CITY OF VANCOUVER

pedestrian safety study

Final Report

URBAN systems

alta PLANNING + DESIGN

Acuere Consulting

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CITY OF VANCOUVER
PEDESTRIAN SAFETY STUDY

FINAL REPORT

Prepared by

URBAN systems

In association with

alta PLANNING + DESIGN

Acuere Consulting

Dr. Tarek Sayed, P.Eng.,
Department of Civil Engineering,
University of British Columbia

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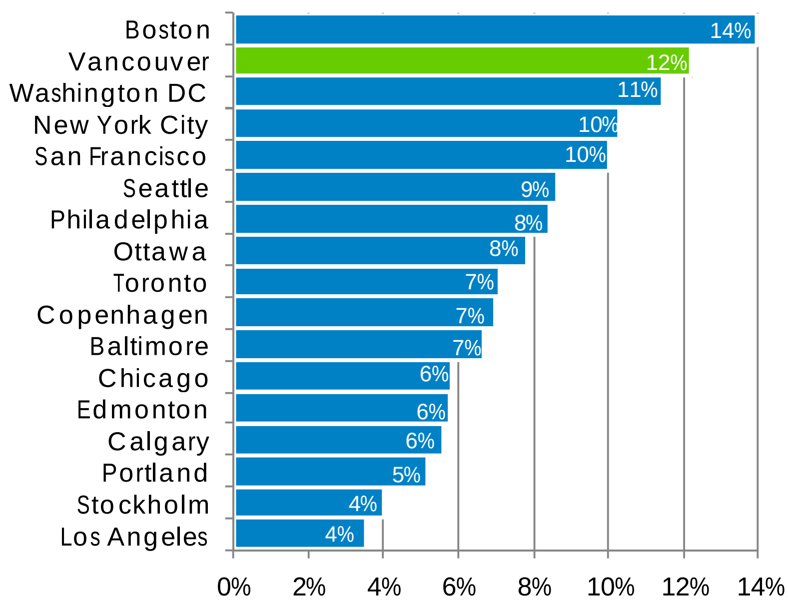
Executive Summary

Walking is the most fundamental form of transportation. Walking is part of every trip, whether that trip is made by car, transit, or bicycle. The City of Vancouver is committed toward making walking a safe, accessible and enjoyable experience for residents and visitors alike. Walking was identified as the top transportation priority in the City's 1997 Transportation Plan and subsequently in the 2002 Downtown Transportation Plan. In addition, the City's Greenest City Action Plan recognizes the role that walking can play in helping the City work to its goal of being the greenest city in the world by 2020, and sets a target that the majority of trips in the City of Vancouver (over 50%) will be made on foot, bicycle or public transit. Vancouver is renowned as a walkable city. In fact, walking currently accounts for over 12% of all trips to work made in the City of Vancouver – one of the highest walking mode shares among several Canadian and international 'peer cities', as shown in Figure ES.1.

Figure ES.1
Walking Mode Share of Work Trips in Canadian and International Peer Cities



Significant steps have been taken to improve pedestrian safety in recent years, including the installation of a number of engineering treatments such as intersection safety cameras, pedestrian countdown timers, speed reader boards, and corner bulges, among other things. The City also recently formed an Active Transportation Advisory Committee to advise on matters that encourage and enhance walking as a means of transportation, recreation and health.

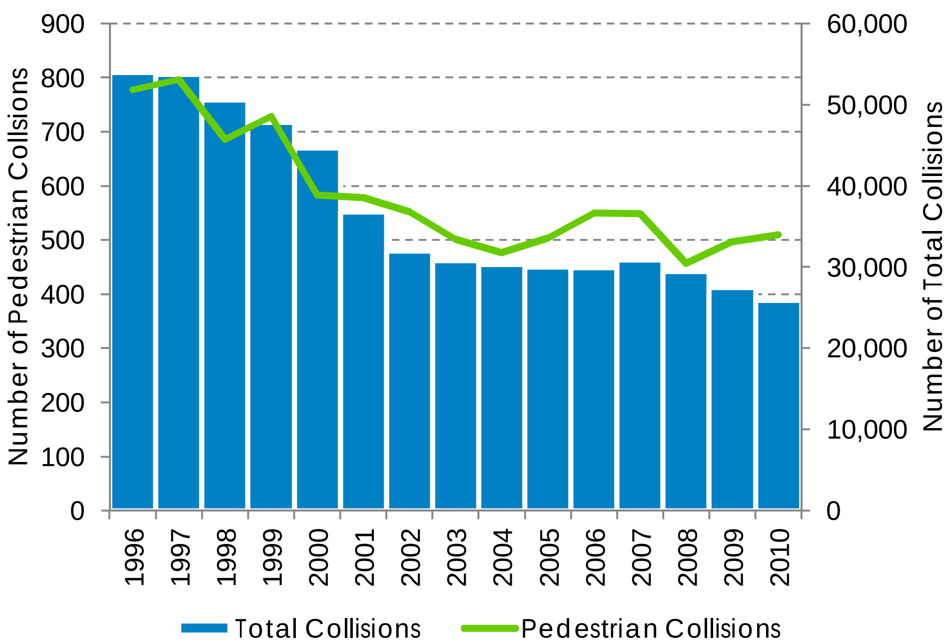
The purpose of the Pedestrian Safety Study is to help the City gain a better understanding of the effectiveness of existing pedestrian safety treatments, and to help identify opportunities to improve pedestrian safety through engineering, enforcement and communication measures throughout the City.

This study involved an in-depth analysis of all reported collisions involving pedestrians in the City of Vancouver between 2005 and 2010. The analysis examined where collisions were occurring, when they took place, who was involved in the collisions, and how the collision occurred. The analysis was based on collision data provided by the Insurance Corporation of British Columbia (ICBC) and the Vancouver Police Department (VPD) as well as a variety of other datasets, including data regarding infrastructure, spatial, demographic, weather, and light conditions.

There were 3,066 reported collisions involving pedestrians between 2005 and 2010, equivalent to an average of 511 collisions involving pedestrians per year. In comparison, there was an average of 28,933 total reported traffic collisions over this period. As such, on average approximately 1.8% of all reported traffic collisions involved a pedestrian over this period.

Looking back beyond 2005, the number of overall traffic collisions as well as the number of pedestrian collisions have been steadily declining in the City of Vancouver, as shown in Figure ES.2.

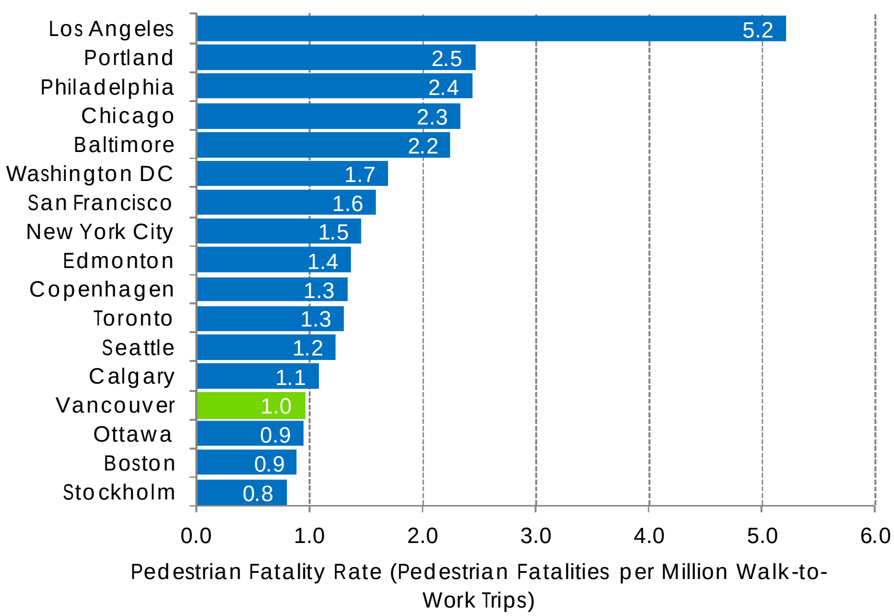
Figure ES.2
Total number of collisions and pedestrian collisions (1996 – 2010)



Based on ICBC data between 1996 and 2010, 2010 saw the fewest number of traffic collisions since 1996. This decrease in the number of collisions is notable, particularly because the City's population increased significantly over this period. In fact, despite an increase in the City's population of approximately 20% between 1996 and 2010, the total number of collisions in the City decreased by 52%, while the total number of collisions involving pedestrians declined by 34%. As a result, the annual pedestrian collision rate – defined as the number of pedestrian collisions per 100,000 residents – has been steadily declining since 1996.

Between 2005 and 2010, the City of Vancouver had an overall traffic fatality rate for all reported collisions of 3.3 fatalities per 100,000 residents. This is a relatively low fatality rate as compared to most other large communities in British Columbia, as well as other peer cities across North America and internationally. When considering the number of pedestrian fatalities based on the overall number of walk to work trips, Vancouver has a pedestrian fatality rate of 1.0 pedestrian fatalities per million walk to work trips, which is relatively low compared to other peer cities, as shown in Figure ES.3.

Figure ES.3
Pedestrian Fatalities per Million Walk to Work Trips

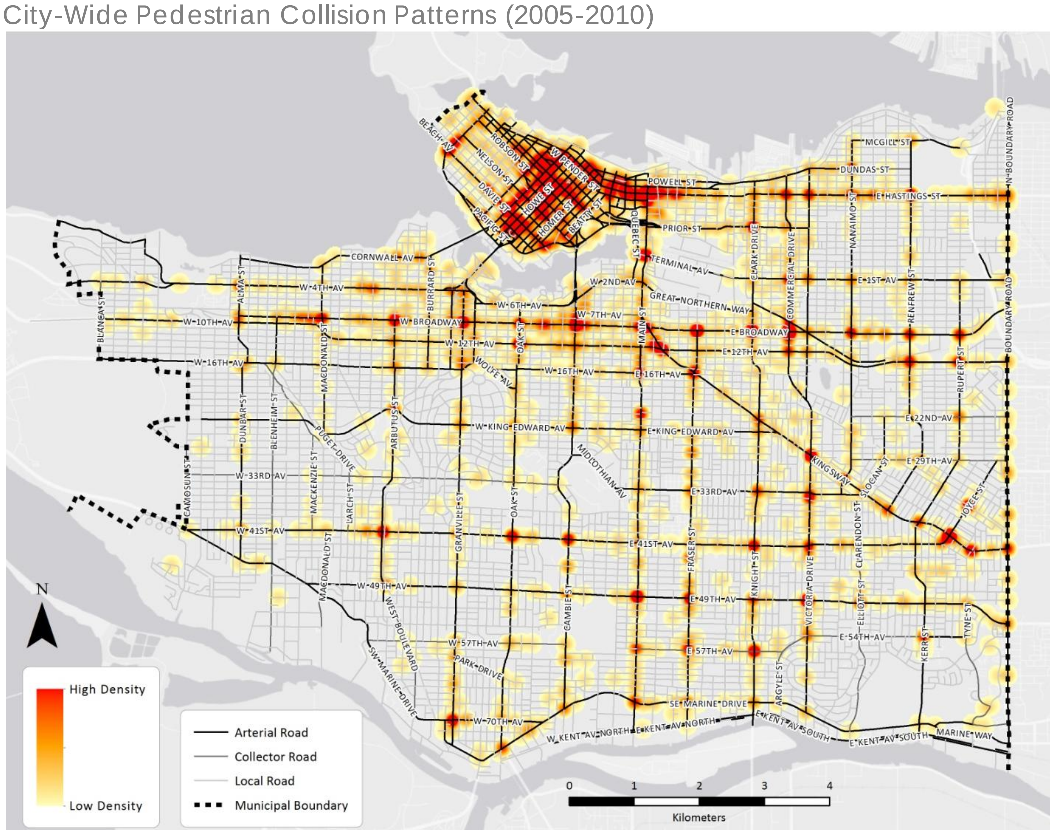


Traffic collisions are considered a global epidemic of staggering, but often overlooked consequences. A recent study by Transport Canada estimates that the annual cost of traffic collisions to the Canadian economy, including health care, environmental damage, lost productivity, and induced traffic congestion, is $CDN 62.7 billion – approximately 5% of the Canadian Gross Domestic Product

(GDP). Although all road users are impacted by the cost of collisions, non-motorized and sustainable modes of travel such as walking and cycling suffer a higher level of risk because of their increased vulnerability. It is estimated that the average cost of a pedestrian collision in the City of Vancouver – including human consequences as well as other costs such as lost earnings, medical care, administration costs and other indirect costs -- is approximately $234,000. Based on the number of pedestrian collisions in the City of Vancouver between 2005 and 2010, the total cost of pedestrian collisions in the City of Vancouver over the five year period was in excess of $760 million, or approximately $127 million per year, although this has declined significantly since 2008 due to the decline in the number of pedestrian collisions since 2008.

Overall pedestrian collision patterns between 2005 and 2010 in the City of Vancouver are shown in Figure ES.4. The section below provides a brief summary of the key pedestrian safety issues that were identified based on the analysis of pedestrian collisions over the past six years in the City of Vancouver, including WHEN collisions took place, WHO was involved in the collisions, WHERE the collisions were occurring, and HOW the collision occurred

Figure ES.4
City-Wide Pedestrian Collision Patterns (2005-2010)



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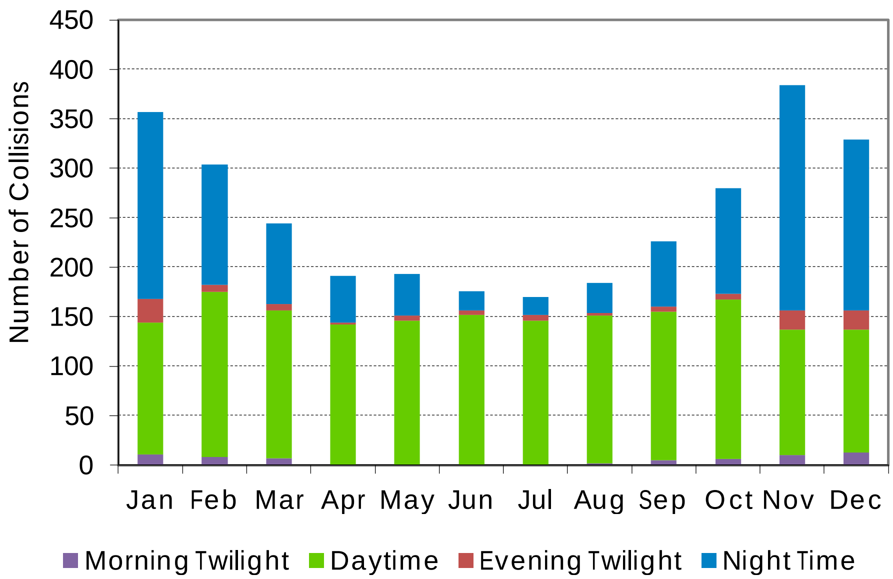
- When
  - Nearly half of all pedestrian collisions occurred between November and February.
  - Most of the increase in collisions in winter months can be attributed to the increase in nighttime collisions as a result of the shorter days and longer nights, as shown in Figure ES.5.

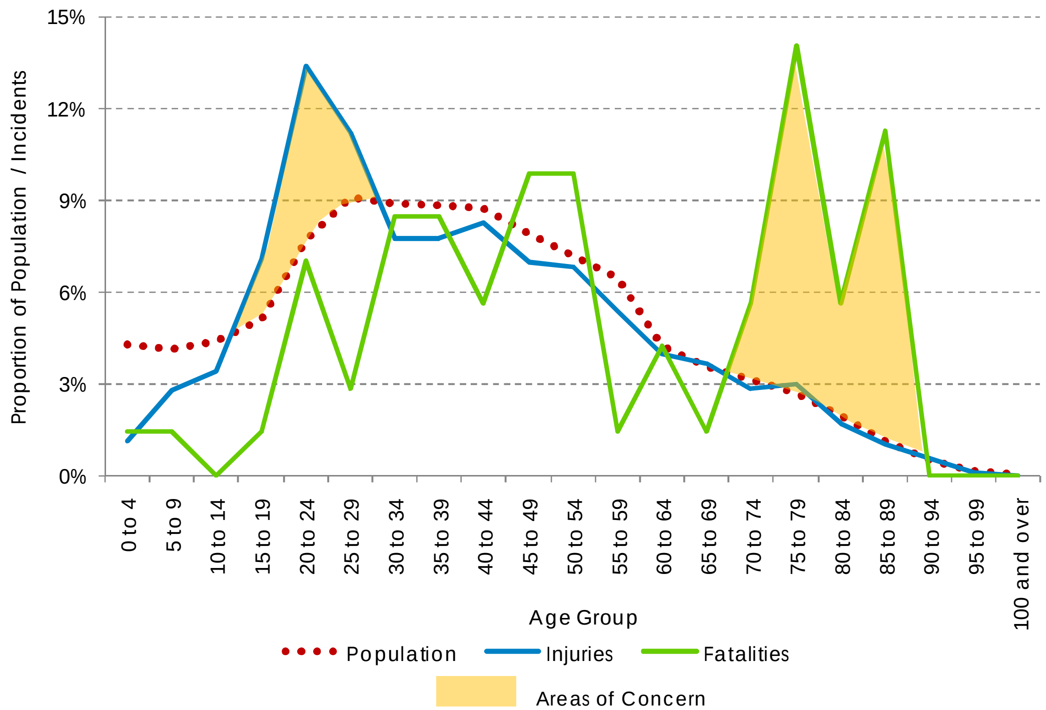
Figure ES.5
Total Pedestrian Collisions by Month and Light Conditions (2005 – 2010)



- January accounted for the highest proportion of pedestrian collisions resulting in fatalities.
- Pedestrian collisions were more likely to occur on weekdays.
- The highest proportion of pedestrian collisions occurred during the PM peak period (3:00 – 6:00pm)
- Although late night pedestrian collisions (12:00 – 6:00am) were relatively infrequent, they were nearly twice as likely to lead to a fatality compared with other time periods.
- Pedestrians were particularly vulnerable when it was both dark and rainy.

- Who
  - Young adults aged 20 to 29 are the most likely to be involved in a collision as a pedestrian. As shown in Figure ES.6, this age group is much more likely to be involved in pedestrian collisions resulting in injury than would be expected based on the population distribution. Collisions involving young adults are more likely to result in injury and less likely to result in fatality.
  - As shown in Figure ES.6, collisions involving seniors are more likely to result in fatality. In fact, the proportion of pedestrian collisions resulting in fatalities is significantly higher than could be expected based on the population distribution.
  - On a positive note, children aged 9 and under account for 15.4% of walking trips in Vancouver, but represent only 3.9% of pedestrian collisions.

Figure ES.6
Proportion of Pedestrian Injuries and Fatalities Compared to Overall Population Distribution

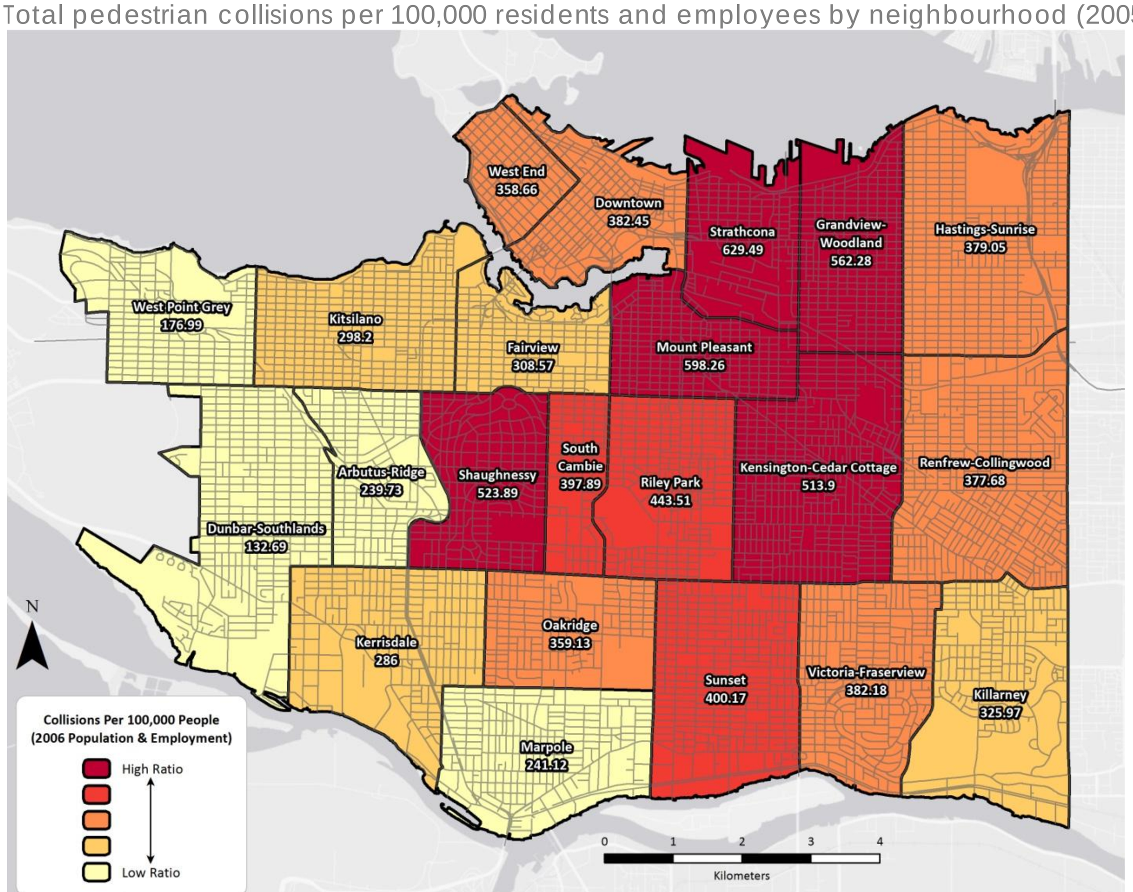


  - There is a relatively even distribution of pedestrian collisions involving males and females.
  - Males are somewhat more likely to be involved in a collision resulting in fatality, as 54.9% of all pedestrian fatalities involved males, compared to 45.1% females.

- Females aged 20 to 29 are more likely than males of the same age group to be involved in a pedestrian collision, as this age group accounts for 26.2% of collisions involving females compared to 22.7% of collisions involving males.

- Where
  - A significant number of pedestrian collisions occurred in the Downtown core and along Primary Arterial streets, such as Broadway, 12th Avenue, 41st Avenue, Kingsway, Hastings Street, Main Street, Fraser Street, Knight Street, and Commercial Drive, among others
  - The neighbourhoods with the highest number of pedestrian collisions per 100,000 residents and employees included Strathcona, Mount Pleasant, Grandview-Woodland, Shaughnessy, and Kensington Cedar Cottage, as shown in Figure ES.7.

Figure ES.7
Total pedestrian collisions per 100,000 residents and employees by neighbourhood (2005 – 2010)



- Approximately 75% of all pedestrian collisions were located at intersections.
- The majority of pedestrian collisions at intersections (61%) were at signalized intersections, even though signalized intersections only represent 3.6% of all intersections in the City.
- 21 locations were identified that had 11 or more pedestrian collisions over the six year period. All of these locations are located at intersections and were also located at an intersection with an arterial road. Seven of these locations were identified as Collision Prone Locations which present the highest risk for pedestrian collisions.

- What & How
  - The most common driver action in pedestrian collisions was a left turning movement.
  - The vast majority of collisions at intersections involved drivers failing to yield to pedestrians when pedestrians had the right-of-way.
  - One quarter of all pedestrian collisions took place at mid-block locations, where the pedestrian was either crossing the street at a mid-block crosswalk or a location without a traffic control, crossing a driveway or laneway, or was struck at the sidewalk or at a bus stop.
  - The top five pedestrian collision types listed below accounted for approximately two-thirds of all pedestrian collisions:
    1. Vehicle turns left while pedestrian crosses with right-of-way at signalized intersection (25.6% of known collision types);
    2. Vehicle turns right while pedestrian crosses with right-of-way at signalized intersection (17.1%);
    3. Pedestrian hit while crossing mid-block without a traffic control, or jaywalking (11.5%);
    4. Vehicle proceeds straight through while pedestrian crosses at stop sign or crosswalk (6.9%); and
    5. Pedestrian hit while crossing driveway or laneway (6.5%).

The study included a comprehensive review of the effectiveness of a range of types of engineering treatments that can be considered to improve pedestrian safety. This includes a review of measures commonly used in Vancouver as well as measures with limited or no current use in Vancouver, as shown in Table ES.1. The effectiveness of each treatment was assessed based on a comprehensive literature review and by contacting staff at five peer cities in Canada and the Pacific Northwest (Calgary, Toronto, Seattle, Portland, and San Francisco).

Table ES.1
Relative Cost and Effectiveness of Pedestrian Treatments

Treatment	Relative Cost	Relative Effectiveness
Pedestrian Activated Signals	High	High
Corner Bulges	Moderate	Moderate
Speed Reader Boards	Moderate	Moderate-Low
Pedestrian Countdown Timers	Moderate-Low	Moderate
Crosswalks	Moderate-Low	Low
Pedestrian Scrambles	Moderate-High	High
Audible Pedestrian Signals	Moderate-Low	Moderate-Low
Leading Pedestrian Intervals	Low	Moderate
Left Turn Bays	Varies	Varies
Greenways	Varies	Varies
Crossing Guards	Moderate-Low	Moderate-Low
Yield to Pedestrian Signs	Low	Low
Raised Intersections	Moderate-High	Moderate-Low
Midblock Crossings	Varies	Varies
Raised Crosswalks	Moderate-High	Moderate
Separated vs Mixed Modes	Low	Moderate
New/Upgraded Intersection Lighting	Moderate	High

Based on the results of the collision analysis, the study identified the following 12 key pedestrian safety issues.

a. WHEN	Key Issue 1	Winter and Adverse Weather Conditions
	Key Issue 2	High Activity Periods
	Key Issue 3	Late Night
b. WHO	Key Issue 4	Senior Fatalities
	Key Issue 5	Young Adults
c. WHERE	Key Issue 6	Intersections
	Key Issue 7	Arterial Corridors
	Key Issue 8	Local Street Intersections
d. WHAT & HOW	Key Issue 9	Left Turning Vehicles at Intersections
	Key Issue 10	Right Turning Vehicles at Intersections
	Key Issue 11	Jaywalking
	Key Issue 12	Driver Failure to Yield

The Action Plan includes a description of each issue as well as engineering, education and enforcement countermeasures recommended to address each issue, as described below.

a. When

Key Issue 1 Winter and Adverse Weather Conditions

The collision data indicates that visibility is a key contributing factor in many pedestrian collisions. Pedestrian collisions are more common during the winter months, with the additional collisions largely taking place after dark. Days are shorter in winter and a greater percentage of pedestrian activity takes place during nighttime and adverse weather conditions. Strategies to address this issue include installing and upgrading lighting at key intersections and launching a road safety awareness campaign at the beginning of the winter season to remind pedestrians and motorists to exercise additional caution in dark and rainy conditions; remind motorists that safe speeds depend on weather and light conditions, not just the posted speed limit; and remind pedestrians to wear visible clothing in poor lighting conditions.

Key Issue 2 High Activity Periods

The highest proportion of pedestrian collisions occurs during the PM peak period between 5 and 7 pm. More generally, pedestrian collisions are most common between 3 and 8 pm, when pedestrian activity levels are high. The prominence of pedestrian collisions in the afternoon/evening peak period offers opportunities to efficiently improve safety, such as coordinating enforcement actions for speeding, jaywalking, and crosswalk yielding to occur more frequently during high activity periods and adjusting traffic signal timing during peak periods to provide additional time for pedestrians to complete crossings

Key Issue 3 Late Night

While pedestrian collisions are relatively uncommon late at night, when they do occur they are nearly twice as likely to result in a fatality as compared with other periods. With fewer cars on the road late at night, drivers are able to operate at higher speeds, contributing to increased collision severity. Because there are fewer pedestrians on the road during these times as well, motorists may be less likely to be looking for people walking. Potential pedestrian safety measures include installing and upgrading lighting at key intersections, installing speed cameras or implementing police enforcement on corridors where motorists tend to speed, adjusting traffic signal timing to reduce the minimum green times for through movements, and developing a road safety awareness campaign aimed at minimizing drunk driving/walking.

b. Who

Key Issue 4 Senior Fatalities

Older pedestrians are less likely to survive a pedestrian collision. For Vancouver residents to successfully rely on walking or public transportation as they age, it is essential that the transport system be pedestrian friendly and forgiving of mistakes in judgment and changes in walking speed that occur naturally. There are a number of ways to improve safety for seniors, including evaluating the presence of safe crossing facilities throughout the City and particularly areas with higher concentrations of seniors, conducting outreach to seniors, developing a safe routes for seniors program, and setting enforcement priorities for speeding and crosswalk yielding that include areas where seniors are more likely to be present.

Key Issue 5 Young Adults

Young adults aged 20 to 29 are over-represented in pedestrian collisions and are the age group most likely to be involved in a pedestrian collision. While not available in the data, young people may also be more likely to be under the influence of alcohol while walking, which can impair their ability to make good decisions about safe walking and crossing behaviour. Pedestrian safety measures include a road safety awareness campaign targeted towards young drivers and pedestrians, enforcement actions focusing on places where young people tend to congregate, and a safe routes to school program to instill road safety knowledge at an early age.

c. Where

Key Issue 6 Intersections

The majority of pedestrian collisions in the City of Vancouver take place at intersections. Twenty-one intersections experienced 11 or more pedestrian collisions over the past six years, and seven intersections in particular were identified as Collision Prone Locations. Recommended pedestrian safety measures include pedestrian countdown timers, road safety awareness campaigns, and crosswalk enforcement.

Key Issue 7 Arterial Corridors

The majority of both intersection and mid-block pedestrian collisions take place on primary and secondary arterial streets. Furthermore, pedestrian collisions tend to be concentrated along a number of arterial corridors in the Downtown core as well as along corridors such as Broadway, 12th Avenue, 41st Avenue, Kingsway, Hastings Street, Main Street, Fraser Street, Knight Street, and Commercial Drive, among others. The study recommended that the City undertake a corridor pedestrian safety strategy by evaluating groups of intersections along arterial corridors and considering 'packages' of complementary mitigation measures to deal with primary collision types identified in the What & How Section. Potential treatments could include left turn bays/left turn signals at major cross-streets, or pedestrian signals/greenways/restricted left turns at minor traffic streets and major pedestrian corridors. A multi-agency approach is recommended that complements engineering treatments with police enforcement actions and road safety awareness campaigns aimed at arterial roadway users (i.e., at bus stop shelters).

