where appropriate.

## Traffic Control – Signs, Signals and Markings

### *Signs and Signals*

- At intersections install signs warning drivers to watch for pedestrians and signs to prompt pedestrians to watch for turning vehicles.
- At intersections install signs indicating "YIELD TO PEDESTRIANS" or "STOP HERE FOR PEDESTRIANS".
- Place placards at signalised crosswalks with instructions on how to use pedestrian -activated signals and the meaning of pedestrian signal indications where there are frequent pedestrian violations.
- Introduce innovative applications such as the "EYES" pedestrian signals and voice messages indicating when it is safe to cross.
- Install count-down pedestrian signals.

***Pavement Markings***

- Install advance stop bar markings at least 15 metres in advance intersections.
- Install markings warning pedestrians of turning vehicles.
- Install within-pavement flashing lights at appropriate locations.
- Limit the use of markings for crosswalks to roads with an ADT of less than 12,000 vehicles.
- Maintain crosswalk markings to ensure high visibility.

## Volume Dispersion

- The following measures may be considered as volume control measures: direction closure; diverter, full closure, intersection channelization, raised median through an intersection, right-in/right-out island. More information on the aforementioned countermeasures may be found in the TAC *Canadian Guide to Neighbourhood Traffic Calming*.

## Sidewalks and Sidewalk Design

- The following measures may be used for sidewalk design to improve pedestrian safety: boulevards, sidewalks, ramps, streetscaping and fencing. More information on the aforementioned may be found in the TAC *Geometric Design Guide for Canadian Roads*.

## Speed Reduction and Traffic Calming

- Establish community safety zones and reduced speed limits. Create 30 km/h, or 40 km/h, speed zones in areas where there exists a pedestrian/vehicle mix. Reduce the speed limit on residential streets to 30 km/h or 40 km/h. This can also be accomplished, in part, by providing local governments with the legal authority to reduce urban speed limits to less than 50 km/h in blanket geographic zones.
- Establish a three-tiered default speed limit at 30 km/h where there are no pavement markings; 50 km/h in other urban areas and 80 km/h in rural areas.
- Introduce traffic calming and other engineering measures that generally slow traffic
- Extend school speed zones to all schools from Kindergarten to Grade 12.
- The following measures are known to reduce speed of motor vehicles and increase pedestrian safety in general: rumble strips; sidewalk extension; raised crosswalk and speed bump; speed hump; speed table, raised intersection, textured crosswalk, chicanes and curb extensions; curb radius reduction, mini roundabouts, chokers, gateways; landscaping, paving treatments; serpentine design; woonerf; roadway narrowing; reduced speed limits. For more information on the aforementioned measures may be found in the TAC *Canadian Guide to Neighbourhood Traffic Calming*.

## Rail-grade Crossings

- Provide adequate warning of approaching trains. Pedestrian-focused solutions include:
    - Signs prompting pedestrians to take a particular action (look both ways for trains or do not cross here) may increase safe behaviour.
    - Pavement markings that delineate the pathway up to and across the crossing and to indicate the desirable location to stop while waiting for approaching train/s.
    - Barrier treatments such as fencing and "Z"/maze barriers which encourage pedestrians to look both ways.
    - Surface treatments such as visually contrasting materials, raised truncated domes, directional surfaces, and flangeway gap treatments to provide a smooth and continuous crossing surface across the tracks.
    - Install active systems that activate auditory/visual signals when a train is approaching or crossing. Systems which also activate pedestrian gates should be considered at locations and at crossings with more than one track.
- Reduce risky pedestrian behaviour at crossings through enforcement of trespassing laws and warning signal/sign violations.
- Educate pedestrians concerning the dangers of crossing railway tracks without paying attention to train traffic.
- Young people in particular need to be made aware of the need to pay attention at crossings when they are using entertainment and communication devices.

## Work Zones

- The guidelines for work zone safety of pedestrians, as outlined by Chadda and McGee in their report entitled: "Pedestrian Safety Through Workzones: Guidelines" should be adopted as the "gold standard" when designing transition areas around work zones

## Improving the Safety of Vehicles for Pedestrian Protection

- Consider development of regulations related to passive pedestrian protection regulation including the introduction of requirements based on the United Nations Global Technical Regulation No. 9 (GTR No. 9), in the context of the U.S.-Canada Regulatory Cooperation Council.