Key Issue 8 Local Street Intersections

The majority of collisions in the City occur on arterial streets or at intersections with arterial streets. As a result, collision patterns on local streets become underrepresented in City-wide analyses. Although the vast majority of collisions on local streets are isolated incidents with only one reported collision over this period, 20 locations have been identified at local street locations with at least two reported collisions over this period. Potential pedestrian safety measures on local streets include a range of traffic calming measures such as corner bulges and raised crosswalks.

d. What & How

Key Issue 9 Left Turning Vehicles at Intersections

The most common pedestrian collision type includes a left turning vehicle at an intersection. Most of these left turning collisions occur at signalized intersections and involve a pedestrian crossing with the right of way (i.e., with a walk signal). This is to be expected, as traffic signal phasing typically allows the pedestrian crossing phase to run simultaneously with the through and permitted turning movements on the parallel street segment. There are a number of measures that can reduce potential conflicts between pedestrians and left turning vehicles:

- Leading Pedestrian Intervals give pedestrians an advanced walk signal, allowing them to clearly establish their right of way in the crossing before vehicles are given a green light.
- Left turn bays can be implemented at intersections where there is room for a dedicated left turn lane. Left turn bays provide a dedicated space for vehicles to make a left turn, allowing them to concentrate on making a safe turn with less pressure from following vehicles.
- Left turn movements can be given their own protected phase separate from the pedestrian walk phase. Left turns can also be prohibited at all times or at certain times of day at certain high collision intersections or at minor cross-streets to allow the turning movement to occur at a more appropriate location.
- A road safety awareness campaign can be directed at both drivers and pedestrians, reminding them to look out for each other at intersections.
- Enhanced enforcement by police can focus on intersections with high numbers of pedestrian collisions.

Key Issue 10 Right Turning Vehicles at Intersections

Collisions involving right turning vehicles are the second most common type of pedestrian collision. Similar to collisions involving left turning vehicles, most of these collisions occur at signalized intersections when the pedestrian is crossing with the walk signal. Actions to reduce potential conflicts between pedestrians and right turning vehicles are similar to those cited in above. In addition, right turn on red movements can be restricted at select intersections where this type of collision is common.

Key Issue 11 Jaywalking

The third most common type of pedestrian collision (11.5%) occurred where pedestrians were attempting to cross the street at a mid-block location without an intersection control. Potential pedestrian safety measures can include additional mid-block crossing facilities based on crossing demand and collision history, a “cross at the corner” road safety awareness campaign to remind pedestrians to cross at intersections or other dedicated crossing facilities, crossing guards, adjusting signal timing, and police enforcement at known jaywalking locations.

Key Issue 12 Driver Failure to Yield

Failure to yield refers to cases where a driver fails to yield to a pedestrian that is crossing the street at a signalized intersection with the right-of-way, at a stop sign, or at a marked or unmarked crosswalk. Strategies to address failure to yield collisions include red light cameras, enhanced enforcement, and a "pay attention" road safety awareness campaign.

Based on the actions identified for each of the twelve key issues identified above, the Action Plan identifies the following high priority measures that are anticipated to be particularly effective to address the identified pedestrian safety issues:

- Minimize conflicts between motorists and pedestrians at intersections
  - Continue to install countdown signal timers as standard practice for new signals and at high pedestrian collision intersections as resources permit.
  - Continue to install corner bulges and raised crosswalks on local streets.
  - Upgrade lighting at intersections with high night-time pedestrian volumes and/or collisions.
  - Assess high pedestrian collision intersections and consider installation of the following:
    - Leading pedestrian intervals
    - Left turn bays as well as protected or prohibited left turns
    - Increased pedestrian walk and clearance intervals
- Improve visibility at night
  - Improve lighting to enhance visibility at key intersections.
- Use road safety awareness campaigns to target behaviour related to common collision types
  - Road safety awareness campaigns can be developed in partnership with other agencies such as ICBC and the Vancouver Police Department to focus on:
    - Increased risk of pedestrian collisions at night and in adverse weather conditions
    - Safe walking and driving by young adults

        - High incidence of conflicts between drivers and pedestrians at intersections
        - Safe driving and crossing behaviour on arterial corridors

- Work with police to target enforcement actions to improve pedestrian safety
    - The City of Vancouver can partner with the Vancouver Police Department to tailor enforcement actions to occur:
        - During high pedestrian activity periods
        - At high collision intersections
        - Along high collision corridors

The improvement of pedestrian safety within the City of Vancouver will require the involvement and coordination of a number of agencies involved in pedestrian-related infrastructure, operations, services, and enforcement. These include the City of Vancouver, ICBC, Vancouver Police Department (VPD), the BC Ministry of Health (MoH), TransLink, and the Vancouver School Board (VSB). In addition, other stakeholders, such as the Vancouver Area Cycling Coalition (VACC) and the British Columbia Automobile Association (BCAA), could play a role in identifying needs, education and advocacy. Each of these agencies can contribute to pedestrian safety through four general areas:

1. Provision of primary data and information;
2. Planning/engineering/operations;
3. Communication; and
4. Enforcement.

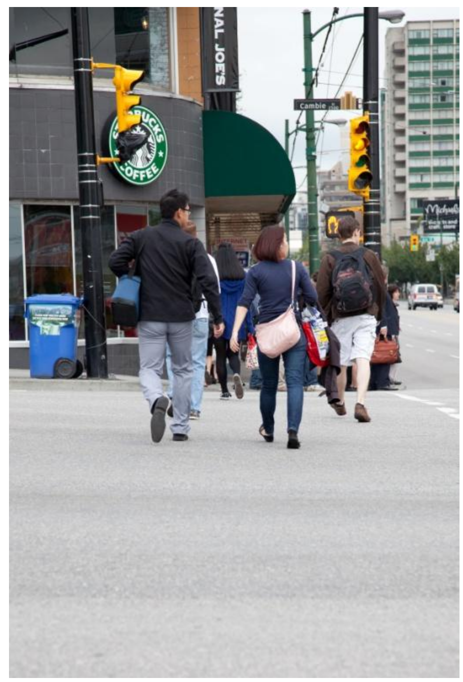
Each of the agencies could take on either a lead or supporting role in these areas, working together in cooperation to plan, deliver, and evaluate strategies to improve pedestrian safety.

It is recommended that pedestrian collision data from various agencies be harmonized and include injury severity to enable a more robust analysis in the future and to facilitate the planning and evaluation process.

1.0 Introduction

Walking is the most fundamental form of transportation. Walking is part of every trip, whether that trip is made by car, transit, or bicycle. The City of Vancouver recognizes the critical role that walking can play in creating vibrant, livable, and healthy communities, as walking can help reduce automobile dependence and greenhouse gas emissions, improve public health outcomes, increase social connections, and reduce infrastructure demands.

The City of Vancouver is widely regarded as one of the most livable, vibrant and walkable cities in the world. Walking is an important form of transportation within the City, as walking represents 17% of all trips in the City – approximately 318,000 daily trips.[1] In addition, walking has been a rapidly increasing form of transportation in the City, as the number of walking trips has increased by 44% since 1994.



The City is committed toward making walking a safe, accessible and enjoyable experience for residents and visitors alike. Walking was identified as the top transportation priority in the City's 1997 Transportation Plan and subsequently in the 2002 Downtown Transportation Plan. In addition, the City's Greenest City Action Plan recognizes the role that walking can play in helping the City work to its goal of being the greenest city in the world by 2020, and sets a target that the majority of trips in the City of Vancouver (over 50%) will be made on foot, bicycle or public transit.

Despite its advantage as a common activity that can also serve to improve personal and public health, there are many systemic barriers to walking. Of all road users, pedestrians are the most vulnerable to injury and death as a result of motor vehicle collisions. They are also more sensitive to weather conditions and to the scale and form of the built environment. A lack of safe and convenient pedestrian facilities, including sidewalks and crossing opportunities, can deter people from choosing to walk or take transit.

As pedestrians are vulnerable road users, it is essential that safety be a key consideration for pedestrians. A wide range of engineering treatments can be used to improve pedestrian safety and accessibility, such as pedestrian countdown timers, curb bulges, marked crosswalks, and pedestrian signals, among others. In addition, enforcement and education measures are required as part of a comprehensive strategy to improve pedestrian safety.

Several significant steps have been taken to improve pedestrian safety in recent years, including the installation of a number of engineering treatments such as intersection safety cameras, pedestrian countdown timers, speed reader boards, and corner bulges, among other things. The City also recently formed an Active Transportation Advisory Committee to advise on matters that encourage and enhance walking as a means of transportation, recreation and health.

1.1 Purpose of Study

The City is currently developing a long-term Transportation 2040 Plan as well as an Active Transportation Implementation Strategy. In particular, the Active Transportation Master Plan will form the basis for Vancouver's long-term walking and cycling network and will include policies for the next ten years and beyond. To help develop the Active Transportation Implementation Strategy, the City needs a solid, evidence-based foundation to qualitatively and quantitatively understand pedestrian safety issues throughout the City. The Pedestrian Safety Study involves undertaking an innovative, comprehensive, and robust analysis that will help inform and guide the development of the Transportation 2040 Plan, and which will also be critical in helping monitor the success of the Active Transportation Implementation Strategy.

This study will help the City gain a better understanding of the effectiveness of existing pedestrian safety treatments, and identify opportunities to improve pedestrian safety through engineering, enforcement and education measures throughout the City.

1.2 Report Structure

This report includes six chapters, as follows:

- Chapter 1 – Introduction provides an overview of the Pedestrian Safety Study, including the purpose and scope of the Pedestrian Safety Study.
- Chapter 2 – Vancouver in Context summarizes overall collision patterns in the City of Vancouver and describes how these patterns compare with other cities internationally and throughout Metro Vancouver.
- Chapter 3 – Cost of Collisions identifies the economic, public health, sustainability, and quality of life costs associated with pedestrian safety issues in the City of Vancouver.
- Chapter 4 – Collision Analysis summarizes the methods that were used for the

collision analysis and provides detailed results of the analysis in terms of where pedestrian collisions have occurred, when they took place, who was involved in the collisions, and how the collisions occurred.

- Chapter 5 – Pedestrian Safety Toolbox provides a 'toolbox' of engineering, education and enforcement measures that can be considered to address identified pedestrian safety issues.
- Chapter 6 – Action Plan includes a comprehensive set of actions to address the identified pedestrian safety issues based on the measures identified in the Pedestrian Safety Toolbox.

2.0

Vancouver in Context

2.1 Existing Pedestrian Safety Initiatives

The City is committed toward making walking a safe, accessible and enjoyable experience for residents and visitors alike. The City has taken several significant steps to improve pedestrian safety in recent years, including a variety of engineering treatments as well as education campaigns and communications initiatives, as summarized below:

- Engineering
  - Installing intersection safety cameras at 43 intersections throughout the City as part of a Provincial initiative in conjunction with the Insurance Corporation of British Columbia (ICBC);
  - Installing pedestrian countdown timers at 12 locations throughout the City, including the top ten pedestrian collision locations, as well as planned installations at all new or upgraded traffic signals;
  - Installation of speed reader boards at several locations in the City in coordination with ICBC and the Vancouver Police Department (VPD);
  - Supporting a Downtown Eastside Pedestrian Safety Study published by the Vancouver Area Network of Drug Users (VANDU) which recommended a number of pedestrian safety improvements, including establishing a 30 km/h pedestrian safety zone on Hastings Street between Abbott and Jackson Streets;
  - Increasing walk times for pedestrians at numerous signal locations in the Downtown Eastside;
  - Installing new corner bulges to reduce pedestrian crossing distances and improve pedestrian safety and accessibility; and
  - Installing traffic calming measures at schools as part of the City's Active and Safe Schools Transportation Program.
- Education
  - Launching a road safety awareness program in February 2012 in collaboration with ICBC and the VPD targeting pedestrians, cyclists and motorists.
- Communication
  - Forming an Active Transportation Advisory Committee that would advise on matters that encourage and enhance walking as a means of transportation, recreation, health, and environmental design.

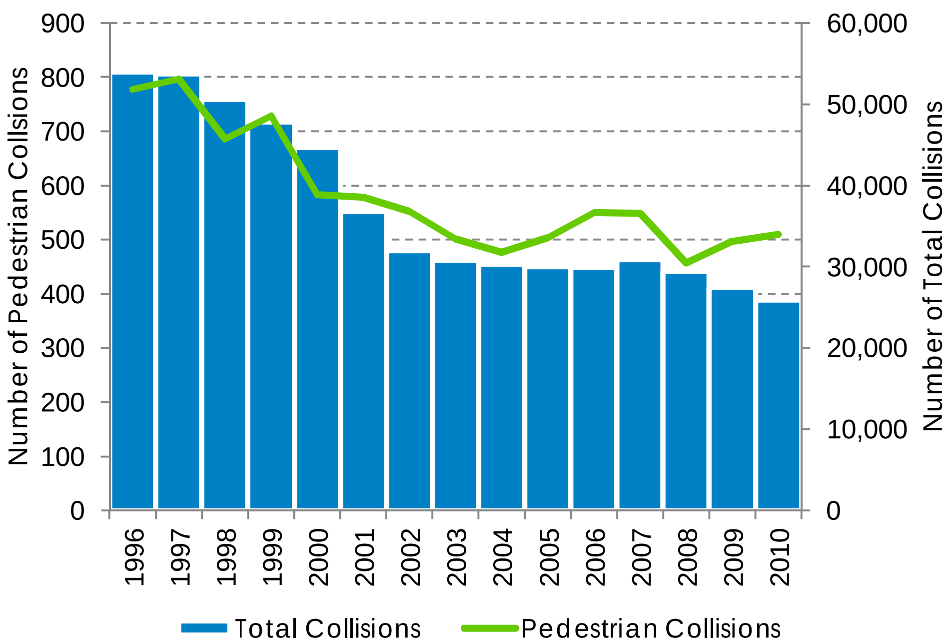
2.2 Current Collision Trends

Pedestrian injuries and fatalities vary significantly on an annual basis due to a number of factors, such as driver and pedestrian behavior, legislation, infrastructure, environment, and other factors. However, the general trend in Vancouver over the past several years has been a declining number of pedestrian collisions and pedestrian fatalities. To account for the annual variability in pedestrian collisions and fatalities, collisions involving pedestrians are summarized in the sections below for the six year period from January 1, 2005 to December 31, 2010.

Based on motor vehicle collision data provided by ICBC, between 2005 and 2010, there were 3,066 reported collisions involving pedestrians, equivalent to an average of 511 collisions involving pedestrians per year. In comparison, there was an average of 28,933 traffic collisions per year over this period. As such, on average approximately 1.8% of all reported collisions involved a pedestrian over this period.

Looking back beyond 2005, the number of overall collisions as well as the number of pedestrian collisions has been steadily declining in the City of Vancouver, as shown in Figure 2.1. In fact, based on ICBC data between 1996 and 2010, 2010 saw the fewest number of traffic collisions since 1996.

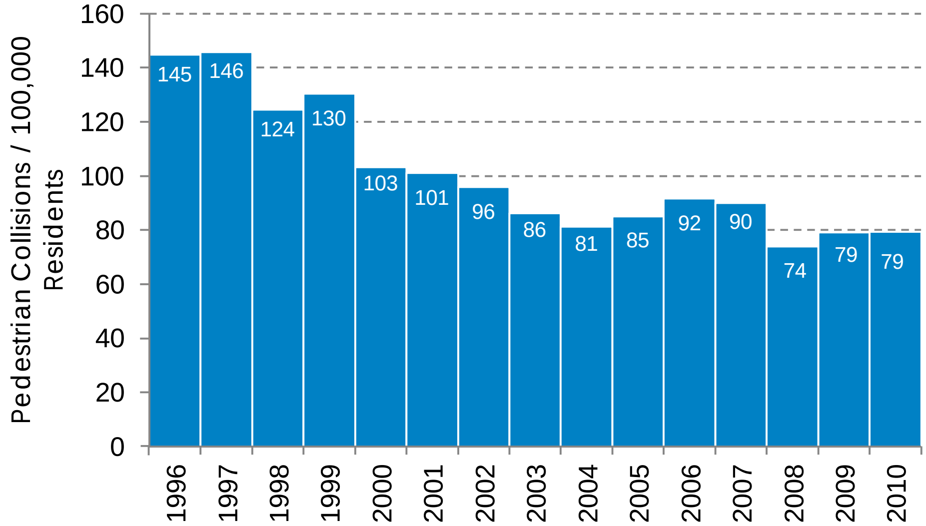
Figure 2.1
Total number of collisions and pedestrian collisions (1996 – 2010)



This decrease in the number of collisions is notable, particularly because the City's population increased significantly over this period. In fact, *despite an increase in the City's population of approximately 20% between 1996 and 2010, the total number of collisions in the City decreased by 52%, while the total number of collisions involving pedestrians declined by 34%.*

As a result, the annual pedestrian collision rate – defined as the number of pedestrian collisions per 100,000 residents – has been steadily declining since 1996. As shown in Figure 2.2, the annual pedestrian collision rate decreased by approximately 45% between 1996 and 2010, from approximately 145 to 79 pedestrian collisions per 100,000 residents.

Figure 2.2
Pedestrian Collisions per 100,000 Residents (1996 – 2010)



Although this study focuses on pedestrian collisions, it is important to recognize that pedestrians are part of a broader group commonly referred to as vulnerable road users. Vulnerable road users are generally defined as road users outside of a closed vehicle, including pedestrians, cyclists, and motorcyclists.

Between 2005 and 2010, vulnerable road users accounted for 3% of all reported collisions in Vancouver, as shown in Figure 2.3. However, vulnerable road users are particularly prone to injury and fatality, as vulnerable road users accounted for 6% of all collisions resulting in injury, and 59% of all collisions resulting in fatality, over this period in Vancouver as shown in Figure 2.4.

Even among vulnerable road users, pedestrians are particularly susceptible to injury and fatality. Pedestrians accounted for 1.8% of all reported collisions, as compared to 6% of all collisions resulting in injury, and 45% of all collisions resulting in fatality in Vancouver over this period, as shown in Figure 2.3 and Figure 2.4. Since pedestrians account for the largest percentage of traffic fatalities in Vancouver, addressing safety among this group is an important strategy to reduce traffic injuries and fatalities in general.

Figure 2.3
Collisions in Vancouver by Road User (2005-2010)

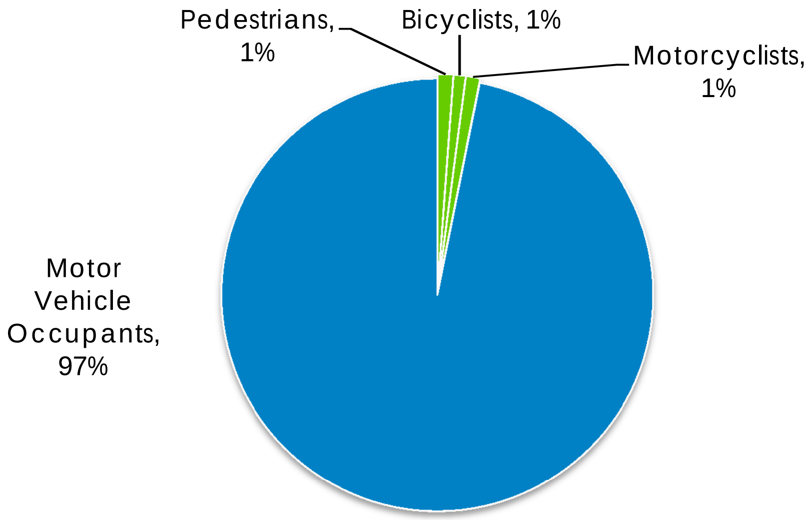
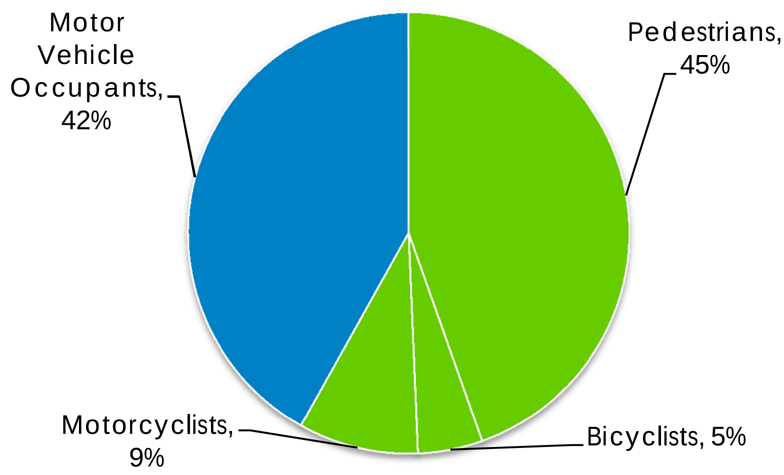


Figure 2.4
Collisions Resulting in Fatality in Vancouver by Road User (2005-2010)



2.3 Collisions in Context

To put Vancouver's collision trends in context, overall collision rates as well as pedestrian collision rates were compared with a number of other cities across British Columbia as well as elsewhere in Canada, the United States and internationally.

As shown in Table 2.1, eleven peer cities were selected from across British Columbia. These eleven cities represent some of the largest communities throughout the province in a range of contexts.

In addition, 16 peer cities were selected from across Canada, the United States and internationally. These peer cities were selected based on a range of criteria, including:

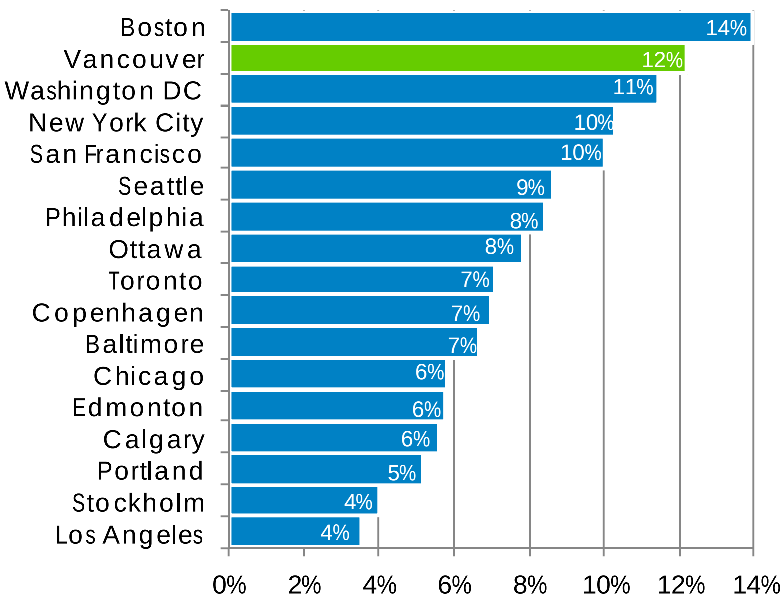
- Population of at least 500,000 residents; and
- Population density of at least 2,000 people/km^2; or
- Walking, bicycle, and transit mode share of at least 30%.

Table 2.1
Peer Cities

British Columbia	Canada	USA	Global
▪ Surrey	▪ Toronto	▪ New York	▪ Stockholm
▪ Burnaby	▪ Ottawa	▪ Los Angeles	▪ Copenhagen
▪ Richmond	▪ Calgary	▪ Chicago	
▪ Abbotsford	▪ Edmonton	▪ Philadelphia	
▪ Kelowna		▪ San Francisco	
▪ Saanich		▪ Baltimore	
▪ Kamloops		▪ Boston	
▪ Nanaimo		▪ Seattle	
▪ Victoria		▪ Washington	
▪ Chilliwack		▪ Portland	
▪ Prince George			

In comparison to the 16 Canadian and international peer cities indicated above, Vancouver has among the highest proportion of trips to work made by walking, with 12.2% of trips to work made by walking (see Figure 2.5).

Figure 2.5
Walking Mode Share of Work Trips in Canadian and International Peer Cities



Traffic and pedestrian fatalities as a proportion of population are common metrics used to assess overall traffic safety. This is often measured as the proportion of fatalities per 100,000 residents. Between 2005 and 2010, the City of Vancouver had an overall traffic fatality rate for all reported collisions of 3.3 fatalities per 100,000. This is a relatively low fatality rate as compared to most other large communities in British Columbia (as shown in Figure 2.6), as well as other peer cities across Canada and internationally (as shown in Figure 2.7). In fact, this fatality rate is lower than most other North American peer cities.

Figure 2.6
Total Fatalities per 100,000 Population (British Columbia Comparison)

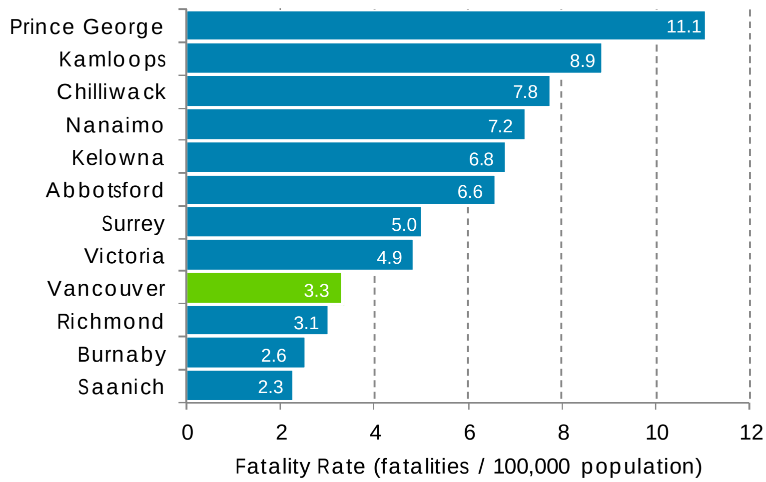
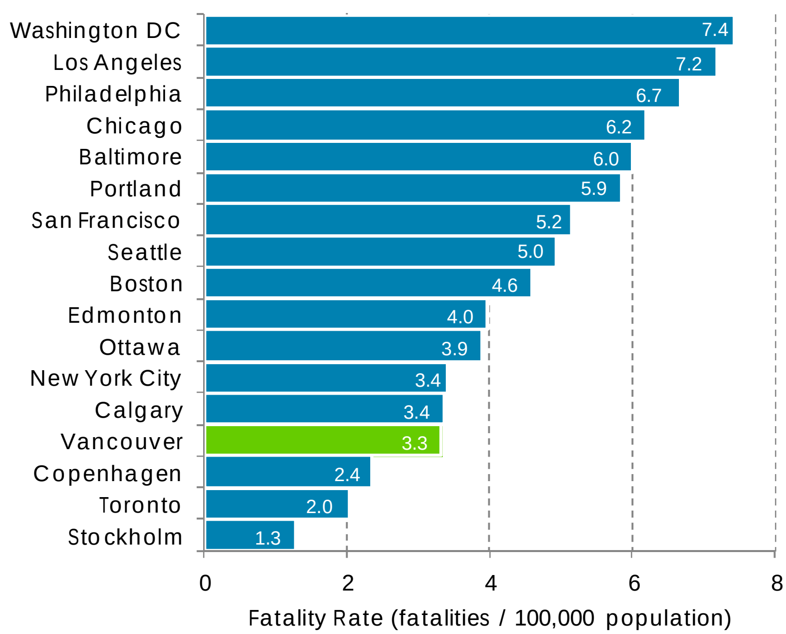


Figure 2.7
Total Fatalities per 100,000 Population (International Comparison)



When considering pedestrians in particular, there were 1.5 pedestrian fatalities in Vancouver per 100,000 residents between 2005 and 2010. This is comparable to many other large cities in British Columbia as well as many other peer cities, as shown in Figure 2.8 and Figure 2.9.

Figure 2.8
Pedestrian Fatalities per 100,000 Population (British Columbia Comparison)

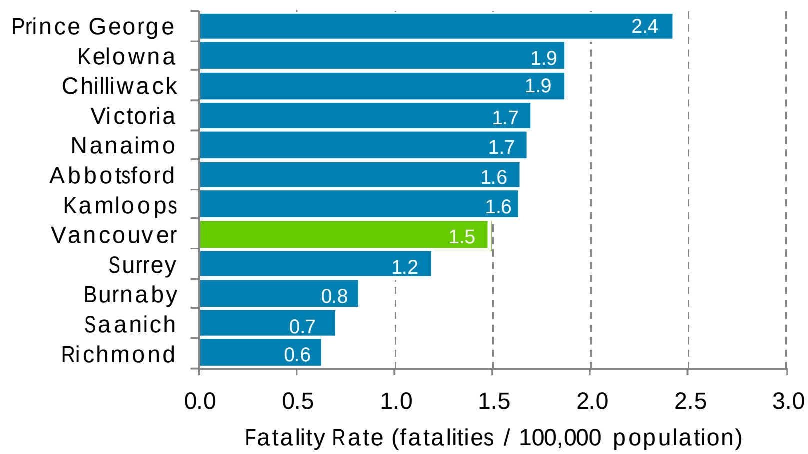
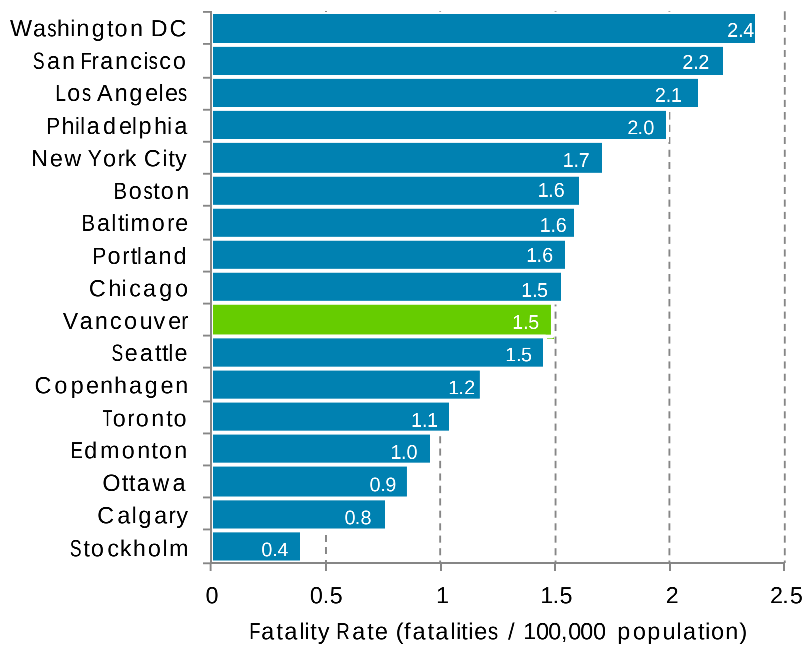
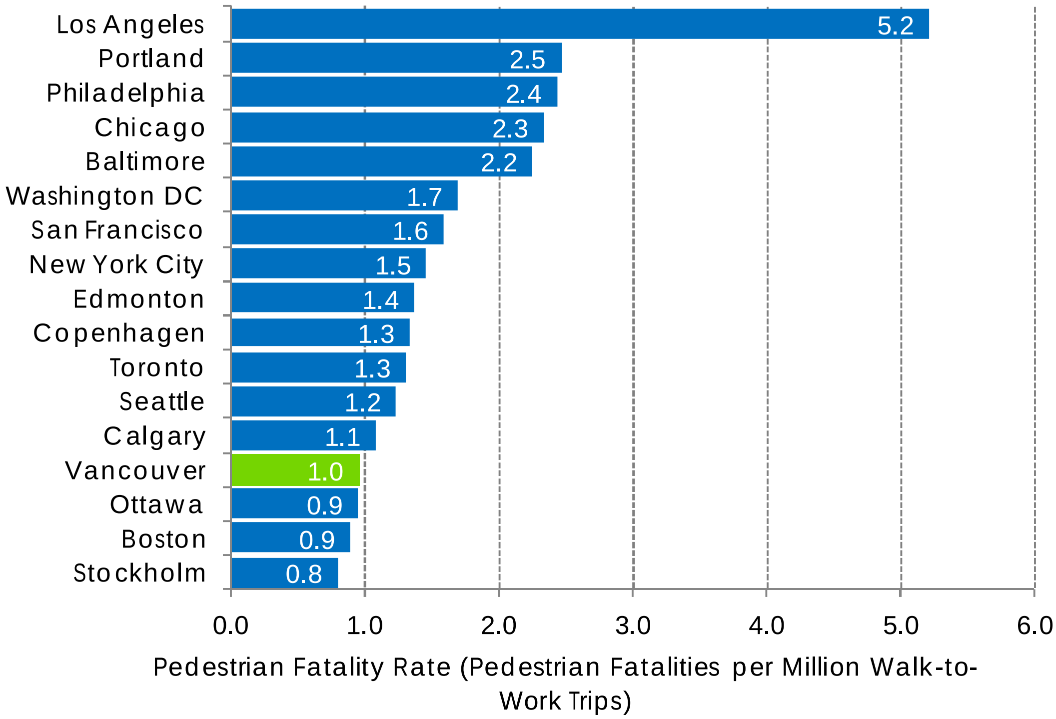


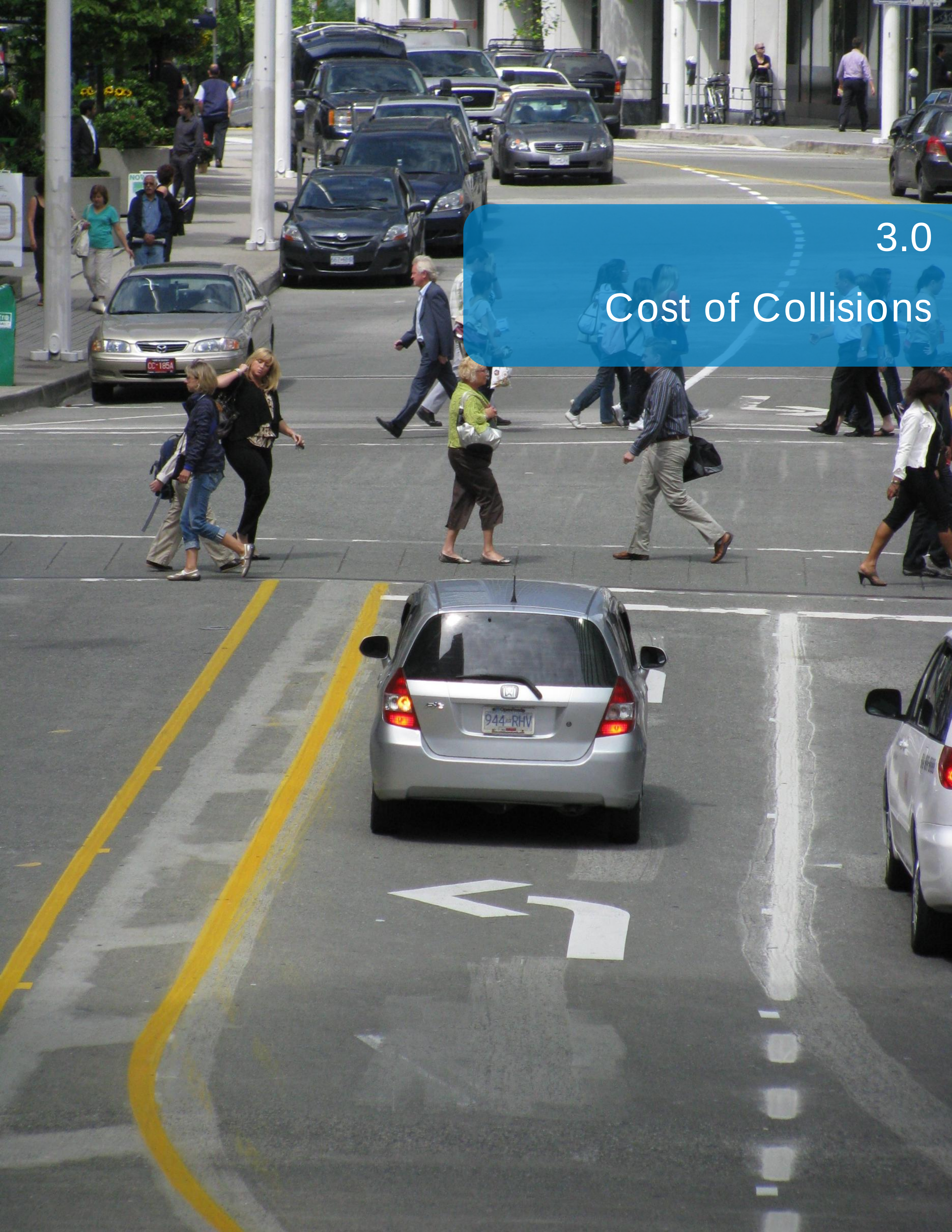
Figure 2.9
Pedestrian Fatalities per 100,000 Population (International Comparison)



When considering the number of pedestrian fatalities based on the overall number of walk to work trips, Vancouver has a pedestrian fatality rate of 1.0 pedestrian fatalities per million walk to work trips, which is relatively low compared to other peer cities, as shown in Figure 2.10.

Figure 2.10
Pedestrian Fatalities per Million Walk to Work Trips





3.0

Cost of Collisions

Every trip, regardless of mode, begins and ends with walking. It is the oldest and most efficient, affordable, and environmentally-friendly mode of transportation. Walking is also the most basic and popular form of outdoor recreational activity. Numerous studies link the "walkability" of a community to its attractiveness as a place of residence, business, and tourism.[1]

A pedestrian system that supports the replacement of vehicle trips with pedestrian trips reduces demand for the roadway network and the severity and duration of traffic congestion. Because sidewalks and street crossings serve as gateways to transit, walking is also a critical element of transit trips. Safe and convenient pedestrian facilities are essential to encourage the use of rail, bus and other transit modes for longer trips. Promoting walking is also a key element to addressing local and global public health and environmental concerns. Public and environmental health problems related to poor air quality, physical inactivity and global climate change have motivated cities to invest in pedestrian facilities to improve the health of local residents and reduce greenhouse gas emissions.

The following sections identify some of the economic, public health, sustainability, and quality of life costs associated with pedestrian safety issues.

3.1 Economic

There has been serious concern about traffic safety since the start of the automobile age, approximately twelve decades ago. In spite of this, traffic safety problems have prevailed over the past century causing enormous economic and social costs. It is commonly accepted that there are many costs associated with vehicular mobility such as air pollution, noise, visual intrusion, and collisions. However, the economic and social costs associated with road collisions greatly exceed other mobility costs due to the pain, grief, loss of property, injury, and deaths attributed to road collisions.

Road collisions are considered a global epidemic of staggering, but often overlooked consequences. Approximately 1.3 million traffic fatalities take place annually worldwide. A recent study by Transport Canada estimates that the annual cost of road collisions to the Canadian economy, including health care, environmental damage, lost productivity, and induced traffic congestion, is $CDN 62.7 billion.[2] This represents an enormous 5% of the Canadian Gross Domestic Product. This far exceeds the highly publicized traffic congestion costs estimated at $CDN 3.7 billion/year on Canadian roads.[3] All road users are

[1] For example studies and references, see "Paved with Gold: The Real Value of Good Street Design," *Commission for Architecture and the Built Environment* (2007) and "Evaluating Non-Motorized Transportation Benefits and Costs," *Victoria Transport Policy Institute* (2010)

impacted by the cost of collisions. However, non-motorized and sustainable modes of travel such as biking and walking suffer a higher level of risk because of their vulnerability. Road collisions involving non-motorized traffic are usually highly injurious and physically damaging. This is very apparent in the case of walking which is arguably the most important mode of travel.

Most of the previous work on estimating collisions cost has focused primarily on vehicle collisions. However, the recent increased interest in sustainable modes of travel such as walking raises the need for studying the cost of pedestrian collisions. Approximately 22% of fatal road collisions in Canada and 30% of fatal road collisions in British Columbia involve vulnerable road users; respectively 13% and 15% of which are pedestrians.

A description of the methodology used to estimate the average cost of pedestrian collisions in the City of Vancouver is provided in Appendix A. The estimated costs per pedestrian collision for the City of Vancouver are presented in Table 3.1. These costs include human consequences (based on the severity of the injury, resulting disability, etc.) as well as market related costs which include lost earnings, medical care, administration costs and indirect costs that are borne by other road users.

The average cost of pedestrian injury shown in Table 3.1 is a weighted average cost of all injury severities (severe, minor or disabling injury). The average cost of a pedestrian collision is estimated at $234,000 based on the ratio of 2.1% pedestrian fatalities and 97.9% injuries (based on 2005-2010 pedestrian collision data). This includes the direct human consequences costs; market-related costs such as medical care costs, administrative costs (police, ambulance, etc), and lost earnings; and indirect costs for other road users including time lost, fuel loss, and extra pollution as a result of the traffic delays associated with the collision.

Table 3.1
Pedestrian collision cost in Vancouver (2010 Canadian dollar)

Average cost of pedestrian fatality	$ 6,209,000
Average cost of pedestrian injury	$ 106,000
Weighted average cost of a pedestrian collision	$ 234,000

Based on the cost values shown in Table 3.1, the pedestrian collision costs for the City of Vancouver for the years 2005 – 2010 are shown in Figure 3.1. As indicated in Table 3.2, the total cost of pedestrian collisions in the City of Vancouver over the six year period was in excess of $760 million, or approximately $127 million per year. However, as the number of pedestrian injuries and pedestrian fatalities was significantly lower from 2008 to 2010, the average cost of pedestrian collisions between 2008 and 2010 was approximately $107 million per year.

Figure 3.1
Cost of Pedestrian Collisions in the City of Vancouver (2005 – 2010)

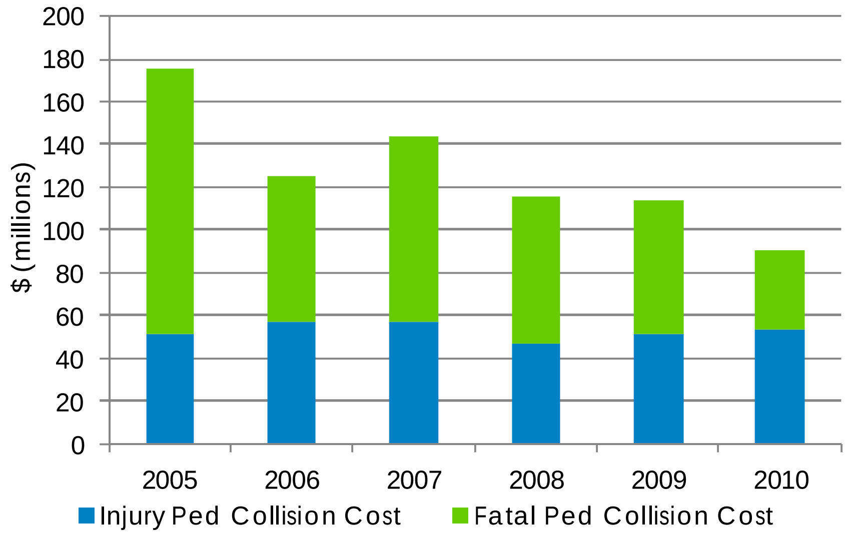


Table 3.2
Cost of Pedestrian Collisions in the City of Vancouver (2005 – 2010)

	Injury Collisions	Fatal Collisions	Total Collisions
2005	$51,304,000	$124,180,000	$175,484,000
2006	$57,134,000	$68,299,000	$125,433,000
2007	$56,710,000	$86,926,000	$143,636,000
2008	$47,170,000	$68,299,000	$115,469,000
2009	$51,622,000	$62,090,000	$113,712,000
2010	$53,424,000	$37,424,000	$90,678,000
2005 – 2010 Total	*$317,364,000*	*$447,048,000*	*$764,412,000*
2005 – 2010 Average	*$52,894,000*	*$74,508,000*	*$127,402,000*

3.2 Public health

The ability to safely access destinations on foot or to walk for recreation has important implications for public health. Indeed, the links between sedentary activity, physical inactivity and health are well known. Inactivity is not only associated with increased rates of obesity, but also a number of other related illnesses including heart disease, diabetes and hypertension. According to the report Obesity in Canada,[4] approximately one in four Canadian adults are obese, according to measured height and weight data from 2007-2009. Of children and youth aged six to 17, 8.6% are obese. Between 1981 and 2007/09, obesity rates roughly doubled among both males and females in most age groups in the adult and youth categories.

The correlation between active transportation and obesity is highlighted in Figure 3.2 below, modified from the article *Walking, Cycling, and Obesity Rates in Europe, North America, and Australia* which appeared in the Journal of Physical Activity to highlight this correlation in several countries as well as the City of Vancouver. The figure indicates that nations with higher walk, bike and transit mode share tend to have lower rates of obesity, and this pattern holds true in the City of Vancouver. In addition, as shown in Table 3.3 below, several of the leading causes of death in British Columbia are associated with a sedentary lifestyle, including cancer, heart disease, stroke and diabetes. Furthermore, accidents (unintentional injuries) are the fifth leading cause of death in British Columbia, of which traffic accidents make up approximately one third.

Figure 3.2
Relationship Between Obesity Rates and Mode Share[5]

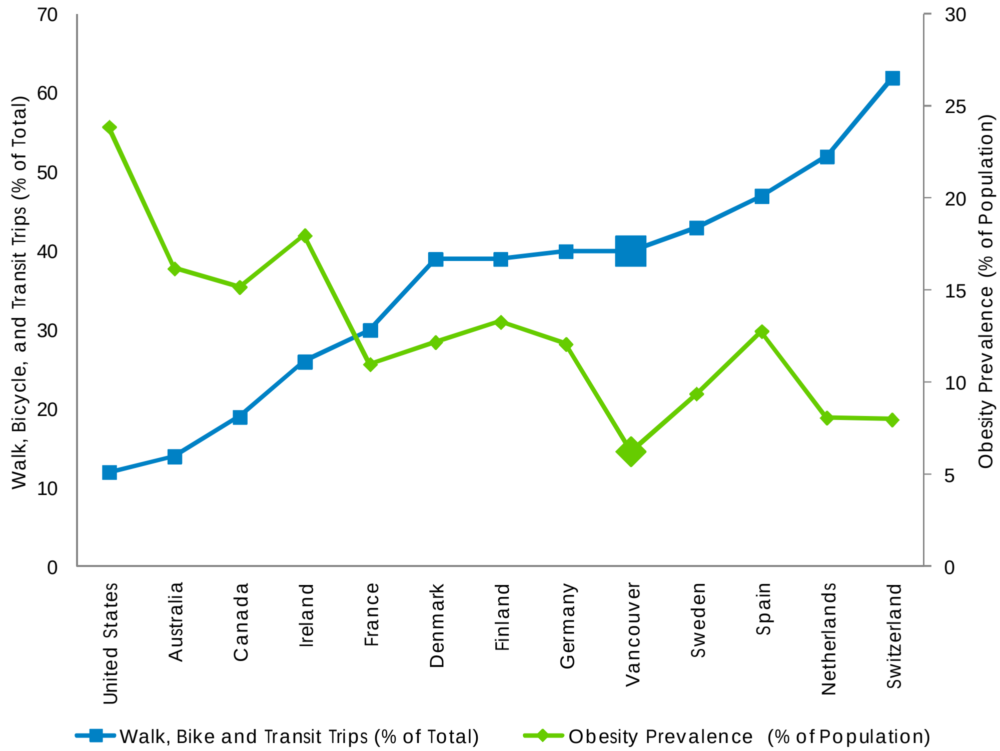


Table 3.3
Leading Cause of Death in British Columbia (2008)[6]

	Rank	Number	%
Total, all causes of death	…	238,617	100.0
Malignant neoplasms (cancer)	1	70,558	29.6
Diseases of heart (heart disease)	2	50,722	21.3
Cerebrovascular diseases (stroke)	3	13,870	5.8
Chronic lower respiratory diseases	4	10,923	4.6
Accidents (unintentional injuries)	5	10,234	4.3
Diabetes mellitus (diabetes)	6	7,521	3.2
Alzheimer's disease	7	6,573	2.8
Influenza and pneumonia	8	5,386	2.3
Nephritis, nephrotic syndrome and nephrosis (kidney disease)	9	3,846	1.6
Intentional self-harm (suicide)	10	3,705	1.6

According to the World Health Organization report *Transport, Environment and Health*[7] the health benefits of active transportation as a means to getting adequate physical exercise include:

- 50% reduction in the risk of developing coronary heart disease (a similar effect to not smoking);
- 50% reduction in the risk of developing adult diabetes;
- 50% reduction in the risk of becoming obese;
- 30% reduction in the risk of developing hypertension;
- 10/8-mmHg decline in blood pressure in people with hypertension (a similar effect to drugs);
- reduced osteoporosis;
- relief of symptoms of depression and anxiety; and
- prevention of falls in the elderly

3.3 Sustainability

Vancouver is a leader in sustainability and has a long history of planning for compact, walkable communities. Vancouver's commitment to a compact urban form not only minimizes sprawl, but creates conditions where Vancouver residents and visitors can access desired goods and services through multiple modes, including walking and public transport. Since 1996, the city has seen a 44% increase in walking, a 180% increase in bicycle trips, a 20% increase in transit use, and a 10% reduction in vehicle trips.[8] Walking and public transport provide important environmental benefits, through improved air quality and reductions in transportation sector generated greenhouse gas emissions.

Real and perceived safety risks associated with walking have a significant impact on how people choose to travel. This is especially true for children and seniors. Safety is one reason that many parents do not allow their children to walk to school. Seniors can be challenged to cross busy streets and face increased risk of not surviving a pedestrian crash. As a result, children and seniors are often transported by automobile, paratransit, etc., with impacts to both personal health and the environment.

The City of Vancouver recently adopted its Greenest City 2020 Action Plan (GCAP), which identifies actions to create a greener and more environmentally sustainable future for the city. Recognizing that a safe and comfortable walking environment is critical for encouraging more people to travel by foot or on transit, the plan identifies the development of this Pedestrian Safety Action Plan as one of the Highest Priority Actions identified in the Green Transportation section. Improved pedestrian safety will help Vancouver attain its sustainability goals of a reduced carbon footprint, reduced dependence on fossil fuels and lower greenhouse gas emissions. Specific goals from the plan that relate to walking and pedestrian safety include:

- Goal 2 - 'Eliminate dependence on fossil fuels.'
- Goal 4 (Green Transportation) - 'Make walking, cycling, and public transit preferred transportation options.'

Continuing to improve pedestrian safety is essential if Vancouver is to build on its success of promoting alternative transportation as a means to reduce greenhouse gas emissions.

3.4 Quality of life

A vibrant pedestrian environment is a defining feature of many global cities, helping to create spaces for social interaction and civic life. It is widely documented that people prefer to live in walkable communities and that pedestrian amenities contribute to the livability of a city. Unsafe walking conditions reduce the attractiveness and use of the mode in the urban realm, with the impact that only the heartiest or transit dependent are willing to choose pedestrian travel.

Unsafe walking conditions have a particular impact on those residents without private automobile access including children, the elderly and the economically disadvantaged.

For example, at the national level between 2004 and 2008, 35% of fatally injured pedestrians were aged 65 or older even though they represent only 13% of the population.

Children are largely dependent upon walking. Pedestrian travel was the fourth leading cause of unintentional deaths among Canadian children aged 0-14 years, representing 12% of child fatalities. Also at the national level, 6% of fatally injured pedestrians were under the age of 16.

4.0 Collision Analysis

This chapter summarizes the methods that were used for the collision analysis, and presents the results of the analysis. It includes a description of the data used for the analysis as well as the limitations.

4.1 Methods

This study conducted an in-depth analysis of all reported collisions occurring involving pedestrians in the City of Vancouver between 2005 and 2010. The analysis only included reported collisions on public streets, and did not include any reported collisions in private parking lots. The analysis examined WHEN collisions took place, WHO was involved in the collisions, WHERE they took place, and HOW the collision occurred.

This section describes the data that was used for the analysis as well as the limitations of the analysis.

4.1.1 Data Sources

The analysis required the assembly, documentation and manipulation of a number of datasets from a variety of sources, as described below.

- Collision Data
  - ICBC Data. The Insurance Corporation of British Columbia (ICBC) collects and maintains statistics for all reported collisions in British Columbia. The collision data classifies collisions based on the type of collision as follows: fatality, injury, or property damage only, and also identifies collisions involving pedestrians or cyclists. The City provided this dataset for all collisions reported to ICBC in the City of Vancouver between 2005 and 2010. This dataset includes:
    - ICBC Incident Number
    - Incident Date and Time
    - Incident Location (Primary Street and Cross Street)
    - Incident Description
    - Intersection or Mid-Block Classification
    - Severity (Fatality, Injury, Property Damage Only)
    - Parking Lot Flag
    - Bicycle Flag
    - Pedestrian Flag
  - VPD Data. The Vancouver Police Department (VPD) also collects and maintains statistics for all collisions reported to the police. The City

provided this dataset for all fatalities resulting from collisions between 1992 and 2011 and all injuries resulting from collisions between 2005 and 2010. This dataset includes:

- VPD Incident Number
- Incident Date
- Incident Time (injuries only)
- Fatality Date (fatalities only)
- Incident Location
- Gender of Victim
- Age of Victim
- Victim Type (driver, passenger, pedestrian, bicyclist, or motorcyclist)

It should be noted that the City considers the VPD dataset as the official record of all traffic-related fatalities, and the ICBC dataset as the official record of all other collisions. The ICBC and VPD datasets do not always correspond directly to each other, as not all incidents are reported both ICBC and the VPD.

- Infrastructure
  - Road Network. This dataset was provided by the City and includes centreline data for public streets, alleyways, and non-public streets as well as intersections. The dataset includes road classification as Primary Arterial, Secondary Arterial, Collector, or Local roads and also identifies one-way streets.
  - Traffic Signals. This dataset was provided by the City and contains the location and types of the City's traffic signals.
  - Traffic Circles. This dataset was assembled based on the City's traffic circles dataset and was validated and updated using the Orthophoto data.
  - Bicycle routes. This dataset was assembled based on the City's Bikeways dataset and published bicycle route map and includes the location and type of bicycle facility, including local street bikeways, painted bicycle lanes, painted shared use lanes, and separated bicycle lanes.

- Spatial
  - Neighbourhoods. This dataset was provided by the City and contains the boundaries, names, residential population, and employment for the City's 22 local areas.
  - Traffic Analysis Zones. Boundaries were generated from the regional Emme transportation model

- Orthophoto. This dataset was provided by the City and includes orthophotos captured in April 2009.

- Exposure
  - Intersection Turning Movement Counts. This dataset was provided by the City and contains motor vehicle, pedestrian, and bicycle counts as collected by City staff at intersections. Counts are conducted by lane and direction, typically over a 2-hour period in both the AM and PM peak periods.

- Other
  - Weather. This dataset was obtained from the Environment Canada National Climate Data and Information Archive for the City of Vancouver for all days between January 1, 2005 and December 31, 2010. This data includes both hourly weather and daily weather. The hourly weather dataset includes the date and time, temperature, relative humidity, wind direction, wind speed, visibility, and weather description (ie cloudy, rain, snow), among other features. The daily weather dataset includes the date, maximum temperature, minimum temperature, mean temperature, daily rainfall, and daily snowfall, among other features.
  - Light Conditions. This dataset was obtained from the National Research Council Canada Sunrise / Sunset Calculator for the City of Vancouver for all days between January 1, 2005 and December 31, 2010. This data includes nautical twilight start, civil twilight start, sunrise, local noon, sunset, civil twilight end, nautical twilight end, and total hours of illumination for each day.
  - Demographics. Residential and employment data were provided for the year 2006 for each of the City's 22 local areas. Residential and employment data were for provided for the year 2008 for the Traffic Analysis Zones (TAZs) from the regional Emme transportation model.

4.1.2 Data Limitations

There were a number of limitations to the study based on the data availability. Notably, ICBC and VPD data only includes reported pedestrian collisions involving motor vehicles. It is likely that there are a significant number of pedestrian collisions that are not reported to ICBC or VPD which are not included in the data. In addition, this data does not include 'near misses' or pedestrian collisions that do not involve a motor vehicle, such as collision between a bicycle and pedestrian. It should also be noted that there are discrepancies between ICBC and VPD data, as not all collisions are reported to both agencies, particularly if the collision did not result in a fatality. Finally, the collision data did not include a number of attributes, such as driver attributes (i.e. age, gender, place of residence), alcohol consumption, vehicle type, or contributing factors.

4.2 Findings

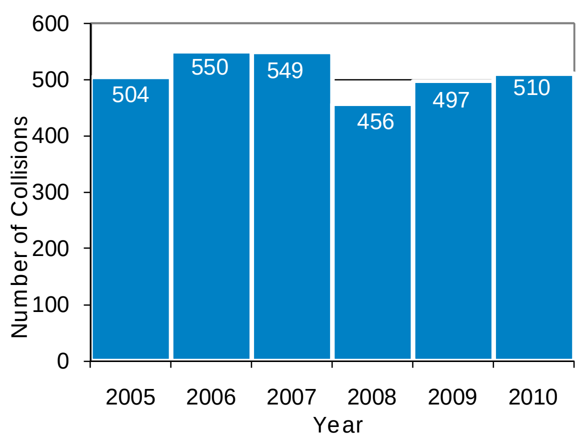
This section describes the results of the analysis, including WHEN collisions took place, WHO was involved in the collisions, WHERE the collisions were occurring, and HOW the collision occurred.

4.2.1 When

- **Annual**

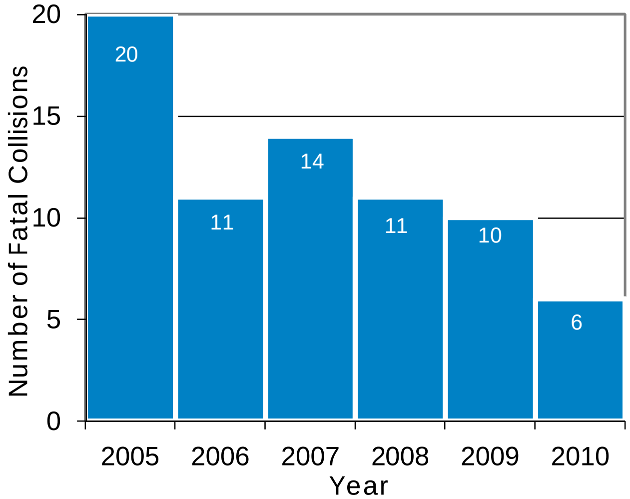
There were 3,066 reported collisions involving pedestrians between 2005 and 2010, representing an average of 511 reported pedestrian incidents per year. Overall, the number of pedestrian collisions has remained relatively constant over the past six years, with a slight decrease in 2008, as shown in Figure 4.1.

Figure 4.1
Pedestrian collisions by year (2005 – 2010)



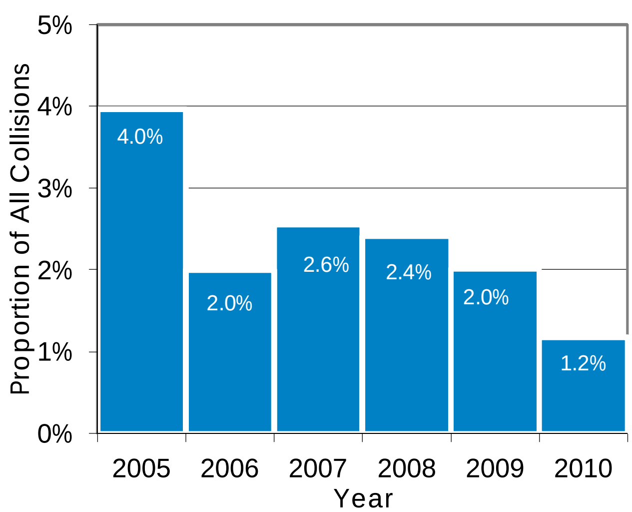
Of the 3,066 total collisions, 2,994 incidents resulted in injuries, and 72 resulted in fatalities, equivalent to approximately 12 pedestrian fatalities per year. Overall, the number of pedestrian fatalities has been declining since 2005, as shown in Figure 4.2.

Figure 4.2
Pedestrian fatalities by year (2005 – 2010)



With 72 fatalities out of 3,066 pedestrian collisions, on average of approximately 2.3% of all pedestrian collisions resulted in a fatality over the past six years. With a relatively constant number of overall collisions but declining number of fatalities, the proportion of collisions resulting in fatality has been declining over the past several years. Approximately 1.8% of collisions resulted in a fatality between 2008 and 2010. This is nearly half the fatality rate between 2005 and 2007, when approximately 2.8% of collisions resulted in a fatality, as shown in Figure 4.3.

Figure 4.3
Proportion of collisions resulting in fatality (2005 – 2010)



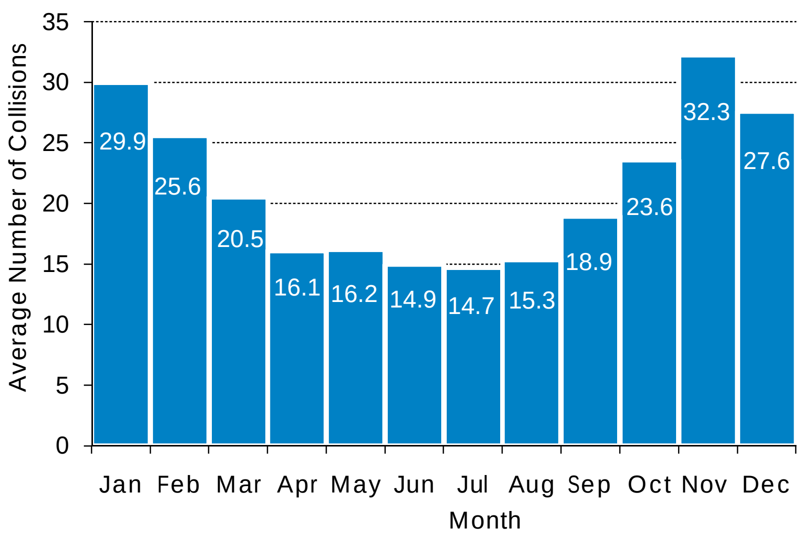
- Monthly

With an average of 511 reported pedestrian collisions per year over the past six years, on average there are approximately 42.6 pedestrian collisions per month in the City of Vancouver.