- Consider a regulation requiring new vehicles sold in Canada to have advanced braking systems including the Brake Assist System and other available systems that assist the driver in the event of a panic or emergency braking situation.

- Consider a regulation to require new vehicles sold in Canada to have adaptive headlights that orient light in the direction the vehicle is turning rather than simply straight ahead.

- Consider a regulation to require new vehicles sold in Canada to have advanced speed assistance technologies to help drivers manage their speed, warn them if they are exceeding the speed limit and thereby assist with speed limit compliance.

- Consider a regulation to require new vehicles sold in Canada to have improved systems to protect those outside vehicles, including children, when vehicles are backing up. A proposed rule-making for improved rear view requirements has been introduced by NHTSA in the US and Canada could adopt similar regulations, if warranted under Canadian regulatory directives.

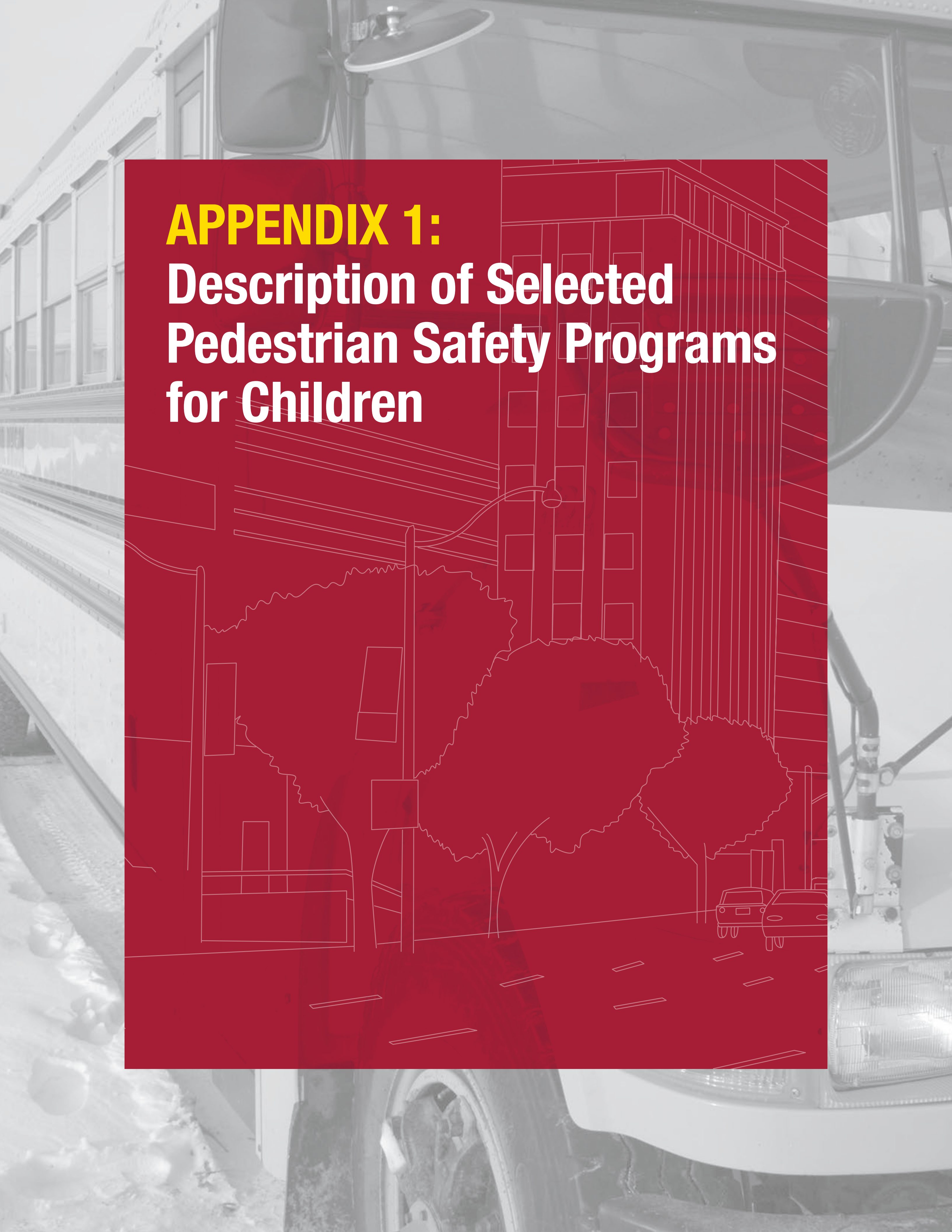
- Consider a regulation to require new vehicles sold in Canada to have radar-brake pedestrian detection systems that would detect the presence of a pedestrian and automatically apply the vehicle's brakes in order to prevent the vehicle from striking a pedestrian.