However, as shown in Figure 4.4, pedestrian collisions in Vancouver follow a distinct seasonal pattern. *Nearly half (45%) of all pedestrian collisions occur between November and February*, even though this only represents one third of the year. In particular, all four of these months have an average of 25 or more collisions per month per year, whereas no other month in the year has reached this number of average collisions. In fact, the average number of monthly collisions between November and February (28.9) is approximately 65% higher than the average number of monthly collisions during remaining eight months of the year (17.5).

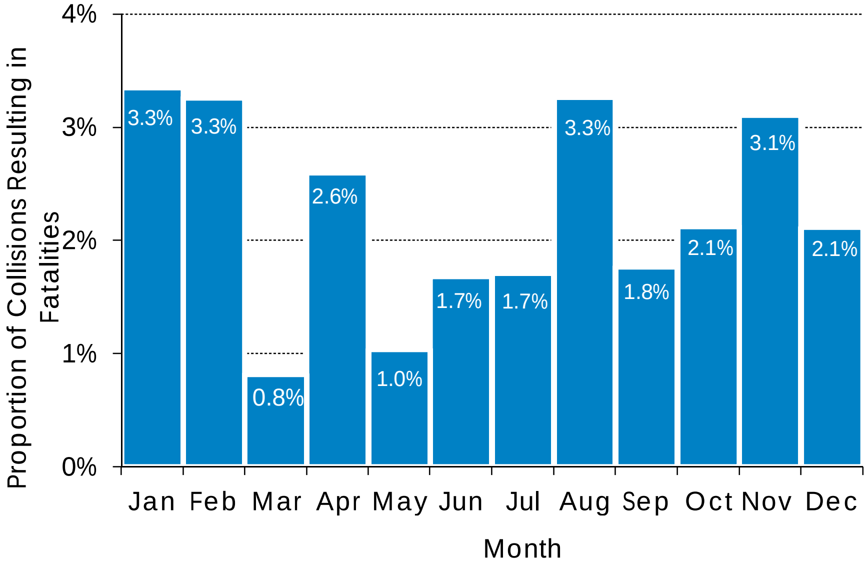
Similarly, *over half (52.4%) of pedestrian fatalities occurred between November and February*, with January alone accounting for the most significant number of fatalities (22.2% of all fatalities occurred in January).

Figure 4.4
Average Annual Pedestrian Collisions by Month (2005 – 2010)



As shown in Figure 4.5, the *month of January accounts for the highest proportion of pedestrian collisions resulting in fatalities*, with fatalities occurring in over 3.3% of all collisions involving pedestrians, nearly double the overall average of 2.3% of pedestrian collisions resulting in fatalities. This is followed closely by the months of February and August, which both had slightly less than 3.3% of all pedestrian collisions resulting in fatalities.

Figure 4.5
Proportion of Fatal Pedestrian Collisions by Month (2005 – 2010)

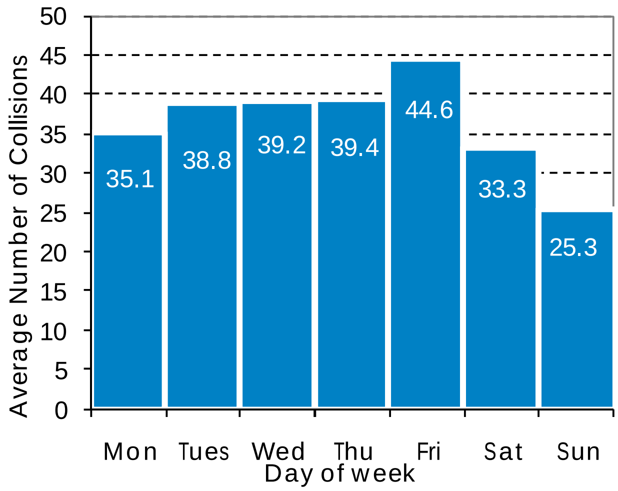


- Day of Week

Pedestrian collisions are more likely to occur on weekdays. As shown in Figure 4.6, over three quarters (77.1%) of all reported pedestrian collisions occurred on weekdays. On average, approximately 35% more pedestrian collisions occurred on weekdays compared to weekends (39.4 average collisions on weekdays compared with 29.3 on weekdays). Studies in other cities have found similar results, and suggest that these higher collision numbers may be attributed to increased pedestrian and motor vehicle volumes on weekdays.

More specifically, the highest number of collisions tended to occur on Fridays, with 17.4% of all pedestrian collisions, while Sundays accounts for the fewest number of pedestrian collisions.

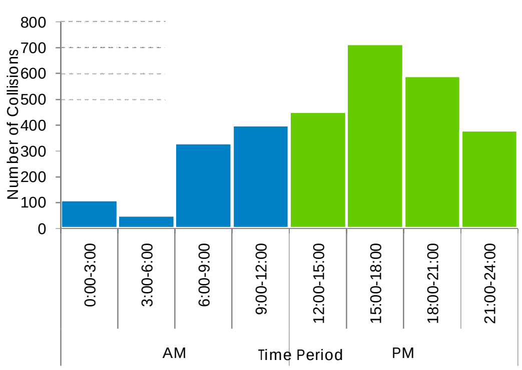
Figure 4.6
Average Annual Pedestrian Collisions by Day of Week (2005 – 2010)



- Time of Day

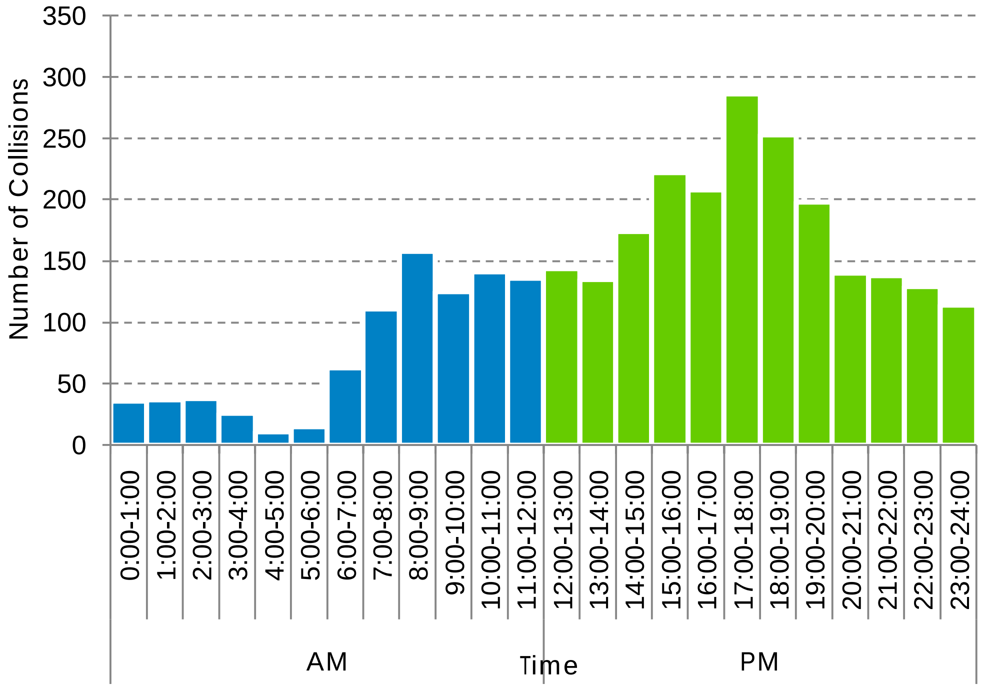
As shown in Figure 4.7, most pedestrian collisions in the City of Vancouver occur during the afternoon, with over two-thirds (70.5%) of all pedestrian collisions occurring between 12:00 noon and 12:00 midnight. More specifically, *the highest concentration of pedestrian collisions occurs during the PM peak period of 3:00 to 6:00pm*, which accounts for nearly a quarter (23.6%) of all pedestrian collisions, and nearly a third (30%) of all pedestrian fatalities. The evening period of 6:00 to 9:00pm also has a high proportion of collisions (19.5%). Together, 43% of all pedestrian collisions occur between 3:00 and 9:00pm.

Figure 4.7
Total Pedestrian Collisions by Time Period (2005 – 2010)



As shown in Figure 4.8, on an hourly basis, the highest proportion of pedestrian collisions is between 5:00 and 6:00pm, with 9.4% of collisions, followed by 6:00-7:00pm with 8.3% of all collisions.

Figure 4.8
Total Pedestrian Collisions by Hour (2005 – 2010)



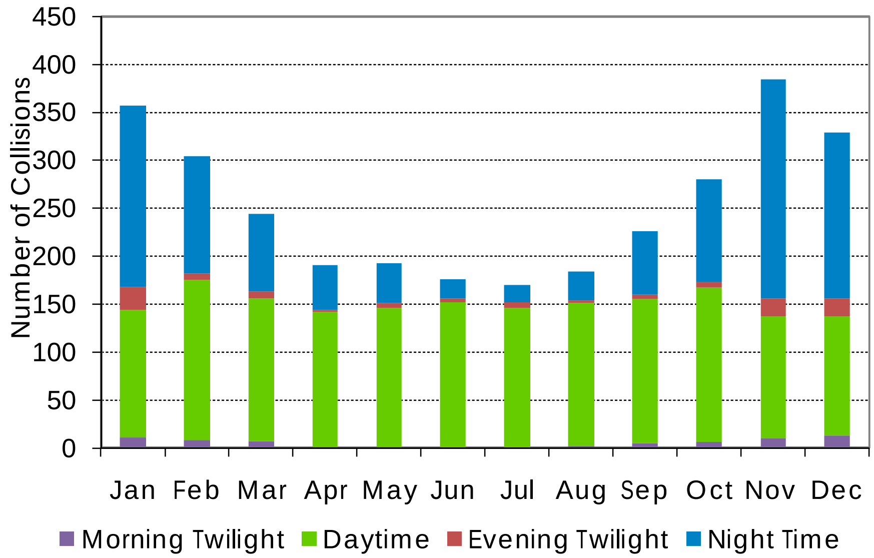
Of particular note is that *although late night pedestrian collisions are relatively infrequent, they are nearly twice as likely to lead to a fatality compared with other time periods.* Although only 5.4% of all pedestrian collisions occur during the overnight period between 12:00 and 6:00am, this time period accounts for approximately 10% of all pedestrian fatalities.

- Light Conditions

As noted previously, most collisions involving pedestrians occur in the winter months between November and February. However, when light conditions are taken into account, it is clear that *most of the increase in collisions in winter months can be attributed to the increase in nighttime collisions as a result of the shorter days and longer nights.* In fact, the number of collisions occurring during the day remains relatively constant throughout the year, with a significant increase in nighttime collisions between October and March, as shown in Figure

4.9. Overall, approximately 57% of all pedestrian collisions throughout the year occurred during daylight conditions, with approximately 37% occurring in dark conditions.

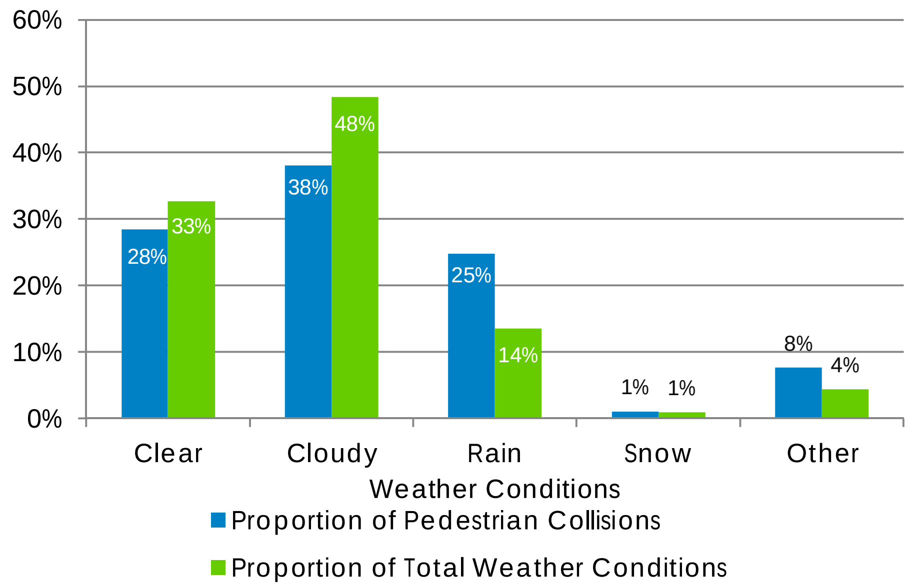
Figure 4.9
Total Pedestrian Collisions by Month and Light Conditions (2005 – 2010)



- ## Weather

The weather conditions associated with each pedestrian collision were determined based on hourly weather data provided by Environment Canada's National Climate Data and Information Archive for the City of Vancouver for all days between January 1, 2005 and December 31, 2010. Based on this dataset, it was possible to determine the weather conditions on an hourly basis between 2005 and 2010. As shown in Figure 4.10, approximately two-thirds (66%) of pedestrian collisions occurred on sunny or cloudy days (28% and 38% of all pedestrian collisions, respectively), However, pedestrian collisions are underrepresented in these weather conditions when compared to the proportion of time over the past six years that was either clear or cloudy (81%). In contrast, there is a high proportion of pedestrian collisions in rainy weather conditions (25%) compared to the overall number of hours when it was raining (14%).

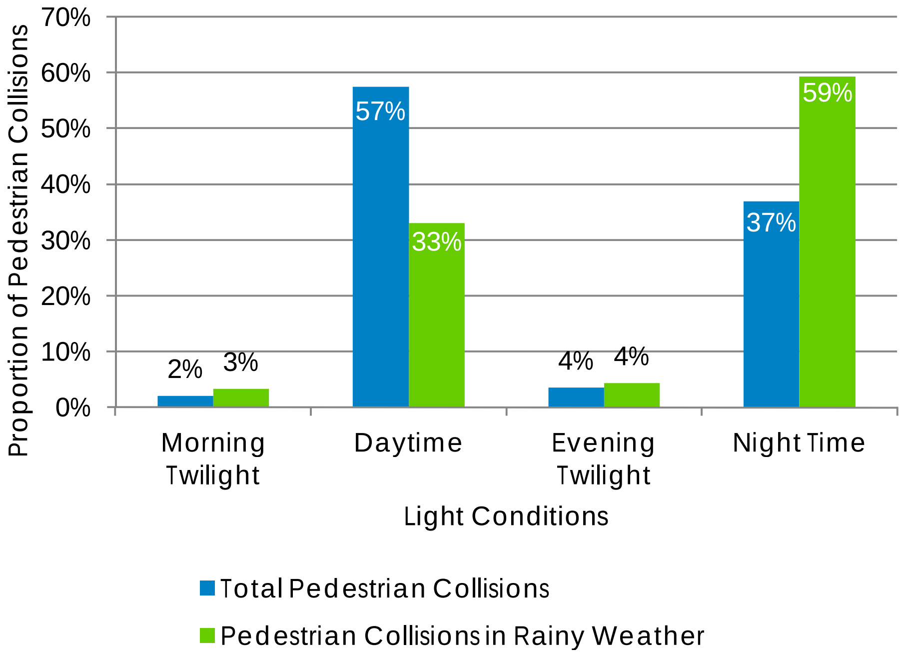
Figure 4.10
Total Pedestrian Collisions by Weather Conditions (2005 – 2010)



Note: 'Other' represents a combination of weather conditions

Additionally, a high proportion of collisions in rainy weather occur in dark light conditions. As shown in Figure 4.11, although in total only 37% of pedestrian collisions occur in dark lighting conditions, approximately 59% of collisions in rainy weather occur in dark lighting conditions. Not surprisingly, *this suggests that pedestrians are particularly vulnerable when it is both dark and rainy.*

Figure 4.11
Pedestrian Collisions on in Rainy Weather by Light Conditions (2005 – 2010)



4.2.2 Who

This section provides summarizes demographic information for pedestrians who were involved in reported collisions. It should be noted that age and gender data was only provided by the VPD data, and this information was not included in the ICBC data. As such, although the analysis elsewhere in this study is based primarily on ICBC data, this section is based on VPD data. As noted previously in the data limitations, these two datasets do not always correspond to each other. However, general observations about the age and gender of the pedestrians are provided. It should also be noted that no demographic data was available for the drivers involved in the reported collisions involving pedestrians.

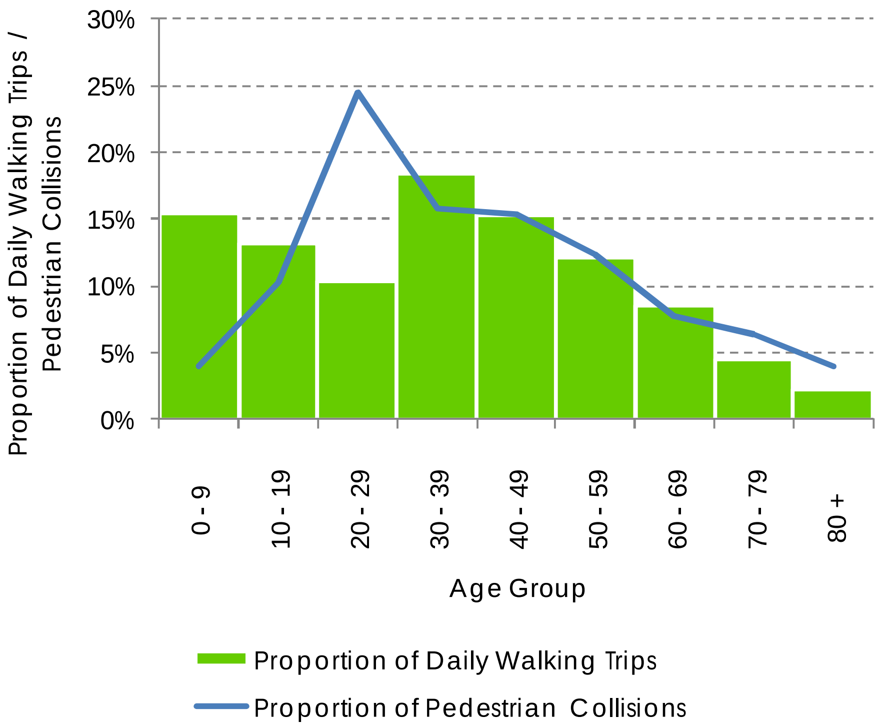
- Age

The highest proportion of collisions involving pedestrians are among young adults between the ages of 20 and 29. In fact, nearly a quarter (24.4%) of the pedestrians involved in reported collisions are between the ages of 20 and 29. This is higher than can be expected based on the distribution of population, as the 20 to 29 age group only represents approximately 16.8% of City of Vancouver residents. Several other studies have found similar results and have suggested that this may be because this age group may be more likely to engage in risky behaviour (such as risky crossings) and also may be more likely to have been drinking alcohol, although it should be noted that such alcohol data was not available for this study.

Further, although the number of collisions is highest among the 20 to 29 age group, this is not necessarily because more people in this age group are walking. In fact, as shown in Figure 4.12, although the 20 to 29 age group accounts for nearly a quarter of all pedestrian collisions, according to the 2008 Metro Vancouver Regional Trip Diary Survey this age group accounts for only 10.4% of all daily walking trips originating in the City of Vancouver.

In contrast, although children aged 9 and under account for a significant proportion of daily walking trips in the City of Vancouver (15.4%), this age group accounts for a very small proportion of pedestrian collisions (3.9%). The proportion of daily walking trips and proportion of pedestrian collisions is relatively similar among most other age groups.

Figure 4.12
Age Distribution of Pedestrian Collisions Compared to Distribution of Daily Walking Trips



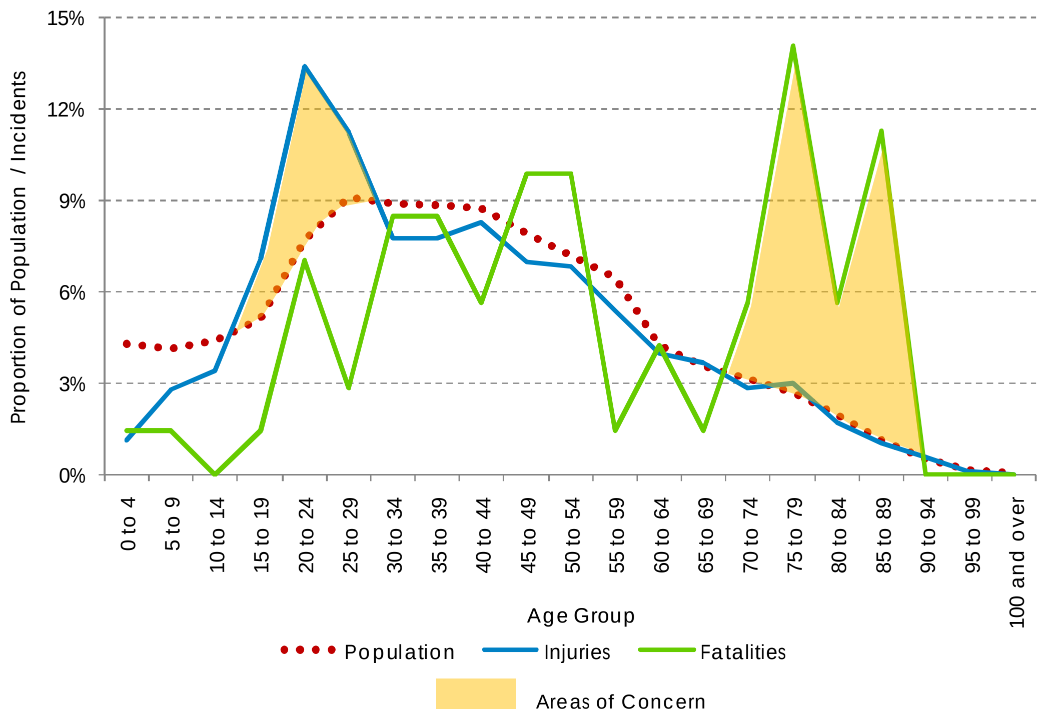
Further, the distribution of collisions by age group varies based on whether the collision resulted in an injury or fatality. Figure 4.13 illustrates the age distribution of pedestrian injuries and fatalities compared to the overall population distribution.

For example, although people aged 65 and under account for the vast majority of all collisions involving pedestrians (85.1%), which is generally consistent with their population distribution (86.9% of the population are under age 65), this group only accounts for 62% of all pedestrian fatalities.

However, *although there is a high proportion of collisions resulting in injury among the 20 to 29 age group (24.6%) compared to the overall population distribution (16.8%), this age group represents a smaller proportion of fatalities (9.9%) than would be expected based on the population distribution*.

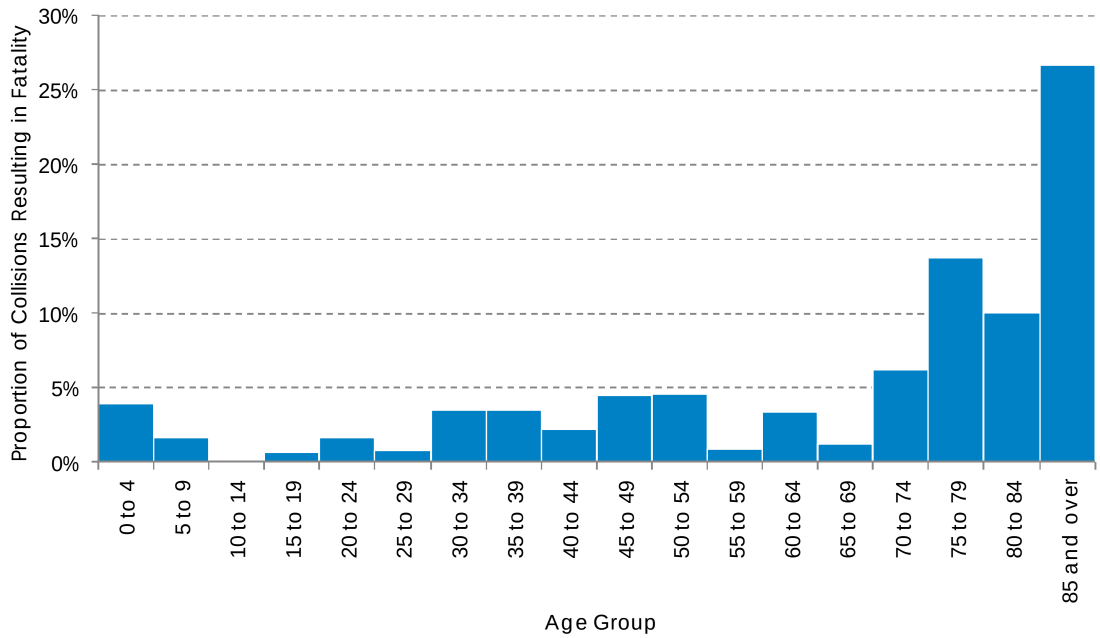
In contrast, *seniors experience a significantly higher proportion of fatalities than the overall population distribution*. In fact, although seniors aged 65 and over represent 13.2% of the population and account for 14.1% of all pedestrian collisions resulting in injury, this age group accounts for 38% of all pedestrian fatalities.

Figure 4.13
Proportion of Pedestrian Injuries and Fatalities Compared to Overall Population Distribution



In fact, as shown in Figure 4.14, *approximately 14% of collisions involving someone aged 75 years or over results in fatality*. This increases to 26.7% of collisions resulting in fatality for people aged 85 and over. This is likely a result of increased physical fragility among these age groups which results in a higher risk of dying if a collision occurs.

Figure 4.14
Proportion of Collisions Resulting in Fatality by Age Group



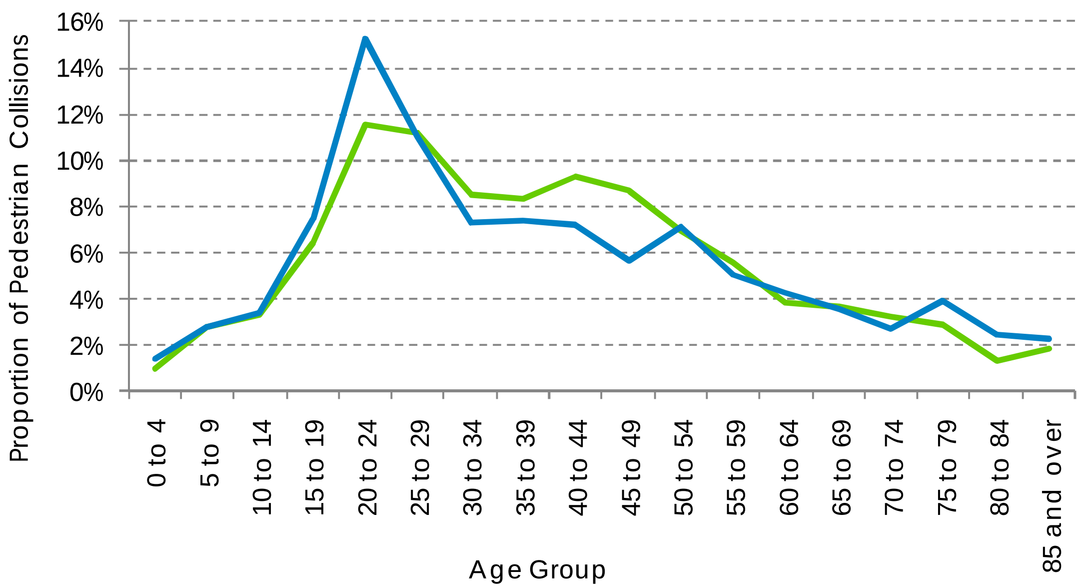
- **Gender**

Overall, there is a relatively even distribution of pedestrian collisions involving males and females, with 50.3% of pedestrian collisions involving males and 49.7% involving females. This is generally consistent with the City of Vancouver's population distribution, as approximately 48.9% of the City's population is male, compared to 51.1% of the population being female.

As noted above, young adults are most likely to be involved in a pedestrian collision and, as shown in Figure 4.15, this is true for both males and females. However, *among females, the number of collisions among the 20 to 29 age group are particularly high, accounting for over a quarter (26.2%) of all collisions involving females*, with the highest proportion being among females aged 20 to 24 in particular, as 15.2% of all collisions involving females are in this age group.

Similarly for males, the 20 to 29 age group is the highest age cohort among collisions involving males, although this accounts for a smaller proportion of collisions than females (22.7%). In contrast to females, there is also a significant proportion of collisions among the 30 to 39 and 40 to 49 age group among male collisions.

Figure 4.15
Distribution of Pedestrian Collisions by Age and Gender



In contrast to the relatively even distribution of overall pedestrian collisions among males and females, *males are somewhat more likely to be involved in a collision resulting in fatality*. 54.9% of all pedestrian fatalities involved males, compared to 45.1% females.

4.2.3 Where

This section describes the spatial distribution of pedestrian collisions between 2005 and 2010, at a variety of scales, ranging from City-wide and neighbourhood patterns, to the identification of specific collision prone zones and locations.

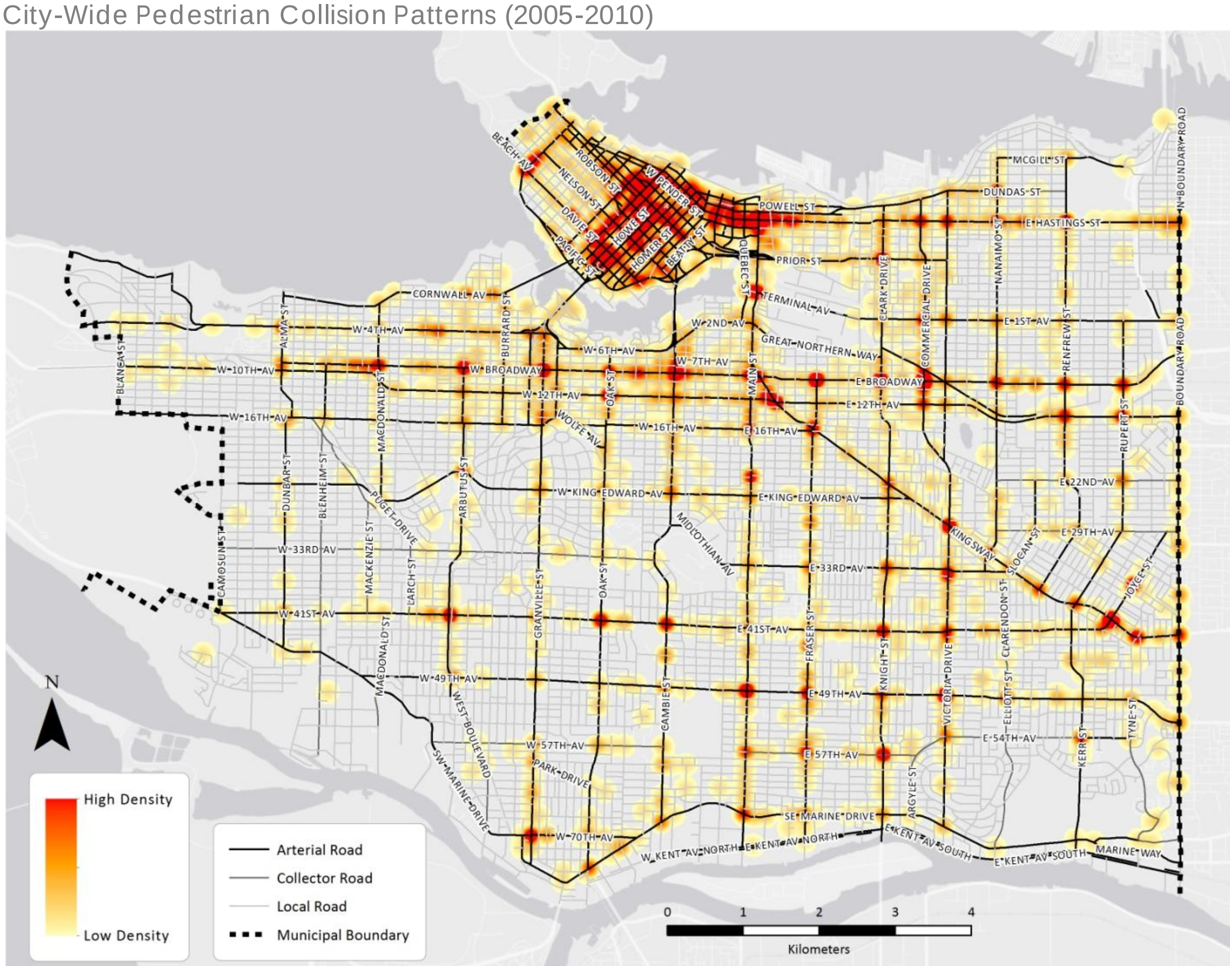
- City-Wide Patterns

Pedestrian collisions are distributed throughout the City, with a high concentration of collisions in particular in the Downtown core and along arterial roads. Figure 4.16 uses a cluster mapping methodology to graphically represent concentrations of pedestrian collisions. The process used in this exercise is known as Kernel Density, wherein a smooth, curved surface is fitted over each collision location. Total collisions within a 150 metre radius of each collision record were calculated and the figure shows the resulting range of low to high collision density areas. Higher collision areas are shown in red and indicate "hot spots" of pedestrian collision activity. As shown in this figure, there is a *high concentration of* *collisions in particular in the Downtown core as well as along Primary Arterial streets* such as Broadway, 12th Avenue, 41st Avenue, Kingsway, Hastings Street, Main Street, Fraser Street, Knight Street, and Commercial Drive, among others.

- ### Intersection vs mid block collisions

The vast majority of pedestrian collisions in the City of Vancouver occurred at intersections. In fact, *approximately 75% of all collisions were located at intersections, compared to just 25% of collisions at mid-block locations*. This is likely a result of the City of Vancouver's relatively dense grid street network pattern, as relatively small block sizes and the grid pattern found throughout much of the City results in a high intersection density and encourages crossing at intersections. In addition, the majority of streets in the City have sidewalks, which makes the incidence of mid-block collisions where pedestrians are forced to walk along the street relatively rare.

Figure 4.16
City-Wide Pedestrian Collision Patterns (2005-2010)



- Collisions by Street Classification

The majority of pedestrian collisions occurred on arterial streets. As shown in Table 4.1, for intersection collisions, over a third of all pedestrian collisions (35.1%) occurred at intersections of two primary arterial streets, and over half (50.3%) of all pedestrian collisions occurred at intersections of primary or secondary arterial streets. Similarly, over half (55.6%) of mid-block collisions occur on arterial streets, while nearly two-thirds (65.8%) of mid-block collisions occurred along primary or secondary arterial streets.

Table 4.1
Pedestrian Collisions by Street Classification (2005 – 2010)

	Primary Arterial	Secondary Arterial	Collector	Local	TOTAL
Primary Arterial	35.1%	7.9%	0.8%	13.1%	57.0%
Secondary Arterial	4.3%	2.9%	1.0%	6.0%	14.2%
Collector	0.9%	0.6%	0.1%	0.3%	1.9%
Local	14.1%	5.5%	0.6%	6.5%	26.8%
Total Intersection	54.4%	16.9%	2.6%	26.0%	100%
Total Mid-Block	55.6%	10.2%	3.8%	30.5%	100%

- Collisions by Traffic Control

The majority of collisions at intersections occur at signalized intersections. There are nearly 13,000 intersections throughout the City, 466 of which have full traffic signals, or approximately 3.6% of all intersections in the City. However, as shown in Figure 4.17 and Table 4.2, approximately 61% of collisions at intersections occurred at a signalized intersection. Approximately a quarter (25%) of pedestrian collisions occurred at unsignalized intersections.

Figure 4.17
Pedestrian Collisions by Type of Traffic Control (2005 – 2010)

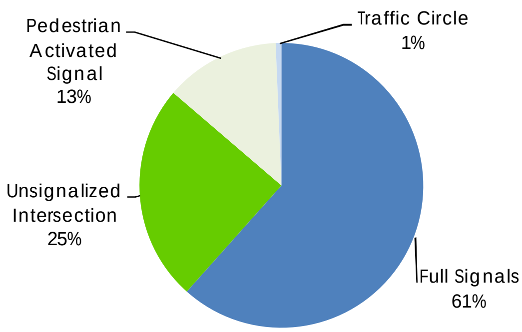


Table 4.2
Comparison of Intersection Controls and Pedestrian Collisions by Type of Control (2005 - 2010)

Intersection Control	Total Intersections		Pedestrian Collisions	
	#	%	#	%
Full Traffic Signal	466	3.6%	1657	61.5%
Pedestrian Activated Signal	343	2.6%	352	13.1%
Traffic Circle	200	1.5%	18	0.7%
Unsignalized	Approx. 12,000	92.3%	663	24.6%
Special Crosswalk	9	0.06%	6	0.2%
Total	Approx. 13,000	100%	2690	100%

Approximately 13% of all pedestrian collisions at intersections occurred at locations with pedestrian activated signals. There are 343 pedestrian activated signals throughout the City. 352 pedestrian collisions occurred at 191 locations throughout the City over this period. As such, pedestrian collisions were reported at over half (55.7%) of all locations with pedestrian activated signals. Table 4.3 highlights the pedestrian activated signals with the highest number of pedestrian collisions over this period.

Table 4.3
Top Pedestrian Collision Locations at Pedestrian Activated Signals (2005 – 2010)

Primary Street	Cross Street	Total Number of Pedestrian Collisions		
		Injuries	Fatalities	Total
East Hastings Street	Jackson Avenue	7	0	7
Fraser Street	East 43rd Avenue	7	0	7
West 4th Avenue	Vine Street	5	1	6
East 12th Avenue	Sophia Street	6	0	6
East 10th Avenue	Commercial Drive	6	0	6
Nelson Street	Beatty Street	5	0	5
Joyce Street	School Avenue	5	0	5
Denman Street	Comox Street	5	0	5
West Broadway	Maple Street	4	1	5
East Hastings Street	Slocan Street	4	0	4
West 4th Avenue	Balsam Street	4	0	4
West 70th Avenue	Cartier Street	4	0	4
Fraser Street	East 47th Street	4	0	4

Traffic circles were present for only approximately 0.7% of all pedestrian collisions at intersections. A total of 18 pedestrian collisions were reported at 17 unique intersections with traffic circles between 2005 and 2010. There are approximately 200 traffic circles located throughout the City. As such, collisions involving pedestrians were only recorded at less than 9% of all intersections with traffic circles in the City. The only traffic circle with more than one period collision over this period was at Chilco Street and Nelson Street.

Special crosswalks (pedestrian activated crosswalks with flashing yellow lights) only accounted for 6 pedestrian collisions at 3 locations: Comox Street and Thurlow Street (3 collisions), SW Marine Drive and Collingwood Street (1 collision), and Nanaimo Street and East 49th Avenue (1 collision). There are 9 special crosswalks located throughout the City.

- Neighbourhood Patterns

At first glance, Downtown appears to be the most collision prone neighbourhood in the City, as the Downtown core has experienced the highest total number of collisions, as shown in Figure 4.18. In fact, more than 1 in 5 (20.4%) pedestrian collisions throughout the entire City occurred in the Downtown core; and the Downtown core experienced over 2.5 times more collisions than the next closest neighbourhood (Mount Pleasant).

However, when the total activity level in the Downtown core as well as the remaining City is taken into account by considering the number of collisions per 100,000 residents and employees, the neighbourhoods with the highest collision rates are Strathcona, Mount Pleasant, Grandview-Woodland, Shaughnessy, and Kensington Cedar Cottage, as shown in Figure 4.19.

Despite this, the Downtown core and West End experience a significantly higher ratio of collisions per kilometre of roadway, as shown in Figure 4.20. In fact, the pedestrian collision rate based on road network distance in the Downtown and West End (11.27 and 8.06, respectively) is more than twice as high as the next closest neighbourhoods of Mount Pleasant, Strathcona and Fairview (4.75, 4.56, and 4.41, respectively).

Table 4.4 summarizes the collision patterns by neighbourhood in terms of overall pedestrian collisions as well as collision rates based on population and employment and based on street network distance.

Figure 4.18
Total pedestrian collisions by neighbourhood (2005 – 2010)

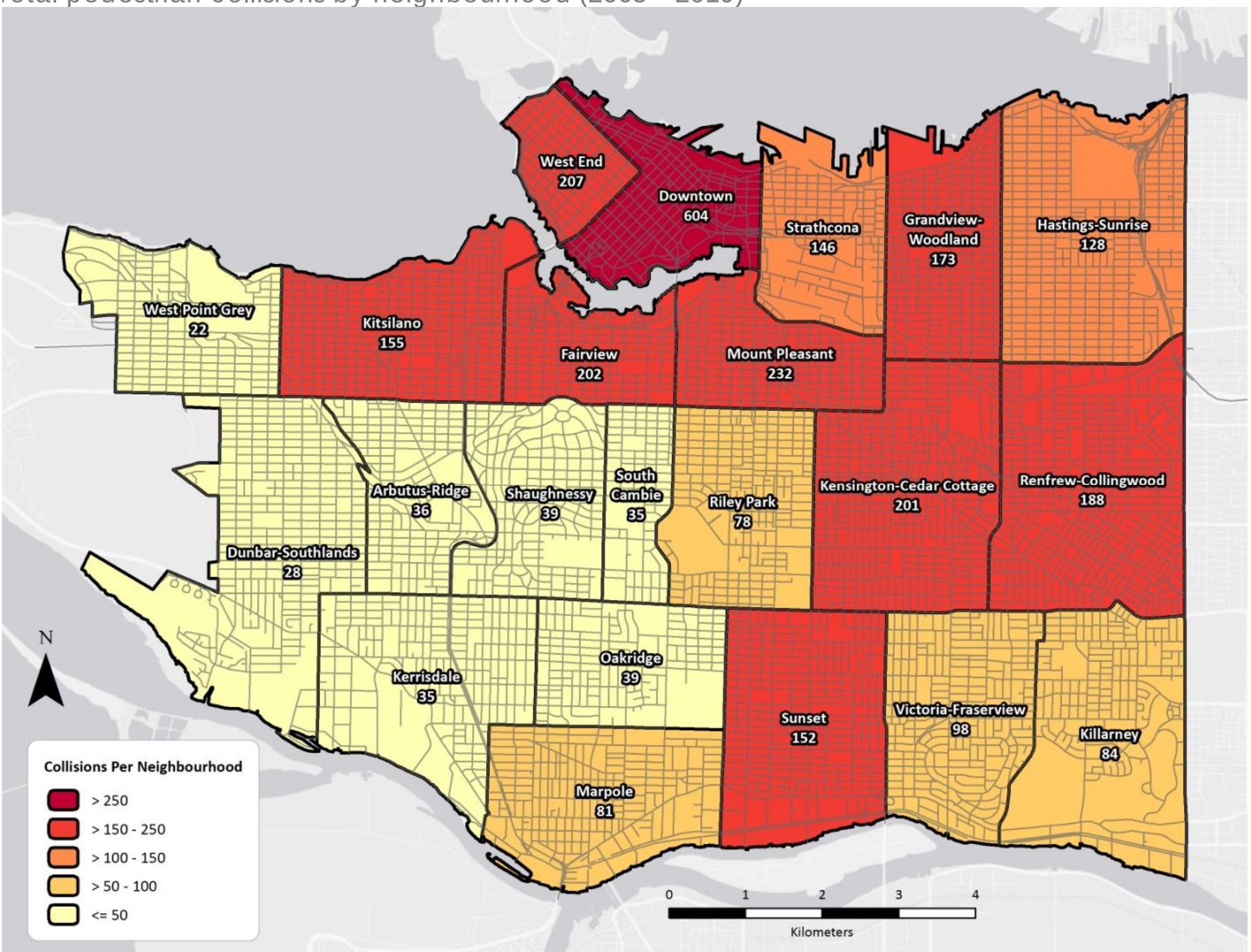


Figure 4.19
Total pedestrian collisions per 100,000 residents and employees by neighbourhood (2005 – 2010)

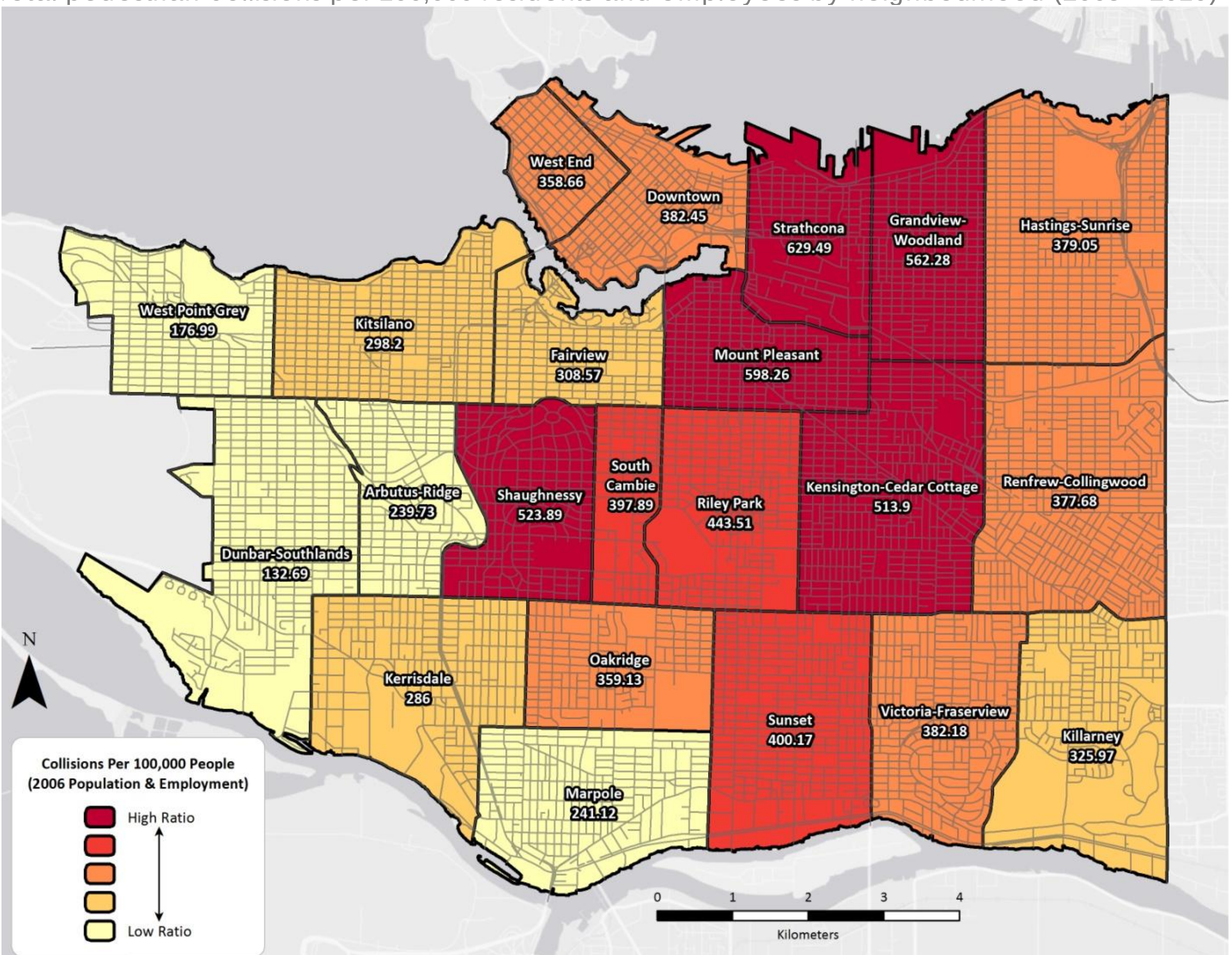


Figure 4.20
Total pedestrian collisions per street kilometer by neighbourhood (2005 – 2010)

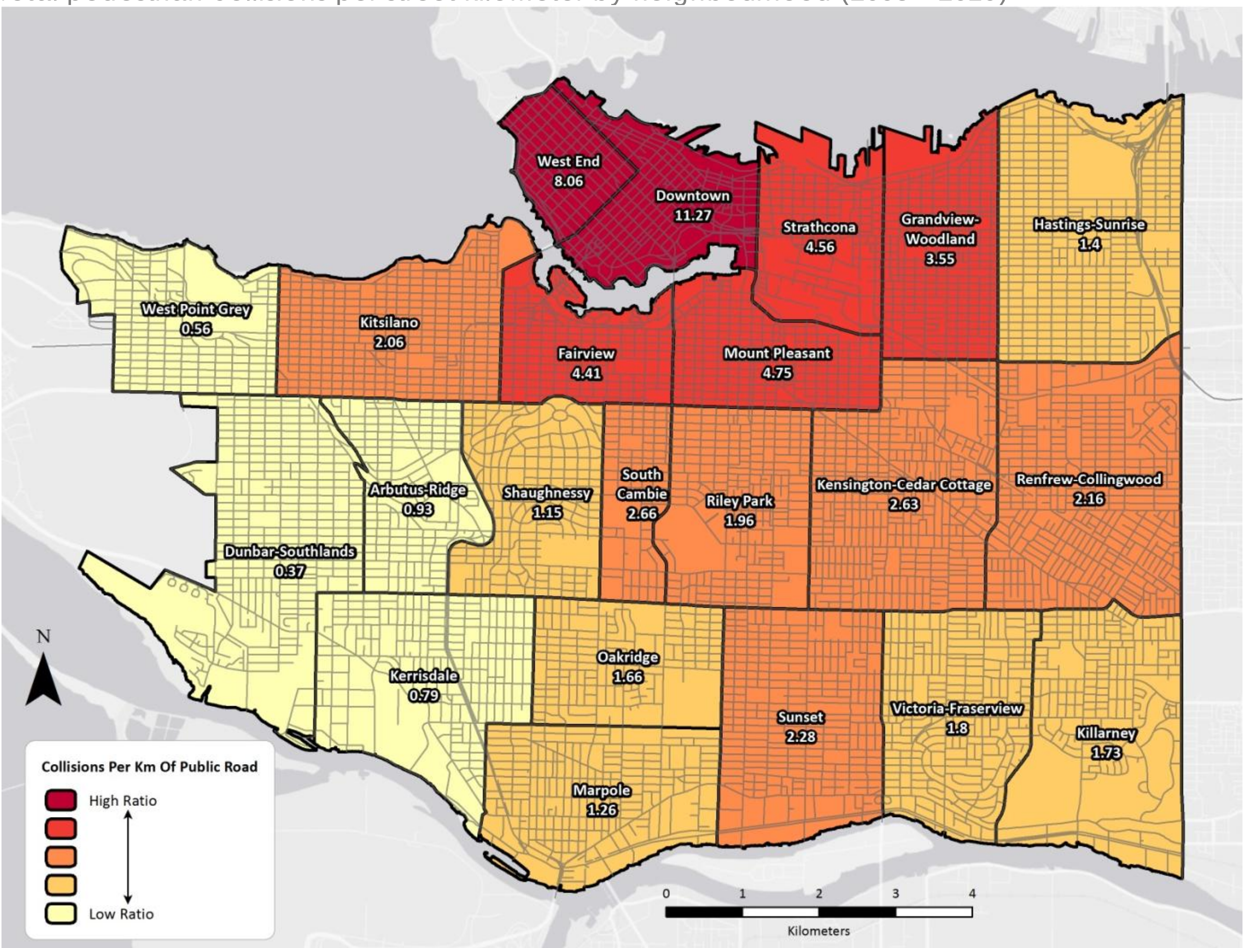


Table 4.4
Pedestrian Collisions by Neighbourhood (2005 – 2010)

Neighbourhood	Number of Pedestrian Collisions*			Pedestrian Collisions / 100,000 residents and employees		Pedestrian Collisions / Street Kilometre	
	Number	%	*Rank*	Number	Rank	Number	*Rank*
Downtown	603.7	20.4%	*1*	382.5	*9*	11.3	*1*
West End	207.0	7.0%	*3*	358.7	*14*	8.1	*2*
Strathcona	145.8	4.9%	*10*	629.5	*1*	4.6	*3*
Mount Pleasant	232.3	7.8%	*2*	598.3	*2*	4.8	*4*
Fairview	201.7	6.8%	*4*	308.6	*16*	4.4	*5*
Grandview-Woodland	173.4	5.9%	*7*	562.3	*3*	3.6	*6*
South Cambie	34.5	1.2%	*20*	397.9	*8*	2.7	*7*
Kensington-Cedar Cottage	201.1	6.8%	*5*	513.9	*5*	2.6	*8*
Sunset	151.7	5.1%	*9*	400.2	*7*	2.3	*9*
Renfrew-Collingwood	188.4	6.4%	*6*	377.7	*12*	2.2	*10*
Kitsilano	155.2	5.2%	*8*	298.2	*17*	2.1	*11*
Riley Park	78.2	2.6%	*15*	443.5	*6*	2.0	*12*
Victoria-Fraserview	98.0	3.3%	*12*	382.2	*10*	1.8	*13*
Killarney	83.7	2.8%	*13*	326.0	*15*	1.7	*14*
Oakridge	38.8	1.3%	*16*	359.1	*13*	1.7	*15*
Hastings-Sunrise	128.3	4.3%	*11*	379.1	*11*	1.4	*16*
Marpole	81.3	2.7%	*15*	241.1	*19*	1.3	*17*
Shaughnessy	38.5	1.3%	*17*	523.9	*4*	1.2	*18*
Arbutus Ridge	36.0	1.2%	*18*	239.7	*20*	0.9	*19*
Kerrisdale	34.8	1.2%	*19*	286.0	*18*	0.8	*20*
West Point Grey	21.8	0.7%	*22*	177.0	*21*	0.6	*21*
Dunbar-Southlands	27.8	0.9%	*21*	132.6	*22*	0.4	*22*

* To avoid double counting, collisions that occurred on neighbourhood boundaries were split so a portion was attributed to each zone.

- ### Collision Frequency and Collision Rates

As noted previously, between 2005 and 2010, 72 collisions with pedestrians resulted in a fatality, with the remaining 2,994 collisions with pedestrians resulting in an injury. Collision frequency is shown in Figure 4.21 and summarized in Table 4.5. In general, pedestrian collisions are distributed throughout the City, with a high concentration of collisions in particular in the Downtown core as well as along Primary Arterial streets such as Broadway, Kingsway, Hastings Street, Main Street, Fraser Street, Knight Street, and Clark Drive, among others.

Overall, pedestrian collisions were reported at 1,280 locations throughout the City between 2005 and 2010. However, the vast majority of these collisions occurred at locations with five or fewer collisions over this period, equivalent to less than 1 collision per year on average.

A relatively small number of locations account for a high proportion of pedestrian collisions in the City. Of the 1,280 collision locations throughout the City, 109 of these locations had at least 6 pedestrian collisions. These 109 locations, which represent 8.5% of all locations in the City, accounted for 1,011 collisions, or over a third (34.1%) of all pedestrian collisions.

Figure 4.21
Frequency of pedestrian collisions (2005 – 2010)

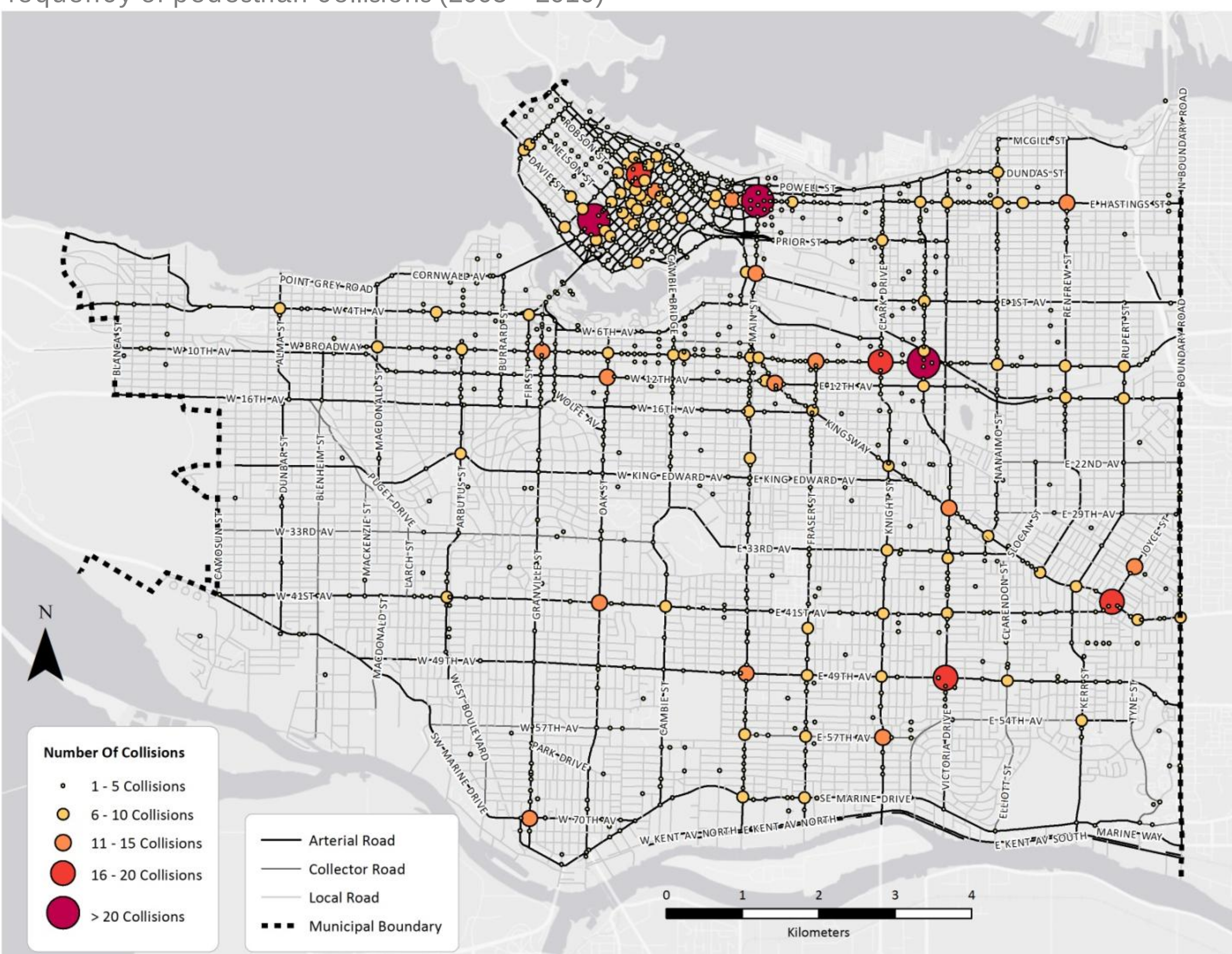


Table 4.4 identifies the top 21 collision locations throughout the City. This includes all locations with 11 or more pedestrian collisions over the past six years. All of these locations are located at fully signalized intersections and were also located at an intersection with an arterial road.

Table 4.5
Top Pedestrian Collision Locations (2005 – 2010)

Primary Street	Cross Street	Total Number of Pedestrian Collisions		
		Injuries	Fatalities	Total
East Hastings Street	Main Street	39	2	41
Davie Street	Burrard Street	25	0	25
East Broadway	Commercial Drive	22	0	22
Kingsway	Joyce Street	20	0	20
East Broadway	Clark Drive	17	1	18
West Georgia Street	Burrard Street	17	0	17
East 49th Avenue	Victoria Drive	16	0	16
Kingsway	Victoria Drive	15	0	15
East Broadway	Fraser Street	15	0	15
Terminal Avenue	Main Street	13	1	14
West Hastings Street	Carrall Street	14	0	14
West 12th Avenue	Oak Street	13	0	13
East 49th Avenue	Main Street	13	0	13
East Hastings Street	Renfrew Street	12	1	13
West Broadway	Granville Street	12	0	12
East 57th Avenue	Knight Street	12	0	12
Vanness Avenue	Joyce Street	12	0	12
East 12th Avenue	Kingsway	12	0	12
West 70th Avenue	Granville Street	11	0	11
West 41st Avenue	Oak Street	11	0	11
West Georgia Street	Granville Street	11	0	11

However, collision frequency alone is not sufficient to accurately reflect overall pedestrian activity. For example, many downtown locations have a relatively high number of collisions, although this is to be expected based on higher pedestrian volumes. As such, pedestrian collision rates were calculated for each of the top 109 collision locations in the City to better understand pedestrian collisions as a reflection of pedestrian volumes. Pedestrian volumes were based on manual counts undertaken by the City, and reflect total pedestrian volumes over a two-hour period in the AM peak and two-hour period in the PM peak. Pedestrian collision rates at the top 109 collision locations in the City are illustrated in Figure 4.22.