- Consider a regulation requiring electric (and other) vehicles to meet a minimum auditory detection threshold in Transport Canada worked with U.S. officials and the latter have published a proposed regulation for comments in order to increase safety for pedestrians, particularly those with visual impairments.

- Consider the need for a provincial/territorial regulation to prohibit or set limits on raising a vehicle's height at the wheel-base because this brings a pedestrian into contact with the rigid vehicle frame rather than the vehicle hood.

- Consider the need for a provincial/territorial regulation prohibiting the installation of rigid bull bars on vehicles as these concentrate blunt force and increase injury severity to pedestrians when struck by motor vehicles.

# APPENDIX 1:
# Description of Selected Pedestrian Safety Programs for Children



### *Kerbcraft*

Kerbcraft originated at the University of Strathclyde in Scotland and is aimed at teaching safe pedestrian habits to school children aged 5-7 years utilizing road-side instruction rather than classroom lessons. The program is endorsed by the European Child Safety Alliance "Child Safety Good Practice Guide". It relies heavily on trained volunteers, and while the small ratio of adult to child is a definite strength of the program, successful implementation is heavily dependent on sufficient volunteers being secured. In 2007 Kerbcraft was evaluated very favourably by the University of West England.

### *Kidestrian*

This program is based on a 28 page guide for parents that was originally created in Germany and adapted by the Hamilton-Wentworth Regional Police (Ontario) in 1994. It provides a variety of simple activities which are accompanied by information regarding children's developmental limitations and how this might affect their ability to navigate traffic safely. It reminds parents that children under nine should not be crossing streets unattended and stresses the importance of parental involvement.

### *Photovoice*

This innovative program has different forms, applications and focus areas internationally, but originated in the UK. It is ideally suited to increasing safe pedestrian practices among children aged ten and above because it incorporates participatory activities including community walks, camera use seminars, photo-taking, observation exercises and storytelling, with the potential for additional activities such as community engagement and advocacy. Children thus create a record of their pedestrian environment engendering within the group a keen awareness of both the risks of unsafe pedestrian behaviour and hazardous pedestrian environments. The lasting effects of this initiative have not been determined. If integrated with a program targeting younger child pedestrians, its impact on children's behaviour could be long-term.

### *Road Safety Resource for Educators*

This is 2009 collaboration between the Ontario Ministry of Transportation and the Ontario Physical and Health Education Association (Ophea) which provides educators with lessons and activities (kindergarten to grade 12) that cover a myriad of safety topics concerning road safety. The pedestrian components are designed for students from kindergarten to grade six and its strength lies in the community walkabout (with two adult teachers) which reinforces the concept of guided practice. There are also school bus safety lessons which are very important in the context of pedestrian vulnerability. Of concern is the absence of any discussion around the essential need for parental/adult accompaniment for children less than nine years of age. (www.ontarioroadsafety.ca)

### *Active and Safe Routes to Schools*

This program offers support to schools and parents who wish to organize a community Walking School Bus program. While the program addresses the environmental and health benefits of walking to school, the handout for parents emphasizes the importance of teaching children safe pedestrian practices throughout childhood and the theme of safety is consistently included in their materials. (www.saferoutestoschool.ca)

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