Figure 4.22
Pedestrian collision rates for top collision locations (2005 – 2010)

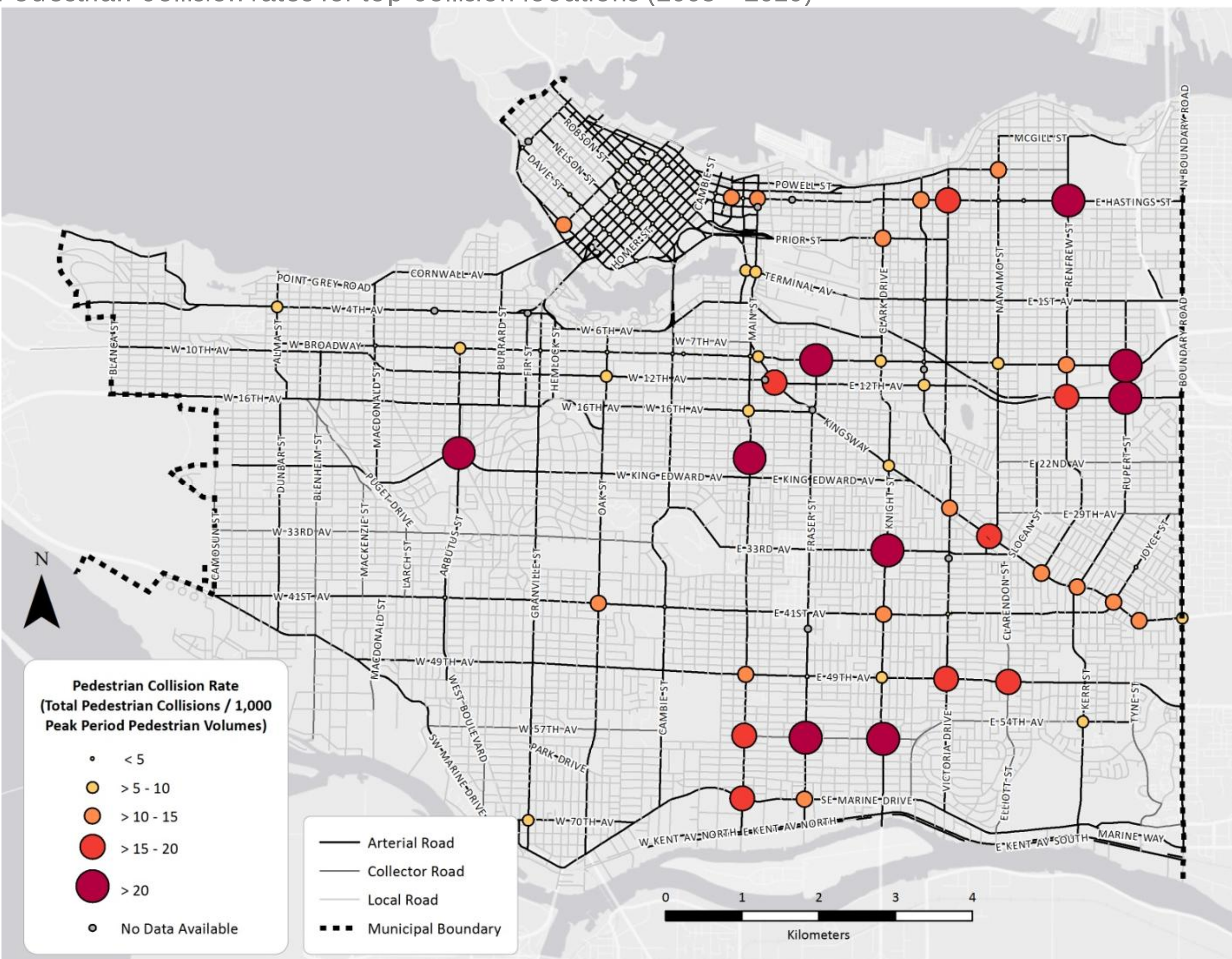
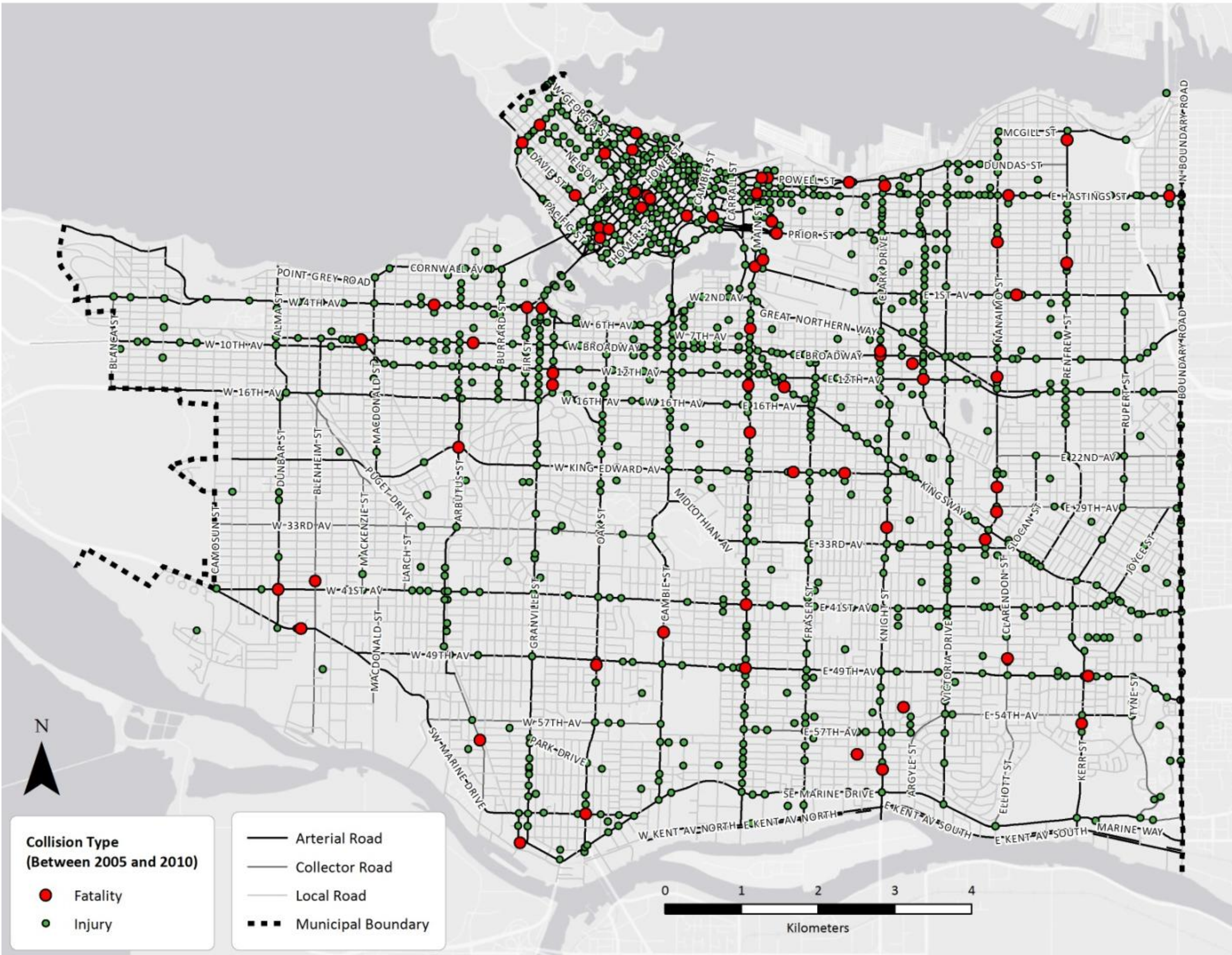


Figure 4.23 illustrates collisions by severity by highlighting locations where pedestrian fatalities occurred as well as pedestrian injuries.

The majority of locations with collisions resulting in fatalities only had one incident resulting in a fatality from 2005 -- 2010. Five locations each had multiple collisions resulting in fatalities over this period, including:

- East Broadway at Clark Drive (two fatalities);
- Gore Avenue at Powell Street (two fatalities);
- Hastings Street at Thurlow Street (two fatalities resulting from one incident);
- 4th Avenue and Anderson Street (two fatalities resulting from one incident); and
- Main Street and Hastings Street (two fatalities).

Figure 4.23
Severity of pedestrian collisions (2005 – 2010)



As noted previously, the majority of collisions in the City occur on arterial streets or at intersections with arterial streets. As a result, collision patterns on local streets become underrepresented in City-wide analyses. Although the vast majority of collisions on local streets are isolated incidents with only one reported collision over this period, 20 locations have been identified at local street locations with at least two reported collisions over this period, as shown in Table 4.6.

Table 4.6
Top Pedestrian Collision Locations at Local Streets (2005 – 2010)

Primary Street	Cross Street	Total Pedestrian Collisions
East Georgia Street	Gore Avenue	4
West 6th Avenue	Yukon Street	4
West 8th Avenue	Ash Street	3
Cardero Street	Barclay Street	2
Chilco Street	Nelson Street	2
East 13th Avenue	Prince Edward Street	2
East Pender Street	Kootenay Street	2
Haro Street	Bute Street	2
Nanaimo Street	Waverley Avenue	2
West 10th Avenue	Ash Street	2
West 10th Avenue	Willow Street	2
West 1st Avenue	Fir Street	2
West 4th Avenue	Yukon Street	2
West 7th Avenue	Maple Street	2
West 8th Avenue	Arbutus Street	2
Haro Street	Thurlow – Bute Street	2
Bayshore Drive	Cardero Street – Menchions Mews	2
East Georgia Street	Gore Avenue – Main Street	2
Blood Alley Square	Trounce Alley	2
East Pender Street	Gore Avenue – Main Street	2

- Collision Prone Locations

For many years, the prevailing measure of safety was the collision rate, which is the number of collisions per unit of exposure as most commonly expressed by number of collisions per million vehicles entering an intersection. However, although collision rates do consider exposure, the use of collision rates alone to gauge the safety of a location can be misleading, as it has been shown the relationship between collision frequency and exposure is non-linear. This finding has led most safety analysts instead to use collision prediction models (CPMs) as the primary tool for estimating road safety. A CPM is a regression model that produces an estimate of the collision frequency for a location based on the site-specific characteristics of the location. For intersections, the CPM utilizes the number of vehicles entering the intersection from the major and minor legs of the intersection, which produces a collision frequency estimate that represents "normal" safety performance for the location.

The use of CPMs allows for an improvement in the accuracy of safety measurement, and can facilitate the establishment of acceptable safety performance benchmarks and thresholds. The use of CPMs for safety analysis is also consistent with evolving safety evaluation techniques. As well, the CPMs can be used for network screening and identifying locations that have a high potential for improvement.

A pedestrian collision prediction model was developed for this study in order to identify and rank pedestrian collision prone intersections in the city. The model was developed for a sample of 80 out of the 1076 intersections. The methodology and statistical measures required to develop collision prediction models are described in more detail in Appendix B. Collision-prone locations (CPLs) are defined as locations that exhibit a significant number of collisions compared to a specific norm. Because of the randomness inherent in collision occurrence, statistical techniques that account for this randomness should be used when identifying CPLs.

The developed CPM was applied to identify and rank collision prone locations. Collisions prone intersections present the highest risk for collisions. Seven pedestrian collision prone locations were identified and their ranking is presented in Table 4.7 and Figure 4.9.

Table 4.7
Ranking of collision prone intersections in the City of Vancouver

Primary Street	Cross Street	Total Pedestrian Collisions (2005 – 2010)	CPL Ranking
East Hastings Street	Main Street	41	1
Davie Street	Burrard Street	25	2
Kingsway	Joyce Street	20	3
East Broadway	Commercial Drive	22	4
East 49th Avenue	Victoria Drive	16	5
East Broadway	Fraser Street	15	6
East 49th Avenue	Main Street	13	7

- Collision Prone Zones

The previous section described the location-specific (micro-level) Collision Prediction Models (CPMs) that were developed to identify and evaluate the safety of individual collision prone locations (CPLs). However, this type of approach has traditionally been *reactive* in nature, such that a significant collision history must have existed before any action was taken. There is a need to take a *proactive* approach that addresses road safety before problems emerge. This proactive approach should complement the more traditional, reactive methods currently in use.

Macro-level CPMs (traffic zone or neighborhood models) can help with the delivery of a proactive road safety measure. Macro-level CPMs, by nature of their neighbourhood-wide or macro-level focus, have the potential to complement the micro-level CPM methods currently in use, by providing an early-warning empirical tool.

A CPM was developed for this study for each traffic zone in the City of Vancouver. Several models were developed that relate pedestrian collisions to specific network, environmental and demographic characteristics of traffic zones. These models are useful for proactive safety planning initiatives. One application of these models is described where pedestrian collision prone zones are identified. Potential explanatory variables were grouped in four themes:

1. Exposure: variables related with traffic collision probability.
2. Transportation Infrastructure: refers to characteristics of the road network.
3. Socioeconomic: variables based primarily on the 1996 census data.
4. Transit Network Group: variables related to bus network elements physically present in the roads.

Collision-prone zones (CPZs) are defined as zones that exhibit a higher potential of collisions compared to a specific norm. Because of the randomness inherent in collision occurrence, statistical techniques that account for this randomness should be used when identifying CPZs.

The models show that collisions are positively associated with the main exposure variable (transit and vehicle kilometers travelled *VKT)*. As well, the following observations can be made:

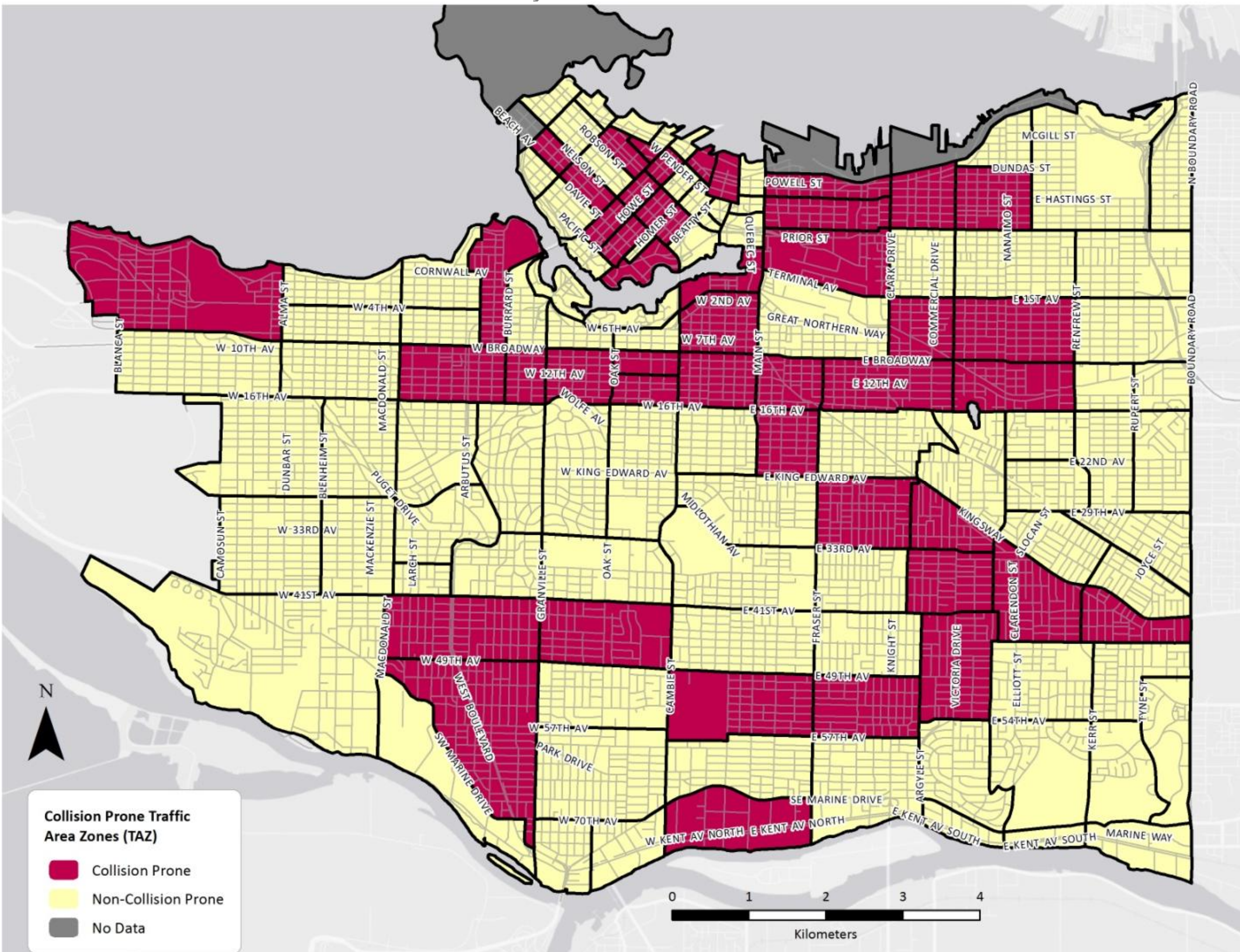
1. Exposure Variables refers to variables related with traffic collision probability. The exposure model shows that decreased pedestrian collision occurrence is related to increases in the average congestion level (VC). This can be explained as the higher level of congestion, the lower the traffic speed, which reduces the risk of pedestrian collisions.
2. Infrastructure Variables: this group includes variables describing the physical elements in the road network. The model shows that pedestrian collisions are positively correlated with the number of signalized intersections (SIG). This result is logical as the higher the number of

signalized intersections the higher the chance of vehicle/pedestrian conflicts. As well, the model indicates decreased pedestrian collisions are related to increases in the percentage of three way intersections (I3WP). This facilitates analyses on street network patterns (e.g. grid versus discontinuous).

3. Socioeconomic Variables: this group includes variables based primarily on the census data, such as population, employment, commuting mode choice and land use. The model shows that increases in the number of pedestrian collisions is related to increases in both the percentage of commercial areas (COMM) and the number of pedestrian commuters (PEDC). This result is similar to the results obtained in the pedestrian models developed by Fernandes et al, which found that pedestrian collisions were positively correlated with the number of entrances/exits to commercial property in close proximity (within 25 meters) of signalized intersections.
4. Transit Network Variables: refer to bus elements physically present in the road network. The model shows that increased collisions are related to an increase in the bus frequency. The positive parameter for bus route frequency suggests that an increased flow of transit vehicles can increase the risk of conflicts between transit users boarding/unloading the bus and other vehicles. In the case of inter-station spacing the inverse relationship with pedestrian collisions is intuitive, as a small spacing between bus stops raises the frequency of transit users boarding and unloading by walking.

The four CPMs developed in the previous section were applied to identify collision prone zones using the Empirical Bayes technique (explained in Appendix B). Collisions prone zones present the highest risk for collisions. The collision prone zones are presented in Figure 4.24. Collision prone zones are located mostly in the downtown area (along Burrard Street, Georgia Street and Davie Street), along Broadway (from MacDonald Street to Renfrew Street), Kingsway (between Knight Street to Boundary Road), Hastings Street (between Main Street to Nanaimo Street) and 41st Avenue (between Knight Street and Boundary Road and between Granville Street and MacDonald Street).

Figure 4.24
Pedestrian Collision Prone Zones in the City of Vancouver



4.2.4 What & How

This section summarizes the types of pedestrian collisions that have occurred throughout the City over the past six years. To determine the type of collision, the incident descriptions for each individual collision were reviewed and classified based on the following four factors:

- Collision location (intersection or mid-block);
- Traffic control device (traffic signal, stop sign, or crosswalk, or no traffic control);

- Driver action (vehicle turning left, turning right, proceeding straight, backing up, or parking); and
- Pedestrian action (pedestrian crossing the street with or without right-of-way, crossing at a driveway, or walking on sidewalk)

Based on these factors, 18 distinct collision classifications were identified. The collision classification was based on the typology developed for the City of Toronto Pedestrian Collision Study and was modified to reflect local conditions. A summary of the 18 collision types and their frequency is provided in Table 4.8.

Table 4.8
Pedestrian Collision Classification and Frequency (2005 – 2010)

Collision Description	Number of Collisions	Proportion of All Collisions	Proportion of Known Collision Types	Rank
Intersection Location				
Vehicle Turns Left				
Pedestrian Crosses at Signal, With Right of Way	544	17.7%	25.6%	1
Pedestrian Crosses at Signal, Without Right of Way	42	1.4%	2.0%	12
Pedestrian Crosses at Stop Sign or Crosswalk	117	3.8%	5.5%	6
Pedestrian Crosses without Intersection Control	17	0.6%	0.8%	16
Vehicle Turns Right				
Pedestrian Crosses at Signal, With Right of Way	362	11.8%	17.1%	2
Pedestrian Crosses at Signal, Without Right of Way	18	0.6%	0.8%	15
Pedestrian Crosses at Stop Sign or Crosswalk	83	2.7%	3.9%	8
Pedestrian Crosses without Intersection Control	8	0.3%	0.4%	17
Vehicle Goes Straight				
Pedestrian Crosses at Signal, With Right of Way	74	2.4%	3.5%	9
Pedestrian Crosses at Signal, Without Right of Way	90	2.9%	4.2%	7
Pedestrian Crosses at Stop Sign or Crosswalk	147	4.8%	6.9%	4
Pedestrian Crosses without Intersection Control	70	2.3%	3.3%	10
Vehicle Backs Up				
Pedestrian Crosses While Vehicle Backs Up	23	0.8%	1.1%	14
SUBTOTAL	1595	52.0%	75.2%	
Mid Block Location				
Pedestrian hit while crossing without a control	243	7.9%	11.5%	3
Pedestrian hit at driveway or laneway	137	4.5%	6.5%	5
Pedestrian hit at mid-block crosswalk	33	1.1%	1.6%	13
Pedestrian hit at sidewalk	52	1.7%	2.5%	11
Pedestrian hit at bus stop	62	2.0%	2.9%	18
SUBTOTAL	527	17.2%	24.8%	
Other / Unknown				
Other	130	4.2%		
Unknown	814	26.5%		
SUBTOTAL	944	30.8%		
TOTAL	3066	100.0%	100.0%	

This classification system allowed for the classification of approximately 69.2% of all collisions. A further 4.3% of collisions involved a different type of incident, while over a quarter of collisions (26.5%) could not be classified based on the level of detail provided in the incident description. Some key observations about the collision classification are provided below.

- Intersection vs mid-block collisions

Approximately three quarters (75.2%) of all known pedestrian collision types involved a collision where the pedestrian was attempting to cross the street at an intersection. The remaining 24.8% of known pedestrian collision types occurred at mid-block locations, where the pedestrian was either crossing the street at a mid-block crosswalk or a location without a traffic control, crossing a driveway or laneway, or was struck at the sidewalk or at a bus stop.

- Left-turning vehicles

The most common driver action in pedestrian collisions was a left turning movement, as left turns accounted for over a third (33.9%) of all known pedestrian collision types, followed by right-turns (22.2%) and vehicles proceeding straight through an intersection (18.0%). In fact, there were 53% more incidents involving left turning vehicles than right-turning vehicles. This is consistent with findings of several other studies, including the City of Toronto Pedestrian Safety Study and City of New York Pedestrian Safety Study and Action Plan, both of which found a high incidence of pedestrian collisions involving left turning vehicles. As noted in the City of New York Pedestrian Safety Study and Action Plan, when turning left, the driver's visibility is partially blocked by the A-Pillar (the support between the windshield and side window), making it harder to see pedestrians in the left crosswalk. In addition, the left turning maneuver requires more mental effort than a right-turn, leading to more driver error.

- Driver Failure to Yield

Several studies have found that drivers failing to yield to pedestrians is a primary driver action that contributes to collisions. Failure to yield refers to cases where a driver fails to stop for a pedestrian that is crossing the street at a signalized intersection with the right-of-way, at a stop sign, or at a marked crosswalk. In addition, this also includes unsignalized intersections, as the BC Motor Vehicle Act indicates that pedestrians have the right-of-way at intersections without marked crosswalks. Nearly all failure to yield collisions occurred at signalized intersections.

The vast majority of collisions at intersections involved drivers failing to yield to pedestrians when they had the right-of-way. The majority of failure to yield incidents occurred at signalized intersections (46.2% of known pedestrian collisions types). Approximately 16.3% of incidents occurred where drivers failed to yield to pedestrians at stop signs or crosswalks, and approximately 4.5% of were a result of drivers failing to yield at intersections without an intersection control.

Only 9% of collisions involved a pedestrian crossing the street at an intersection without the right-of-way.

- Jaywalking

The third most common type of pedestrian collision occurred where pedestrians were attempting to cross the street at a mid-block location without an intersection control. This type of collision accounted for approximately 11.5% of all known pedestrian collisions.

The top five collision types accounted for approximately two-thirds (67.5%) of all known pedestrian collision types, while the top ten collision types accounted for the vast majority (88%) of all known pedestrian collision types. In fact, the top two collision types – which involved pedestrians crossings the street with the right-of-way at a signalized intersection with vehicles turning either left or right – accounted for 42.8% of all known pedestrian collision types.

The top ten pedestrian collision types are listed below (in order):

1. Vehicle turns left while pedestrian crosses with right-of-way at signalized intersection (25.6% of known collision types)
2. Vehicle turns right while pedestrian crosses with right-of-way at signalized intersection (17.1%)
3. Pedestrian hit while crossing mid-block without a traffic control (11.5%)
4. Vehicle proceeds straight through while pedestrian crosses at stop sign or crosswalk (6.9%)
5. Pedestrian hit while crossing driveway or laneway (6.5%)
6. Vehicle turns left while pedestrian crosses at stop sign or crosswalk (5.5%)
7. Vehicle proceeds straight through intersection, while pedestrian crosses at signalized intersection without right-of-way (4.2%)
8. Vehicle turns right while pedestrian crosses at stop sign or crosswalk (3.9%)
9. Vehicle proceeds straight while pedestrian crosses with right-of-way at signalized intersection (3.5%)
10. Vehicle proceeds straight while pedestrian crosses at intersection without intersection control (2.3%)

4.2.5 Summary of Key Issues

This section provides a brief summary of the key issues that were identified in the previous sections based on the analysis of pedestrian collisions over the past six years in the City of Vancouver.

- When
  - Nearly half of all pedestrian collisions occurred between November and February.
  - Most of the increase in collisions in winter months can be attributed to the increase in nighttime collisions as a result of the shorter days and longer nights.
  - January accounted for the highest proportion of pedestrian collisions resulting in fatalities.
  - Pedestrian collisions were more likely to occur on weekdays.
  - The highest proportion of pedestrian collisions occurred during the PM peak period
  - Although late night pedestrian collisions were relatively infrequent, they were nearly twice as likely to lead to a fatality compared with other time periods.
  - Pedestrians were particularly vulnerable when it was both dark and rainy.

- Who
  - Young adults aged 20 to 29 are the most likely to be involved in a collision.
  - Collisions involving young adults are more likely to result in injury and less likely to result in fatality.
  - Collisions involving seniors are more likely to result in fatality.
  - There is a relatively even distribution of pedestrian collisions involving males and females.
  - Males are somewhat more likely to be involved in a collision resulting in fatality.
  - Females aged 20 to 29 are more likely than males of the same age group to be involved in a pedestrian collision.

- Where
  - A significant number of pedestrian collisions occurred in the Downtown core and along Primary Arterial streets.
  - The neighbourhoods with the highest collision rates included Strathcona, Mount Pleasant, Grandview-Woodland, Shaughnessy, and Kensington Cedar Cottage.

- Approximately 75% of all collisions were located at intersections.
- The majority of intersection collisions were at signalized intersections.
- Approximately 13% of all intersection collisions involving pedestrians occurred at locations with pedestrian activated signals.
- Traffic circles were present for only approximately 0.7% of all pedestrian collisions at intersections.
- Special crosswalks only accounted for 6 pedestrian collisions at 3 locations.
- 21 locations were identified that had 11 or more pedestrian collisions over the six year period. All of these locations are located at intersections and were also located at an intersection with an arterial road.
- Collisions prone intersections present the highest risk for collisions. Seven pedestrian collision prone locations were identified.
- 21 intersections at local-local intersections had more than one pedestrian collision

- What & How
  - Three quarters of all pedestrian collisions took place where a pedestrian was attempting to cross the street at an intersection.
  - One quarter of all pedestrian collisions took place at mid-block locations, where the pedestrian was either crossing the street at a mid-block crosswalk or a location without a traffic control, crossing a driveway or laneway, or was struck at the sidewalk or at a bus stop.
  - The most common driver action in pedestrian collisions was a left turning movement.
  - The vast majority of collisions at intersections involved drivers failing to yield to pedestrians when pedestrians had the right-of-way.
  - The most common pedestrian action was jaywalking at mid-block locations, which accounted for approximately 11.5% of all pedestrian collisions.
  - The top five pedestrian collision types listed below accounted for approximately two-thirds of all pedestrian collisions:

    6. Vehicle turns left while pedestrian crosses with right-of-way at signalized intersection (25.6% of known collision types);
    7. Vehicle turns right while pedestrian crosses with right-of-way at signalized intersection (17.1%);

8. Pedestrian hit while crossing mid-block without a traffic control (11.5%);
9. Vehicle proceeds straight through while pedestrian crosses at stop sign or crosswalk (6.9%); and
10. Pedestrian hit while crossing driveway or laneway (6.5%).

5.0

Pedestrian Safety Toolbox

This chapter provides a 'toolbox' of engineering, education, and enforcement measures that can be considered to address the issues identified in the previous section.

5.1 Engineering

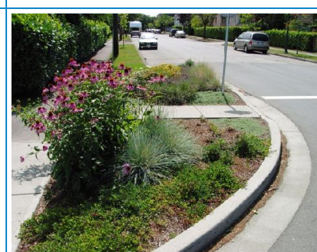
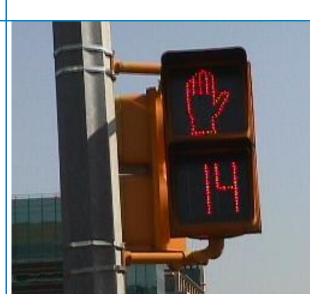
This section provides a summary of the effectiveness of a range of types of engineering treatments that can be considered to improve pedestrian safety. This includes a review of measures commonly used in Vancouver as well as measures with limited or no current use in Vancouver, as shown below.

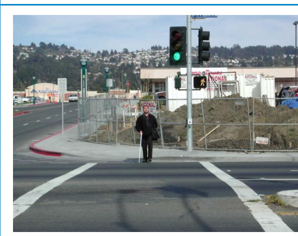
Commonly Used in Vancouver	Some Use in Vancouver	Not Currently Used in Vancouver
▪ Pedestrian Activated Signals	▪ Mid-Block Crossings	▪ Leading Pedestrian Interval
▪ Corner Bulges	▪ Raised Crosswalks	▪ Crossing Guards
▪ Crosswalks	▪ Raised Intersections	▪ Yield to Pedestrian Signs for Right Turn Vehicles
▪ Audible Signals	▪ Separated vs Mixed Modes	▪ Pedestrian Scrambles
▪ Left Turn Bays	▪ Speed Reader Boards	▪ New or Upgraded Intersection Lighting
▪ Greenways	▪ Countdown Timers	
	▪ Crossing Guards	

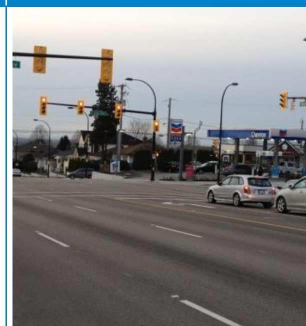
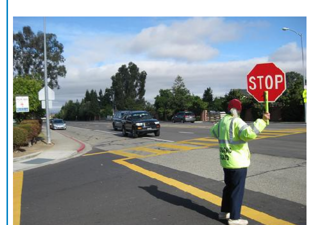
The effectiveness of each treatment was assessed based on a comprehensive literature review and by contacting staff at five peer cities in Canada and the Pacific Northwest (Calgary, Toronto, Seattle, Portland, and San Francisco). Table 5.1 provides a summary of the effectiveness of each pedestrian treatment. A more detailed assessment of each pedestrian treatment is found in Appendix C, including:

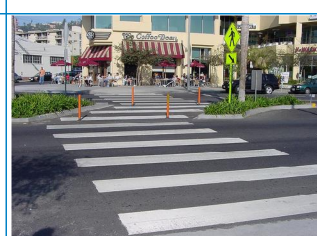
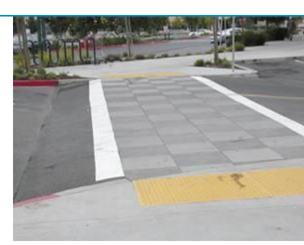
- Description
- Current Use in Vancouver
- Application Guidance
- Benefits
- Costs / Impacts
- Research
- Case Studies
- Lessons Learned

Table 5.1
Summary of Pedestrian Treatments

Treatment	Photo	Description	Application Guidance	Benefits	Collision Reduction Factor	Relative Cost	Relative Effectiveness for Pedestrian Safety
Pedestrian Activated Signal		Pedestrian activated signals are used to assist pedestrians in crossing major streets in areas where there is high pedestrian demand, but where a full traffic signal is not warranted.	▪ Higher speed/volume roadways at mid-block locations or at unsignalized intersections where pedestrian crossing demand is high and distant from an existing crossing	▪ Provides a signal-protected pedestrian crossing phase. ▪ Reduces motor vehicle delay as compared with a fully signalized crossing. ▪ Improves pedestrian safety	58%[9]	High	High
Corner Bulges		Corner bulges are an extension of the curb into the parking lane at intersections to reduce pedestrian crossing distances, and improve visibility between motorists and pedestrians.	▪ Where there is a full-time on-street parking lane. ▪ Can be used to enhance mid-block crossings. ▪ Where bicycles and transit vehicles will travel outside of the curb edge for the length of the streets. ▪ Landscaping or furniture should not obstruct visibility. ▪ Design should ensure adequate drainage.	▪ Improves motorist visibility of pedestrians. ▪ Reduces speed of turning vehicles. ▪ Encourage pedestrians to cross at designated crossings. ▪ Decreases crossing distances for pedestrians.	25%[10]	Moderate	Moderate
Speed Reader Boards		A speed reader board is a sign placed adjacent to a roadway that displays oncoming motorist speeds. Light-emitting diodes (LED) flash the traveling speed near a regulatory speed limit sign as feedback to motorists that they are driving in excess of the posted limit.	▪ Occasional enforcement required to complement this measure. ▪ Boards should not obstruct pedestrian travelway or sightlines. ▪ This measure is a complement rather than a substitute for engineering measures.	▪ Enhances enforcement through public education and awareness.	N/A	Moderate	Moderate-Low
Pedestrian Countdown Timers		Pedestrian countdown timers are used to provide information to pedestrians about how much time is left to cross the street at a signalized intersection	▪ Any signalized intersection where pedestrian displays are provided. ▪ Most appropriate in highly urbanized environments with high pedestrian activity.	▪ Provides pedestrians with the amount of time left to complete their crossing ▪ Reduces the number of pedestrians remaining in the crossing after the crossing interval ends.	25%[11]	Moderate-Low	Moderate

Treatment	Photo	Description	Application Guidance	Benefits	Collision Reduction Factor	Relative Cost	Relative Effectiveness for Pedestrian Safety
Crosswalks		Marked crosswalks are the simplest crossing treatment, which involves pavement markings indicating the crosswalk, and accompanying signs.	▪ All signalized intersections. ▪ Mid-block locations when there is demand for a crossing and no nearby crossing. Additional measures may be required depending on size and speed of the roadway.	▪ Alerts motorists to expect pedestrians. ▪ Indicates preferred pedestrian crossing location.	N/A	Moderate-Low	Low
Pedestrian Scrambles		A pedestrian scramble is an exclusive pedestrian phase at a signalized intersection where vehicular movements are prohibited at all approaches while pedestrians are permitted to cross diagonally and longitudinally. The separation of vehicular and pedestrian movements is intended to reduce conflicts between the two modes.	▪ Most likely to be successful and have fewer violations at intersections with large volumes of both pedestrians and motor vehicles. ▪ Pedestrian scramble phase usually creates a longer cycle length and wait between crossings.	▪ Exclusive pedestrian phase reduces conflicts between pedestrians and vehicles. ▪ Benefits of this treatment may not extend to visually impaired pedestrians.	N/A	Moderate-High	Moderate
Audible Pedestrian Signal		Audible pedestrian signals emit a verbal message, an audible tone, or a vibration to indicate to visually impaired pedestrians when they have the right of way to cross the street.	▪ Need for audible signal usually demonstrated through a user request. Guidance for installation can be found in TAC Accessible Signal Guide. ▪ Set at appropriate volume to avoid noise pollution in urban areas.	▪ Provides crossing assistance to pedestrians with vision impairment at signalized intersections. ▪ Improves safety for visually impaired pedestrians.	N/A	Moderate-Low	Moderate-Low
Leading Pedestrian Intervals		A traffic signal's leading pedestrian interval gives pedestrians the "Walk" symbol several seconds before motor vehicles traveling in the parallel direction are given a green light. This allows pedestrians to get a head start on crossing before vehicles begin turning, making them more visible to motorists.	▪ Intersections with a history of conflict between pedestrians and turning vehicles.	▪ Provides pedestrians with a head start to begin their crossing before vehicles begin turning, making pedestrians more visible to motorists. ▪ Reduces conflicts between pedestrians and turning vehicles. ▪ Research suggests that leading pedestrian intervals reduce conflicts between pedestrians and turning vehicles.	N/A	Low	Moderate

Treatment	Photo	Description	Application Guidance	Benefits	Collision Reduction Factor	Relative Cost	Relative Effectiveness for Pedestrian Safety
Left Turn Bays		A left turn bay is a dedicated left turn lane that can be located at intersections or driveways. This can also refer to a two-way left turn lane.	▪ Left turn pockets can be combined with a variety of left turning schemes (permissive, protected or permissive/protected). ▪ The appropriate turn scheme depends on left-turn and opposing through volumes, number of opposing through lanes, cycle length, speed of opposing traffic, sight distance and crash history.	▪ Reduces the frequency of rear end and pedestrian crashes. ▪ Research indicates reduction in vehicular crashes.	N/A	Varies	Varies
Greenways		Greenways are generally low-volume streets that have been optimized for bicycle and pedestrian travel through traffic calming and diversion, signage and pavement markings, and intersection crossing treatments.	▪ Areas with greater population density and a higher number of destinations, such as the downtown peninsula.	▪ Traffic calming on greenways reduces vehicle speeds, which allows vehicles more time to notice pedestrians and reduces injury severity when crashes do occur. ▪ Traffic calming and diversion reduces vehicle volumes on greenways, reducing potential conflicts between motorists and pedestrians.	N/A	Varies	Varies
Crossing Guards		Crossing guards are paid employees or volunteers that provide assistance to people trying to cross the street. Crossing guards are typically stationed at school crossings to guide children through intersections, though they can also be used at other locations where assistance in judging the safety of crossing in a variety of cross traffic conditions could improve safety.	▪ Typically stationed at school crossings. ▪ Can also be stationed at other locations where people would benefit from assistance in judging the suitability of traffic conditions for street crossings. ▪ Crossing guard programs are often a combined effort between local traffic officials, police, school officials, parents, and students.	▪ Improves pedestrian safety at school crossings when the crossing guard is on duty. ▪ Research suggests that school crossing guard programs are effective	N/A	Moderate-Low	Moderate-Low

Treatment	Photo	Description	Application Guidance	Benefits	Collision Reduction Factor	Relative Cost	Relative Effectiveness for Pedestrian Safety
Yield To Pedestrian Signs		"Yield to Pedestrian" signs for right-turning vehicles are used to tell motorists who are executing turns that they need to yield to pedestrians in crosswalks	▪ Typically used at signalized intersections with heavy right turn volumes where right turn on red movements are allowed. ▪ Overuse of signs tends to lead to non-compliance. Too many signs can lead to visual clutter.	▪ May reduce conflicts between pedestrians and turning vehicles, though evidence is limited.	NA	Low	Low
Raised Intersections		Raised intersections are flat elevated areas that span an entire intersection.	▪ Used as a traffic calming treatment. ▪ May not be appropriate on emergency vehicle or bus routes. ▪ Can provide accessibility solutions for narrow sidewalks.	▪ Reduces vehicle speeds at intersection. ▪ Increases pedestrian visibility.	NA	Moderate-High	Moderate-Low
Midblock Crossings		A midblock crossing is a pedestrian crossing facility implemented to accommodate pedestrian crossing demand between intersections and away from signalized intersections. Midblock crossings can include a number of additional treatments including pedestrian refuge islands, pedestrian signals, high visibility markings, and signage.	▪ Consider the posted speed, traffic volume and number of lanes when selecting the appropriate measures to be included in the crossing. ▪ Should align with pedestrian 'desire lines' to the extent possible to ensure the crossing is utilized.	▪ Accommodates pedestrian crossing demand between intersections and away from signalized intersections. ▪ Alerts motorists to expect pedestrian crossing activity. ▪ Improves pedestrian safety, provided the crossing treatment is appropriate for the roadway.	Depends on the roadway characteristics and crossing treatment elements.	Varies	Varies
Raised Crosswalks		Raised crosswalks are elevated pedestrian crossings that extend the sidewalk across the street through the creation of a flat topped speed hump.	▪ Consider posted speed of road. ▪ May not be appropriate on emergency vehicle or bus routes. ▪ Use detectable warnings at the curb edges to alert vision-impaired pedestrians that they are entering the roadway.	▪ Reduces vehicle speeds. ▪ Increases pedestrian visibility.	▪ 30-35% of fatal/injury pedestrian collision.[12] ▪ 8% of all collisions.	Moderate-High	Moderate

Treatment	Photo	Description	Application Guidance	Benefits	Collision Reduction Factor	Relative Cost	Relative Effectiveness for Pedestrian Safety
Separated vs Mixed Modes		Roadways that mix modes allow for the shared use of space by motor vehicles, pedestrians, and bicyclists, without lane assignment. There generally are no sidewalks or other features to separate modes and these roadways usually have lower posted speed limits.	▪ Special consideration should be given to ensure there are cues that demarcate the travel way for visually impaired pedestrians.	▪ Reduces motor vehicle travel speeds and volumes. ▪ Increases bicycle/pedestrian activity. ▪ Improves attractiveness of street. ▪ Increases social activity amongst neighbours and children.	NA	Low	Moderate
New or Upgraded Intersection Lighting		Increases the visibility of the intersection for motorists to see Vulnerable Road Users	▪ All signalized intersections. ▪ Intersections where pedestrian volumes are high, especially during the night time.	▪ Increases visibility of pedestrians.	▪ 78% of injury pedestrian collisions ▪ 42% of fatal pedestrian collisions	Moderate	High

5.2 Education

Public education campaigns are an effective means of bringing about behavioural change in the general population. Pedestrian safety campaigns can generally focus on increasing awareness of road safety strategies, or specifically target vulnerable populations such as seniors and children.

Road Safety Awareness Campaigns

Educational outreach activities are an ongoing element of successful road safety strategies and continue to be utilized even in places such as the Netherlands that have already achieved excellent road safety records. Most road users lack information about the ways they can contribute to reducing the chances of a pedestrian injury or fatality. Drivers, particularly, are generally not aware that certain behaviors on their part are disproportionately risky for pedestrians. Numerous cities around the world report success with marketing campaigns aimed at particular roadway safety issues such as speeding, giving way to pedestrians at crossings, and drinking and driving.

A multimedia campaign in Vancouver could include the following core messages that address identified issues. Speed and crosswalk messages should support existing enforcement actions.

- Speed kills – Obey the speed limit, and reduce driving speed in adverse weather conditions (dark, rain, fog).
- Crosswalks – Pedestrians have the right of way in both marked and unmarked crosswalks. If drivers disregard the pedestrian right-of-way at a crosswalk, they may end up liable for the crash.
- Introduction of new infrastructure – Should any major new pedestrian infrastructure be introduced a campaign should increase all road users' understanding of the purpose of the change, rights and responsibilities, and expected behavior.

A campaign may include any or all of the following outreach strategies:

- TV
- Print media
- Billboards, bus ads, and other outdoor media

- Social media – both the City of Vancouver's own Twitter/Facebook presence as well as relevant partner groups and agencies
- Creating videos and sharing them via YouTube and/or Vimeo
- Posters and brochures at schools, community centers, and senior centers.

A sample of cities and programs are presented in Table 5.2 below. A variety of resources are available online to support the development of effective road safety awareness campaigns, some of which are included in the links found in Appendix D.

Table 5.2
Example Road Safety Awareness Programs from Around the World

City/Agency	Campaign Messaging	Description
RTA (New South Wales)	Speeding Drunk Driving Motorcycles Alcohol and Drugs Driver Fatigue Seat belts Motorcycles Young Drivers Road Worker Safety	Various marketing campaigns aimed at affecting behavioural change in motorists.
Toronto	We're all Pedestrians (current) "Please Drive Carefully – We're all Pedestrians" (2003/04)	Reinforces the theme that everyone needs to take care and be courteous as they make their way around Toronto. The posters are featured on transit shelters and curb side garbage bins throughout the city.
Think! Road Safety (United Kingdom)	Speed – rural Speed – urban Be Safe Be Seen	Comprehensive website includes a wealth of information highlighting Think! campaigns as well as guidance for road safety professionals and educators.
FHWA	Pedestrian Safety Campaign	Pedestrian safety campaign materials developed by FHWA in 2003 – have been used by over 400 communities in the US.
Oakland and San Francisco, California	Tune in to your surroundings – Drivers can't always see you Walk a Child to School Day (annual event)	Programmatic elements to improve pedestrian safety, including annual events, safety training and public relation

City/Agency	Campaign Messaging	Description
	Pedestrian Safety Week (annual event) Safe Moves Town (pedestrian safety training for children) Public relations campaigns (including "It's Our Town, Let's Slow it Down")	campaigns.
Lausanne, Switzerland	"It is better to stop before…"	Campaign encourages motorists to yield to pedestrians at crossings.
New York City, New York	Curbside Haikus (pedestrian safety) Walk Ways (walking to school) Traffic Safety Calendar	Multimedia safety and event campaigns aimed at drivers and pedestrians of all ages.
Seattle, Washington	See You in the Crosswalk (pedestrian safety for drivers and walkers)	Pedestrian safety campaign for the holiday season. Includes carollers, flash mobs, videos, posters, bus ads, coaster giveaways,
Portland, Oregon	I Brake for People	Multimedia campaign aimed at drivers, encouraging yielding to pedestrians. Includes ads on transit vehicles, benches, and shelters, bumper stickers, and drive-time radio blurbs.
Chicago, Illinois	Pedestrian Safety Campaign	Numerous initiatives, including mannequins representing pedestrians who have died in crashes; outreach to schools, senior facilities, and taxi drivers; stencilled messages on sidewalks; and pedestrian crossing flags.

- Youth Pedestrian Safety Education

Young people tend to be amongst the most vulnerable road users, as their ability to judge safe walking behaviour is not yet fully developed. Pedestrian safety education makes sure that each child understands basic traffic laws and safety rules. Pedestrian safety education teaches children basic traffic safety rules, sign identification and decision-making tools. Pedestrian training is typically recommended for first- and second-graders and basic lessons can include “look left, right, and left again,” “walk with your approved walking buddy,” “stop, look, and listen,” and “lean and peek around obstacles before crossing the street.” Trained safety professionals can administer pedestrian safety in the classroom or gym class or classroom teachers may use established pedestrian safety curriculum.

Pedestrian safety issues can be also incorporated into a general roadway safety curriculum to be delivered at schools to children of all grade levels. It is necessary to transmit to the general public an understanding of the dangers that unsafe driving and excessive speeds pose to all roadway users, including pedestrians. These lessons are best instilled at a young age and carried through the education curriculum as young students become adults, and drivers themselves.

- School Zone Traffic Safety Campaign

A School Zone Traffic Safety Campaign creates awareness that students are walking and bicycling to school. A safety campaign is an effective way to reach the general public and encourage drivers to slow down and be cautious in the school zone area.

A campaign using signs and banners located near schools (for example, in windows of businesses, yards of people’s homes and print publications) can be kicked off at the start of each school year or in conjunction with special events, such as International Walk and Bike to School Month in October.

Large banners can be hung over or along roadways near schools with readable letters cautioning traffic to slow down, stop at stop signs or watch for students in crosswalks with catch phrases such as ‘Give Our Kids a Brake.’ These campaigns are best supported by the actual presence of children walking and bicycling to school, so they should be coordinated with program activities that encourage students to walk to school.

- Seniors

Seniors are disproportionately represented in pedestrian fatalities, as they are much more likely than younger pedestrians to die as a result of their injuries. Educating seniors about risks of walking, while also providing support and resources to help them overcome those risks, is a reasonable way to address this issue. Seniors often also experience decreased mobility and independence as they age, particularly if they have previously been dependent on driving to accomplish basic needs. Senior programs designed to increase walking can help seniors maintain independence and mobility, improve health, and provide an opportunity for social interaction.

Several existing efforts in the Vancouver area that are already addressing senior mobility issues might be willing to partner on including pedestrian safety education in their outreach. These efforts include Better Environmentally Sound Transportation's STAR - Seniors Transportation Access and Resources - program and TransLink's TravelSmart senior outreach. In addition, the City of Vancouver is currently working with Hip4Health on the Walk the Talk project. Sample Programs include:

- Portland Safe Routes to Senior Centers Program: http://www.portlandonline.com/TRANSPORTATION/index.cfm?c=eafeg
- Transportation Alternatives' Safe Routes for Seniors Program: http://www.transalt.org/campaigns/pedestrian/safeseniors

5.3 Enforcement

- Speeding Enforcement

Speed has been shown in many studies to be a factor in pedestrian collisions, and increased speed correlates to increased severity of collision injuries. Targeted speed enforcement can be deployed along major road corridors known to have speed-related crash problems. This may be indicated based on collision data and/or recorded speeds. Complaints from residents can also be evaluated to determine if a speed issue exists that may indicate increased pedestrian crash risk.

Pedestrian Safety Enforcement at Known Risk Times

Vancouver crash data indicates that the rate of pedestrian-involved crashes is higher on Fridays, during the weekday PM peak, and during dark hours. Enforcement campaigns targeting the highest-risk driver behaviors (failure to yield to a pedestrian in the crosswalk at an intersection – see information about crosswalk enforcement actions below) and pedestrian behaviors (crossing mid-block) should be executed along high-crash corridors during the PM peak (particularly on Friday) and with greater frequency as days shorten and increased hours of darkness result in greater pedestrian crash risk.

Red Light Cameras

Red light cameras photograph or record vehicles running red lights, allowing citations to be mailed to the owner and requiring no officer presence. Running red lights represents a serious threat to a safe pedestrian environment, as it endangers pedestrians at signalized crossings and undermines the effectiveness of providing pedestrians with a 'walk' signal. Furthermore, vehicles tend to speed up when running red lights, which can result in more severe collision injuries.

Crosswalk Enforcement Actions Near Senior Centers & Schools

In crosswalk enforcement actions, sometimes known as "pedestrian stings", the local police department targets motorists who fail to yield to pedestrians in a crosswalk. Crosswalk enforcement actions can be regularly executed near senior centers and schools. Crosswalk enforcement actions raise public awareness about the legal obligation of motorists to stop for pedestrians at crosswalks. While crosswalk enforcement actions do result in tickets being distributed, the greater impact comes through media publicity of the event to reinforce the importance of obeying pedestrian crossing laws. For locations near schools, the best timing for an enforcement action is the back-to-school window just after school has begun for the year. Once locations have been determined, the Police Department prepares by marking the safe stopping distance with cones. Then plainclothes police officers or trained volunteer decoys attempt to cross at corners and marked mid-block crossings just before a vehicle passes the cone. Decoys may also be notable community members (such as the mayor or a well-known business leader) to increase media interest in the event. If motorists fail to yield to the pedestrian in a crosswalk, a second police officer issues a warning or a ticket at the officer's discretion. Enforcement actions can be recorded on video to support issued violations should a motorist challenge the ticket.

6.0 Action Plan

This section provides an action plan based on the twelve key pedestrian safety issues that have been identified in the City of Vancouver, as summarized below:

a. WHEN	Key Issue 1	Winter and Adverse Weather Conditions
	Key Issue 2	High Activity Periods
	Key Issue 3	Late Night
b. WHO	Key Issue 4	Senior Fatalities
	Key Issue 5	Young Adults
c. WHERE	Key Issue 6	Intersections
	Key Issue 7	Arterial Corridors
	Key Issue 8	Local Street Intersections
d. WHAT & HOW	Key Issue 9	Left Turning Vehicles at Intersections
	Key Issue 10	Right Turning Vehicles at Intersections
	Key Issue 11	Jaywalking
	Key Issue 12	Driver Failure to Yield

The Action Plan includes a description of each issue as well as engineering, education and enforcement countermeasures recommended to address each issue. The list of measures under each category and the accompanying action items table should not be considered an exhaustive list, but rather are a set of potential pedestrian safety measures that can be considered for addressing the primary types of pedestrian collisions in Vancouver. It is likely that there are other measures not considered in this study that may also be appropriate for improving pedestrian safety.

a. WHEN

Key Issue 1 Winter and Adverse Weather Conditions

Issue

The collision data indicates that visibility is a key contributing factor in many pedestrian collisions. Pedestrian collisions are more common during the winter months, with the additional collisions largely taking place after dark (see Figure 4.9). Days are shorter in winter and a greater percentage of pedestrian activity takes place during nighttime and adverse weather conditions.

Potential Pedestrian Safety Measures

- The city could embark on a program to upgrade lighting at pedestrian crossing locations, beginning with locations with high night-time pedestrian volumes / collisions.

- Road safety awareness campaign targeted at the beginning of the winter season (i.e. at the daylight savings time switch) to:
    - Remind pedestrians and motorists to exercise additional caution in dark and rainy conditions;
    - Remind motorists that safe speeds depend on weather and light conditions, not just the posted speed limit; and
    - Remind pedestrians to wear visible clothing in poor lighting conditions.

Key Issue 2 High Activity Periods

Issue

The highest proportion of pedestrian collisions occurs during the PM peak period between 5 and 7 pm. More generally, pedestrian collisions are most common between 3 and 8 pm, when pedestrian activity levels are high. The prominence of pedestrian collisions in the afternoon/evening peak period offers opportunities to efficiently improve safety.

Potential Pedestrian Safety Measures

- Enforcement actions for speeding, jaywalking, and crosswalk yielding can be coordinated to occur more frequently during high activity periods.
- Opportunities may exist to adjust traffic signal timing during peak periods to provide additional time for pedestrians to complete crossings.

Key Issue 3 Late Night

Issue

While pedestrian collisions are relatively uncommon late at night, when they do occur they are nearly twice as likely to result in a fatality as compared with other periods. With fewer cars on the road late at night, drivers are able to operate at higher speeds, contributing to increased collision severity. Because there are fewer pedestrians on the road during these times as well, motorists may be less likely to be looking for people walking. Another factor is that both motorists and pedestrians are more likely to have consumed alcohol during the late night period, which can contribute to impaired judgment and risky behaviour such as speeding or jaywalking.

Potential Pedestrian Safety Measures

- As discussed in the Winter and Adverse Weather Conditions section above, installing and upgrading lighting at intersections and mid-block crossing locations can increase the likelihood that motorists see pedestrians late at night.
- Speed cameras or police enforcement can be implemented on corridors where motorists tend to speed at night and can reduce the frequency and severity of late night pedestrian collisions.
- Traffic signal timing can also be adjusted to reduce the minimum green times for the through movements, so the signal can respond more quickly to a pedestrian call, encouraging pedestrians to wait for their signal, rather than cross against it.
- The city could also work with ICBC, VPD and others to develop a road safety awareness campaign aimed at minimizing drunk driving/walking.

b. WHO

Key Issue 4 Senior Fatalities

Issue

The characteristics of collisions involving seniors are similar to those of the general population, however, older pedestrians are less likely to survive a pedestrian collision. For Vancouver residents to successfully rely on walking or public transportation as they age, it is essential that the transport system be pedestrian friendly and forgiving of mistakes in judgment and changes in walking speed that occur naturally.

Potential Pedestrian Safety Measures

- There are a number of ways to improve safety for seniors, including evaluating the presence of safe crossing facilities throughout the City, and particularly in areas with a high concentration of seniors. Enhanced crossing treatments and the adjustment of signal timing can accommodate slower walking speeds at locations with a higher proportion of seniors.
- The city can conduct outreach to seniors by way of lunchtime talks or walks, or develop a safe routes for seniors program that works through senior centres and seniors housing to identify and address infrastructure issues, as well as educate seniors about safety issues and organize group walks.

- Enforcement priorities for speeding and crosswalk yielding can include areas where seniors are more likely to be present, such as around senior centres.

Key Issue 5 Young Adults

Issue

Young adults aged 20 to 29 are over-represented in pedestrian collisions (24.4% of pedestrian collisions, but only 16.8% of the population) and are the age group most likely to be involved in a pedestrian collision. Young adults are also over-represented in vehicular collisions. For example, the 2011 Road Safety in Canada report[13] notes that 40% of speeding drivers involved in fatal crashes were 16 to 24 years of age. Younger people are also more likely to be drinking and driving, as indicated in the same report which states that approximately 45% of the HBD drivers (had been drinking) and those drivers over .08 blood alcohol content were aged 20-35 even though only 27% of licensed drivers were in this age group. While not available in the data, young people may also be more likely to be under the influence of alcohol while walking, which can impair their ability to make good decisions about safe walking and crossing behaviour.

Potential Pedestrian Safety Measures

- A road safety awareness campaign can target young drivers and pedestrians.
- Enforcement actions can focus on places where young people tend to congregate, such as around universities or major entertainment districts.
- A safe routes to school program such as the City's School Active and Safe Transportation Program, can instill traffic safety knowledge at an early age.

c. WHERE

Key Issue 6 Intersections

Issue

The majority (75 percent) of pedestrian collisions in the City of Vancouver take place at intersections. Twenty-one intersections experienced 11 or more pedestrian collisions over the past six years, and seven intersections in particular were identified as Collision Prone Locations. Recent efforts have focused on installing safety measures at intersections with the highest collision frequency. The city should praoactively address pedestrian safety issues at Collision Prone Locations and continue to monitor pedestrian safety at locations with high collision rates by utilizing the additional treatments recommended in this study.

Potential Pedestrian Safety Measures

- The research conducted as part of this study supports the city's recently adopted policy of retrofitting high collision intersections with countdown signal timers and of making this treatment standard for all new signalized intersections. The City should continue to install countdown signal timers at high collision locations.
- The city could complement engineering measures with a road safety awareness campaign to alert both motorists and pedestrians of the prevalence of pedestrian collisions at intersections and encourage more caution in these areas.
- The city could also work with the Vancouver Police Department to perform crosswalk enforcement actions at high collision intersections to discourage unsafe behaviour on the part of both motorists and pedestrians.

Additional engineering treatments for intersections are presented in the What & How section (Left Turning Vehicles at Intersections and Right Turning Vehicles at Intersections).

Key Issue 7 Arterial Corridors

Issue

The majority of both intersection and mid-block pedestrian collisions take place on primary and secondary arterial streets. Furthermore, as indicated in Figure 4.16, pedestrian collisions tend to be concentrated along a number of arterial corridors in the Downtown core as well as along corridors such as Broadway, 12th Avenue, 41st Avenue, Kingsway, Hastings Street, Main Street, Fraser Street, Knight Street, and Commercial Drive, among others.

Potential Pedestrian Safety Measures

- Undertake a corridor pedestrian safety strategy by evaluating groups of intersections along arterial corridors and considering 'packages' of complementary mitigation measures to deal with primary collision types identified in the What & How Section. Potential treatments could include left turn bays/left turn signals at major cross-streets; or pedestrian signals/greenways/restricted left turns at minor traffic streets and major pedestrian corridors. A multi-agency approach is recommended that complements engineering treatments with police enforcement actions and road safety awareness campaigns aimed at arterial roadway users (i.e., at bus stop shelters).

Key Issue 8 Local Street Intersections

Issue

While the majority of pedestrian collisions occur at the intersection of arterial streets, pedestrian collisions also occur at the intersection of two lcoal streets. This type of collision represents 6.5% of all pedestrian collisions, and 21 intersections at local-local intersections had more than one pedestrian collision between 2005 and 2010.

Potential Pedestrian Safety Measures

- Greenway Treatments including traffic calming measures such as speed humps, corner bulges, and traffic circles on local roads tends to enhance the pedestrian environment by reducing vehicle speeds. Slower speeds allow drivers and pedestrians more time to notice each other, reducing the likelihood of collisions and reducing injury severity when collisions do occur.
- Speed Reader Boards can be rotated throughout local streets with a history of pedestrian crashes to encourage people to drive at speeds appropriate for neighborhoods.
- Raised Crosswalks reduce speeds and increase the visibility of pedestrians.

d. WHAT & HOW

Key Issue 9 Left Turning Vehicles at Intersections

Issue

The most common pedestrian collision type includes a left turning vehicle at an intersection (33.9% of pedestrian collision). Most of these left turning collisions occur at signalized intersections and involve a pedestrian crossing with the right of way (i.e., with a walk signal). This is to be expected, as traffic signal phasing typically allows the pedestrian crossing phase to run simultaneously with the through and permitted turning movements on the parallel street segment.

Potential Pedestrian Safety Measures

There are a number of measures that can reduce potential conflicts between pedestrians and left turning vehicles:

- Leading Pedestrian Intervals give pedestrians an advanced walk signal, allowing them to clearly establish their right of way in the crossing before vehicles are given a green light.

- Left turn bays can be implemented at intersections where there is room for a dedicated left turn lane. Left turn bays provide a dedicated space for vehicles to make a left turn, allowing them to concentrate on making a safe turn with less pressure from following vehicles.
- Left turn movements can be given their own protected phase separate from the pedestrian walk phase. Left turns can also be prohibited at all times or at certain times of day at certain high collision intersections or at minor cross-streets to allow the turning movement to occur at a more appropriate location.
- A road safety awareness campaign can be directed at both drivers and pedestrians, reminding them to look out for each other at intersections.
- Crosswalk enforcement by police can focus on intersections with high numbers of pedestrian collisions.

Key Issue 10 Right Turning Vehicles at Intersections

Issue

Collisions involving right turning vehicles are the second most common type of pedestrian collision (22.2% of all pedestrian collisions). Similar to collisions involving left turning vehicles, most of these collisions occur at signalized intersections when the pedestrian is crossing with the walk signal.

Potential Pedestrian Safety Measures

- Actions to reduce potential conflicts between pedestrians and right turning vehicles are similar to those cited in Key Issue 9 above.
- In addition, right turn on red movements can be restricted at select intersections where this type of collision is common.

Key Issue 11 Jaywalking

Issue

The third most common type of pedestrian collision (11.5%) occurred where pedestrians were attempting to cross the street at a mid-block location without an intersection control.

Potential Pedestrian Safety Measures

- Additional mid-block crossing facilities can be considered based on crossing demand and collision history. New mid-block crossings may be appropriate near a particular pedestrian generator or at other locations where there is crossing demand remote from an existing crossing facility.

- A "cross at the corner" road safety awareness campaign can remind pedestrians that they are required to cross at intersections or other dedicated crossing facilities.
- Crossing guards are typically used at school locations, but could also be used at particular locations where jaywalking is common, such as along Hastings Street.
- Police enforcement at known jaywalking locations.

Key Issue 12 Driver Failure to Yield

Issue

Failure to yield refers to cases where a driver fails to yield to a pedestrian that is crossing the street at a signalized intersection with the right-of-way, at a stop sign, or at a marked or unmarked crosswalk Nearly all failure to yield collisions occur at signalized intersections (46.2% of all pedestrian collisions), with a smaller number of failure to yield collisions occurring at stop signs or crosswalks (16.3% of all pedestrian collisions) or intersections without an intersection control (4.5% of all pedestrian collisions).

Potential Pedestrian Safety Measures

Strategies for addressing failure to yield at signalized intersections have largely been covered in Key Issues 9 and 10 above. Strategies to address the other types of failure to yield collisions include:

- Red light cameras to deter motorists from running red lights.
- Crosswalk enforcement, particularly at intersections with high pedestrian activity.
- A "pay attention" road safety awareness campaign to raise driver awareness of the possibility that inattentive or distracted driving could cause pedestrian collisions.

e. Summary

Table 6.1 below summarizes the recommended engineering, enforcement and communication measures to address the primary pedestrian safety issues in the City of Vancouver. The following high priority measures are anticipated to be particularly effective based upon the review of best practices relative to Vancouver collisions.

- Minimize conflicts between motorists and pedestrians at intersections
  - Continue to install countdown signal timers as standard practice for new signals and at high collision intersections as resources permit.
  - Continue to install corner bulges and raised crosswalks on local streets.
  - Upgrade lighting at intersections with high night-time pedestrian volumes and/or collisions.
  - Assess high collision intersections and consider installation of the following:
    - Leading pedestrian intervals
    - Left turn bays as well as protected or prohibited left turns
    - Increased pedestrian walk and clearance intervals
- Improve visibility at night
  - Improve lighting to enhance visibility at intersections.
- Use road safety awareness campaigns to target behaviour related to common collision types
  - Road safety awareness campaigns can be developed in partnership with other agencies such as ICBC and the Vancouver Police Department to focus on:
    - Increased risk of pedestrian collisions at night and in adverse weather conditions
    - Safe walking and driving by young adults
    - High incidence of conflicts between drivers and pedestrians at intersections
    - Safe driving and crossing behaviour on arterial corridors
- Work with police to target enforcement actions to improve pedestrian safety
  - The City of Vancouver can partner with the Vancouver Police Department to tailor enforcement actions to occur:
    - During high pedestrian activity periods
    - At high collision intersections
    - Along high collision corridors

Table 6.1

Summary of Engineering, Communication, and Enforcement Countermeasures to Address Key Pedestrian Safety Issues

		Where			When			Who		What & How			
Action	Typical Application	Intersections	Arterial Corridors	Local Street Intersections	Winter & Adverse Weather	High Activity Periods	Late Night	Senior Fatalities	Young Adults	Left Turning Vehicles	Right Turning Vehicles	Jaywalking	Driver Failure to Yield
	Engineering												
Alternative left turn schemes	• Consider protected or prohibited left turns to remove conflicts with pedestrians in crosswalk	✓								✓			✓
Pedestrian Countdown timers	•Countdown timer retrofit program for high collision locations	✓	✓							✓	✓		
High crash corridor assessment	• Evaluate high collision corridors and treat with engineering, enforcement and education strategies		✓										
Install/upgrade lighting	• Install/upgrade lighting to improve pedestrian visibility at intersections	✓			✓		✓						
Intersection assessment	• Assess and improve high collision intersections and treat as required (LPIs, left turn schemes, lighting, red light cameras, etc.)	✓								✓	✓		✓
Leading pedestrian intervals	• Consider leading pedestrian intervals at intersections with high numbers of pedestrian collisions with turning vehicles	✓								✓	✓		✓
Left turn bays	• Consider left turn bays at intersections with pedestrian collisions involving left turning vehicles	✓	✓							✓			✓
Mid-block pedestrian crossings	• Consider at high crash locations with consistent pedestrian crossing demand and/or distant crossings											✓	
Pedestrian crossings	• Consider new pedestrian crossings to serve areas with high numbers of seniors							✓					
Pedestrian signals	• Consider new pedestrian signals at unsignalized high collision intersections	✓				✓							✓
Prohibit right turn on red	• Consider prohibiting right turns on red at intersections with high numbers of pedestrian collisions with right turning vehicles	✓									✓		✓
Raised crosswalk	• Consider installing raised crosswalks to improve pedestrian visibility and slow vehicles	✓		✓				✓					
Raised intersection	• Consider installing raised intersections to increase yielding and slow vehicles	✓		✓									
Signal timing	• Consider adjusting signal timing to minimize pedestrian delay late at night • Consider reducing assumed walking speed at signalized intersections with high numbers of seniors • Consider coordination of signal timing to limit vehicular speeds • Consider separate phasing plans to provide additional walk time at select intersections during the PM peak period	✓	✓			✓	✓	✓	✓			✓	
Signs	• Install signage to remind turning vehicles to yield to pedestrians at intersections	✓				✓				✓	✓		✓

		Where			When			Who		What & How			
Action	Typical Application	Intersections	Arterial Corridors	Local Street Intersections	Winter & Adverse Weather	High Activity Periods	Late Night	Senior Fatalities	Young Adults	Left Turning Vehicles	Right Turning Vehicles	Jaywalking	Driver Failure to Yield
Traffic calming	• Consider traffic calming to reduce speeds near intersections and on local streets with a history of collisions, with higher ADT than desired, and near schools or senior centers	✓						✓					
	Communication												
Individualized marketing	• Promote safer night walking by distributing reflective materials				✓		✓						
Lunch talks and/or educational walks	• Conduct activities to educate seniors on minimizing risks when walking							✓					
Safe Routes to School	• Consider working to increase active transportation and traffic safety awareness from a young age								✓				
Safe Routes for Seniors Program	• Work through senior centers and senior housing to identify and address infrastructure issues as well as educating seniors about safety issues and organize group walks							✓					
Road safety awareness campaigns	Consider the following targeted road safety awareness campaigns: • High collision arterials and downtown core message • Encourage pedestrians to cross at the corner • Emphasize pedestrians have right of way in crosswalks • Remind road users that most pedestrian collisions occur at intersections • Remind road users that pedestrian collisions are more likely during winter and adverse weather • Remind drivers that safe speed depends on conditions, not just posted speed • Encourage slow speeds on local streets • Reminder that drinking impacts judgment while driving and walking • Target young drivers and young pedestrians to make safe traffic decisions • Target distracted driving • Slow down for seniors	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
	Enforcement												
Crosswalk stings	Targeted crosswalk and jaywalking enforcement: • at high collision intersections • during high activity periods	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Mobile enforcement	Targeted enforcement (speeding, failure to yield) • in collision prone zones • during high activity period • along high collision arterial corridors • late at night • in senior zones	✓	✓			✓	✓	✓					✓
Speed reader boards	• Install speed reader boards in areas with localized speeding problems		✓										

6.1 Multi-Agency Coordination and Cooperation

The improvement of pedestrian safety within the City of Vancouver will require the involvement and coordination of a number of agencies involved in pedestrian-related infrastructure, operations, services, and enforcement. These include the City of Vancouver, ICBC, Vancouver Police Department (VPD), the BC Ministry of Health (MoH), TransLink, and the Vancouver School Board (VSB). In addition, other stakeholders, such as the Vancouver Area Cycling Coalition (VACC) and British Columbia Automobile Association (BCAA), could play a role in identifying needs, education and advocacy. Each of these agencies can contribute to pedestrian safety through four general areas:

5. Provision of primary data and information;
6. Planning/engineering/operations;
7. Communication; and
8. Enforcement.

Each of the agencies could take on either a lead or supporting role in these areas, working together in cooperation to plan, deliver, and evaluate strategies to improve pedestrian safety. Table 6.2 provides a summary of the agencies and their potential roles.

Table 6.2
Multi-Agency Pedestrian Safety Roles

	City of Vancouver	ICBC	VPD	BC MOH	TransLink	VSB	Stakeholders
Data and Information	Co-Lead	Co-Lead	Support	Support	Support	Support	Support
Planning, Engineering, Operations	Lead	Support	Support	Support	Support	Support	Support
Communication	Support	Lead	Support	Support	Support	Support	Support
Enforcement	Support	Support	Lead	Support	Support	Support	Support

A cooperative between agencies could be made through the Pedestrian Subcommittee of the recently formed Active Transportation Advisory Committee, or through another separate cooperative model. The scope of the cooperative could be the recommendation of plans and investments through the identification of issues and the development of business cases based on evidence and research of documented pedestrian safety improvements and successes.

A key component in the success in the improvement of pedestrian safety is in the monitoring of measures of effectiveness (MOEs) that are designed to not only evaluate success, but provide feedback in the development of remediation strategies when needed. This requires an evidence-based approach in which data from a number of sources is required. Section 6.2 provides further discussions on pedestrian safety monitoring, data collection, and compilation.

6.2 Data Collection

As noted in this report, the availability of pedestrian-related safety data is limited for any given location due to the relatively low number of reported pedestrian safety incidents. In order to develop an evidence-based decision process that provides the best basis for effective investment decisions, data is required to be collected, assembled, and compiled from a number of sources. Key data types required to support a robust pedestrian safety program include:

Collision / Injury Data Reported collision and injury data is the core of safety analyses. Collision data typically are reported when a vehicle is involved and are available through ICBC or VPD. However, injuries can also be reported through medical institutions, especially for non motor-vehicle related incidents (i.e. pedestrian/cyclist collision). It is recommended that pedestrian collision and injury data be harmonized so that it can be more effectively and efficiently used in pedestrian safety analyses. Data is also required regarding injury severity.

Violations / Complaints Data Citation data for violations can be obtained by the VPD. These include violations made by both pedestrians and vehicles related to pedestrian-related or pedestrian-significant (i.e. speeding or red-light running from ICBC operated Intersection Safety Cameras) violations. Violations may be evaluated regarding conscious disregard or lack of comprehension of regulations, which can help assess changed conditions such as the installation of new traffic devices. Citizen complaints related to pedestrian-safety can also be a source of issues that may warrant further investigations.

Infrastructure Data Infrastructure data such as geometric or as-built drawings and sidewalk locations (COV), bus-stop locations and designs (TransLink), and general road network information (Provincial Digital Road Atlas) are required to provide contextual information to support pedestrian safety analyses. A standard spatial referencing system for all datasets should be developed to ensure optimal data usability.

Demographic Data Demographic data related to residential and commercial information, both during night-time and daytime periods can be used to provide further contextual information to support the analysis of pedestrian safety. Data can be provided from the City, as well as BC Stats, and StatCan.

Exposure / Operation Data Exposure data typically refers to traffic volumes (by class and type of road user), specifically average annual daily traffic (AADT) volumes. However, current research in the use of video analytics can provide more rich exposure data that also provides a level of safety measurement, in the form of conflict data. As a key variable in determining safety significance, exposure data is an important dataset in safety analyses. Other data such as traffic signal timing and phasing data is useful in detailed analyses at particular locations.

Weather and Light Conditions Data Visibility is a key variable in the safety of pedestrians. Information regarding weather and light conditions can therefore play an important role in the evaluation of safety metrics related to pedestrian collisions and incidents. Furthermore, glare during sunrise and sunset can affect visibility. This data is provided by Environment Canada. Illumination can also vary by location as tall buildings and foliage can reduce lighting and visibility, therefore site specific assessment should consider such information (obtained both from site observations and City data).

Civic Events Events that draw in large numbers of pedestrians can cause an increase in pedestrian incidents. Therefore, major events such as sporting events in the downtown core, or national holidays, should be noted to ensure analysis of such data can take into consideration these unique situations. The City of Vancouver should keep a record of such events to be used in conjunction with pedestrian safety analysis.

Table 6.3 provides a summary of the types of pedestrian-related data that can be assembled and their sources.

Table 6.3
Inter-Agency Pedestrian Safety Data Types and Sources

Data Source: Data Type	COV	ICBC	VPD	BC MoH	TransLink	Other Province	StatsCan	Other Federal
Collision / Injury		✓	✓	✓				
Violations / Complaints		✓	✓					
Infrastructure	✓				✓	✓		
Demographic	✓					✓	✓	
Exposure / Operations	✓				✓			
Weather & Light Cond.	✓							✓
Civic Events	✓							

The use of a variety of appropriate datasets can be a challenging effort at the start, however a rich set of data will provide the best “viewpoint” in identifying the key issues and trends related to pedestrian safety, while allowing for analysts to deal with issues such as data quality and confounding factors.

However, before a specific data collection and assembly plan is developed, it is important to identify the data needs. This requires the development of MOEs that will provide the strategic summary of the data broad enough for decision makers, yet, detailed enough for the development of specific strategies. It is recommended that MOEs are developed with the following five considerations:

1. Appropriate: All measures should provide a strong representation of what are the key characteristics from which decisions should be based on. The higher the degree of appropriateness, the greater the applicability and usefulness of the MOE’s representation.
2. Measureable: An MOE needs to be measureable, in that a study and related equipment is feasible enough such that observations can be made to provide adequate data for the MOE.
3. Sensitive: An MOE should be sensitive enough to be able to differentiate changes in a significant manner within the time period desired. Considerations for statistical significance, measurement error, and any biases are required in order to ensure an MOEs sensitivity is adequate for analysis needs.
4. Repeatable: As analyses that deal with trend require multiple observations, MOEs need to be designed such that the collection of supporting data can be repeated in identical fashion.

5. Cost-Effective: The collection of data for MOEs should consider the amount of resources required (budget, staffing, equipment, time). The affordability of MOEs will play a role in determining their cost-effectiveness and priority within an overall pedestrian safety monitoring program.

Appendix A

Detailed Economic Cost of Pedestrian Collisions

Background

Costs associated with collisions generally include market and non-market costs. It is relatively straight forward to estimate the market-related costs of collisions such as medical care, administration costs, lost earning and production because of an injury or disability, etc. On the other hand, it is difficult to obtain reasonable estimates of the non-market costs of a collision which include the value of human life, the value of disability or injury, pain, suffering and grief of family and friends of a person involved in a collision. Two common approaches are usually used to quantify the value of human life, namely the human capital cost approach and the willingness to pay approach.

The human capital cost method only measures market costs (property damage, medical treatment, and lost productivity). The willingness to pay approach adds non-market costs, including pain, grief, and reduced quality of life, as reflected by people's willingness-to-pay for increased safety (reduced crash risk and damages). The willingness to pay approach is currently used by most road agencies for evaluating road safety programs as it is considered a more appropriate measure of the true cost to society of crashes.

Many people will find the concept of assigning a monetary value to human life unacceptable. However, people, businesses and governments frequently make decisions that involve tradeoffs between monetary costs and incremental changes in health and safety risks. For example, people may decide to buy vehicles with different safety features and price ranges or to choose among different jobs with different risk levels and salaries. These decisions implicitly reflect an estimate of the monetary value of a statistical change in human injury and death. Therefore, the value of human health and life estimated simply reflects what people and society seem willing to pay monetarily for marginal changes in health and safety risks.

These cost values can depend on the demographic attributes of the population under consideration. For example, values are generally considered higher for people in the prime of life than older people who expect to live fewer years. Some studies evaluate risks based on Potential Years of Life Lost (PYLL), which accounts for age when people are harmed, or Disability Adjusted Life Years (DALYs), which also accounts for years of disability. Vehicle crashes tend to injure younger people more than other common health risks such as heart disease and cancer (traffic crash death age averages 39 years, compared with 71 years for all causes), and therefore impose a relatively high cost per death or disability.

Previous Work

This section is dedicated to review previous work on estimating the non-market cost of collisions as it represents the main component of the total collision cost.

Parry (2004) estimated total and external accident costs in the US, and the portion of these costs borne by insurance. His estimate of different types of quality of life costs for various accident severities was: $3,000,000 for fatality, $83,239 for disabling injury, $19,560 for evident injury, $10,725 for possible injury and $464 for property damage.

A recent report published in 2010 by the Victoria Transport Policy Institute has surveyed the non-market costs of collisions used by agencies all over the world. Among the agencies surveyed in the report, non-market collision cost estimations of three agencies in North America are reported here:

- In 2008 the U.S. Department of Transportation established the economic value of a statistical human life to be $5.8 million, with a range of $3.2 million to $8.4 million for cost-benefit calculations of transportation projects that affect fatality rates.
- A study for Capital Region Intersection Safety Partnership (CRISP) committee developed a collision cost model that includes estimates of direct costs, human capital costs and willingness-to-pay to reduce damages from various types of crashes. The results indicate that Willingness-to-pay costs average $5,416,200 for a fatality, $1,385,600 for a major injury (including injuries that lead to disabilities), $30,600 for a minor injury and $11,400 for a property damage only crash.
- The US National Safety Council published two monetized estimates of motor vehicle crash costs. This includes $3,760,000 for fatality, $188,000 for non-fatal disabling injury, $48,200 for no-incapacitating evident injury, $22,900 for possible injury and $2100 for property damage (all costs are in 2004 US dollar)

A report published in 2007 by the Transportation Association of Canada (TAC) entitled “Analysis and estimation of the social cost of motor vehicle collision in Ontario” estimates the total collisions cost of Ontario as well as the collision cost of four subgroups (pedestrians, drunk drivers, trucks, and motor vehicle collisions on freeway). Table A.1 summarizes the human consequences cost estimates used by the TAC report:

Table A.1
Core Willingness To Pay Parameters for Human Consequences Used by TAC report (2004 CAD)

Type of effect	Value by type of effect by scenario:		
	Upper bound	Lower bound	Mean value
Death	$19.7 million	$7.5 million	$13.6 million
Activity day used for short-term disabling injury below	$2,885	$577	$1,730
Per major injury	$215,510	$43,102	$129,231
Per minor injury	$43,275	$8,655	$25,950
Per minimal injury	$2,308	$462	$1,384
Partial disability	$1,201,977	$240,395	$721,186
Total disability	$2,403,954	$480,790	$1,442,372

Using these values and adding the market related costs, the report estimated pedestrian collision costs in Ontario in 2004. Pedestrians were involved in 4,555 collisions in 2004 in Ontario which resulted in 108 fatalities, 711 major injuries, 4,687 minor injuries and 2,810 minimal injuries. The total fatalities costs were $1.476 billion and the total injuries cost were $400 million (2004 Canadian dollar) with a weighted average social cost of $412,000 for each pedestrian.

Analysis

To estimate the cost of pedestrian collisions in Vancouver, both human consequences costs and the market-related costs need to be estimated.

1. Human Consequences Costs

Table A.2 summarizes the value estimated for human consequences used in this analysis. All values are based on the willingness to pay approach and are presented in 2010 Canadian dollars. The value assigned to the willingness to pay to prevent a fatality ($6,200,000) is the typical value used for safety analysis in BC as reported by the BC Ministry of Transportation and Infrastructure. The values for injuries for different severities are not available for BC. Therefore, values from the 2007 TAC report were used after adjustment using the ratio between the average GDP per capita of BC and Ontario (0.88)[2].

[2] This ratio is calculated based on data from Stats Canada

Table A.2
Human consequences cost estimates (2010 CAD)

Fatality	$6,200,000
Major injury (But doesn't lead to a disability)	$128,777
Minor injury (But doesn't lead to a disability)	$27,238
Partial disability	$718,650
Total disability	$1,437,300
Activity day lost	$1,724

British Columbia pedestrian collision data does not classify injuries into minor and major (severe) injuries. It was assumed that the ratio of major (severe) injuries is 10% of total injuries based on Ontario data presented in the 2007 TAC report. In order to estimate the ratio of partial and total disabilities, the probability values in Table A.3 were used. The table shows the probability that collision could lead to a partial or total disability (TAC, 2007).

Table A.3
Probability of partial and total disabilities

Injury Severity	Probability that injury will result in:	
	Total disability (%)	Partial disability (%)
Major injury	1.62	14.93
Minor injury	0.09	1.73

The number of activity days lost as a result of an injury in a collision is available in the 2007 TAC report and is presented in Table A.4.

Table A.4
Estimated Number of activity days lost because an injury

Injury severity	Number of Activity days lost
Major injury	74.4
Minor injury	15.8

2. Market Related Costs

The market-related costs include the medical care costs, administration costs (police, ambulance, etc.), lost earnings in addition to indirect costs for other road users including time lost, fuel loss and extra pollution as a result of the traffic delays associated with collision event.

- Lost Earnings

According to Stats BC, the average wage in BC is estimated at $20.40 / hr (2010 CAD). This estimate is used to predict the lost earnings for injured pedestrians using the average number of working days lost of different injury severities reported in TAC report 2007 which is presented in Table A.5.

Table A.5
Average work days lost because an injury

Injury severity	Number of Working days lost
Major injury	45
Minor + minimal injury	6.7

- 2.3.2.2 Medical care:

According to a study conducted by the New South Wales risk management research center in 2002, the average number of days a pedestrian is hospitalized because of an injury is estimated to be 10 days. This estimate is the weighted average of different injury severities of different groups of pedestrians classified according to gender and age.

The average hospital day in Ontario costs $216.30 in 2004 as stated in the TAC report. This value was adjusted for BC using the ratio of GDP per capita for both provinces discussed before and the cost was updated to 2010 Canadian dollars using the average consumer price index (which is available in Stats BC). Finally, we place a value of $ 215.50 per hospital day for this analysis.

- 2.3.2.3 Administration cost

Table A.6 summarizes the administration costs assigned for this study. The values were taken from the TAC report, adjusted for BC using the ratio of GDP per capita for BC and Ontario and updated to 2010 Canadian dollars using the average consumer price index.

Table A.6
Administration costs

Ambulance	$ 780.20 per injury or fatality (2010dollar)
Police	$ 77.70 per hour (2010 dollar)

- 2.3.2.4 Indirect costs (external costs to other road users)

Table A.7 summarizes the elements of external costs and estimation of each element to other road users including the lost time, fuel lost and extra pollution usually associated with traffic delays resulted in collisions. It is estimated that on average a pedestrian collision will result in traffic delay of about half an hour for about 300 vehicles. These values were estimated from similar studies.

Table A.7
Indirect costs

Time loss	Value of Time	$ 13.50 per hr per person (2010 dollar)	Source: Micro Ben-cost Default Values 2007, BC Ministry of transportation and Infrastructure
Fuel loss	Fuel loss	$ 2.25 liter per vehicle per hour delay	Source: TAC report 2007
	Fuel price	$ 1.35 (2011 average price) = 1.32 (2010 dollar)	Source: BC Stats
Extra pollution cost	emissions	$ 7.70 per vehicle per hour delay	Source: Values from TAC report 2007 (adjusted for BC)

Results

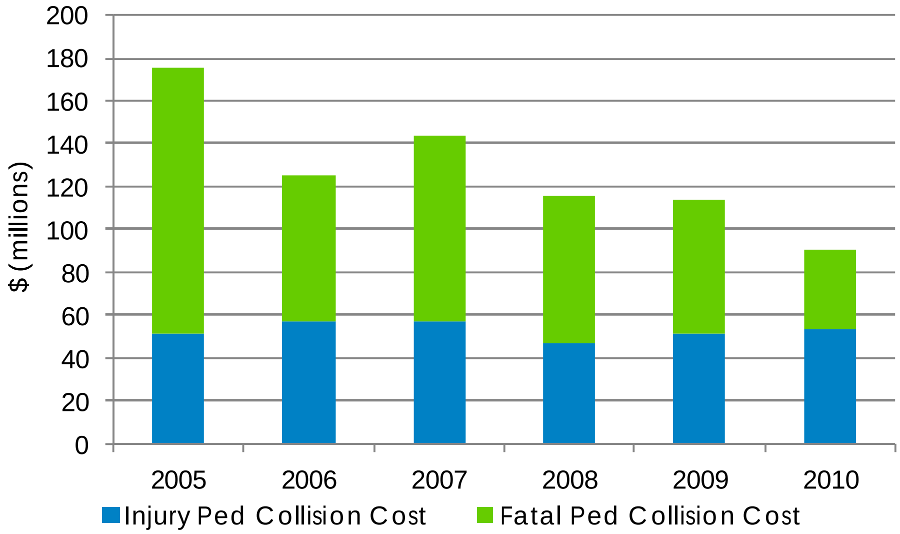
Table A.8 shows pedestrian collision costs estimated for the City of Vancouver. The average cost of pedestrian injury shown in the table is a weighted average cost of all injury severities (severe, minor or disabling injury). The average cost of a pedestrian collision is estimated at $234,000 based on the ratio of 2.1% pedestrian fatalities and 97.9% injuries (based on 2005-2010 BC pedestrian collision data).

Table A.8
Pedestrian collision cost in Vancouver (2010 Canadian dollar)

Average cost of pedestrian fatality	$ 6,209,000
Average cost of pedestrian injury	$ 106,000
Weighted average of a pedestrian collision cost	$ 234,000

Based on the cost values shown in Table A.8, the pedestrian collision costs for the City of Vancouver for the years 2005-2010 are shown in Figure A.1.

Figure A.1
Pedestrian collision cost in Vancouver (2010 Canadian dollar)



Discussion

The cost of injury collisions is significantly dependent on the ratio of major injuries to the minor injuries and the ratio of pedestrians disabled because of an injury. Those ratios are not available for Vancouver as mentioned previously and were estimated for this study based on the TAC 2007 study. A sensitivity analysis was conducted to determine the significance of this assumption. The results suggest that the cost of injury will increase by about 28% if the ratio of severe injuries changed from 10% to 20%. This shows that the results are highly sensitive to the assumed severe collision ratio and specific values for the City of Vancouver should be obtained.

Appendix B

Collision Modelling Methodology

Zonal Collision Prediction Models

Traditional road safety improvement programs (RSIPs) focus on the identification, diagnosis and remedy (improvement) of collision-prone locations or black spots (i.e. black spot programs). These programs usually employ location-specific (micro-level) Collision Prediction Models (CPMs) to identify and evaluate the safety of individual collision prone locations (CPLs). While the use of location specific CPMs and black spot programs have proven to be very successful, this type of program has traditionally been *reactive* in nature, such that a significant collision history must have existed before any action was taken. There is a need to take a *proactive* approach that addresses road safety before problems emerge. This proactive approach should complement the more traditional, reactive methods currently in use.

Macro-level CPMs (traffic zone or neighborhood models) may help with the delivery of a proactive road safety measure. Macro-level CPMs, by nature of their neighbourhood-wide or macro-level focus, have the potential to complement the micro-level CPM black spot methods currently in use, by providing an early-warning empirical tool. The objective of this section is to develop neighbourhood (traffic zone) pedestrian collision prediction models. The models relate pedestrian collisions to specific network, environmental and demographic characteristics of traffic zones (neighbourhoods). These models are useful for proactive safety planning initiatives. One application of these models is described where pedestrian collision prone zones are identified.

Data Collection & Extraction

The data was extracted and compiled using three main sources. TransLink provided geo-coded files of land use, road network, and zone/census tract boundaries. TransLink also provided spreadsheets converted from Emme/2 travel demand data files. Second, socio-demographic, employment, and mode split data for each zone was obtained from Statistics Canada. Zonal employment included figures for the major private or public sectors: government, tourism, retail, and construction. ICBC provided geo-coded files for pedestrian collisions for the years 2005-2010.

Potential explanatory variables were grouped in four themes:

1. Exposure: variables related with traffic collision probability.
2. Transportation Infrastructure: refers to characteristics of the road network.
3. Socioeconomic: variables based primarily on the 1996 census data.

4. Transit Network Group: variables related to bus network elements physically present in the roads.

Table B.1 shows a list of the variables and their definitions.

Table B.1
Variables and summary statistics (134 traffic analysis zones) in the City of Vancouver

Variable	Description	Zonal	
		Average	St. Dev.
Exposure			
V KT	Total transit and vehicle kilometers traveled	4,131.52	2,779.73
VC	Volume to capacity ratio (avg. Congestion, Emme/2)	0.43	0.13
Infrastructure			
INT	No. of intersections in a zone	54.18	33.71
INTD	No. of intersection per Hectare in a zone	0.75	0.28
SIG	No. of signals in a zone	2.68	2.14
SIGD	No. of signals per hectare	0.071	0.11
IW3P	Percentage of 3-way intersection per intersection	0. 31	0.21
IALP	Percentage of arterial-local intersection per intersection	0.20	0.14
Socioeconomic			
POP	Population	4,079.71	2561.53
POPD	Population density POPD=POP/AREA	59.31	49.13
WKG	Residents working in tourism, retail, govt. and construction	893.31	1,050.25
WKGD	Workers per resident (wkg/pop)	0.63	1.17
NHD	Zonal home density in units/Ha	22.64	22.06
FS1	Average zonal family size	2.81	0.40
TCM	Total no. of commuters	1,766.75	1,213.37
DRVC	No. of driver commuters	987.56	676.84
PASC	No. of auto passenger commuters	108.30	85.54
BUSC	No. of transit commuters	420.81	349.15
PEDC	No. of pedestrian commuters	3.81	3.67
COMM	% of commercial land	0.27	0.36
INST	% of institutional land		
RES	% of residential land	0.59	0.4
Transit Network			
NSTOP	Number of bus stops	14.70	9.08
BDEN	Bus stop density	0.26	0.27
NS	Near sided stops	1.45	1.50
FS	Far sided stops	12.31	8.16
MB	Midblock stops	0.37	0.82
TL	Stops in a through lane	7.65	5.81
IS	Average spacing between stops	0.13	0.081
AMF	Sum of route frequencies (AM peak)	123.16	179.99
Collisions			
PEDCOL	Pedestrian collisions over 5 years	21.2	18.52

Development of Collision Prediction Models (CPMs)

The model form used for the development of the CPMs is:

$$PEDCOL/6yrs = a_0 Z^{a_1} \exp\left(\sum b_i x_i\right) \quad (1)$$

Where:

*a*0, *a*1 and *bj*= parameters of the model
PEDCOL= the number of pedestrian collisions/6yrs.
Z= Exposure variable, which refers to variables required in order for pedestrian collisions to happen. In this case study Z= total transit and vehicle kilometers traveled *VKT* for the AM peak period was used.
xi= Additional explanatory variables, which can also explain pedestrian collision occurrence.

The methodology and statistical measures required to develop collision prediction models are described in more detail in Appendix B.1.

Collision-prone zones (CPZs) are defined as zones that exhibit a higher potential of collisions compared to a specific norm. Because of the randomness inherent in collision occurrence, statistical techniques that account for this randomness should be used when identifying CPZs. An Empirical Bayes methodology using collision prediction models is utilized to identify pedestrian CPLs. The process is described in detail in Appendix B.1.

RESULTS

Figure B.1 shows the spatial distribution of pedestrian collision frequency for the 134 traffic zones in the City of Vancouver. The figure shows that the zones with the highest pedestrian collision occurrence are located in the downtown area, along Broadway, Hastings Street, Kingsway and 41st Avenue.

Figure B.1

Spatial distribution of pedestrian collisions in the City of Vancouver (2005 – 2010)

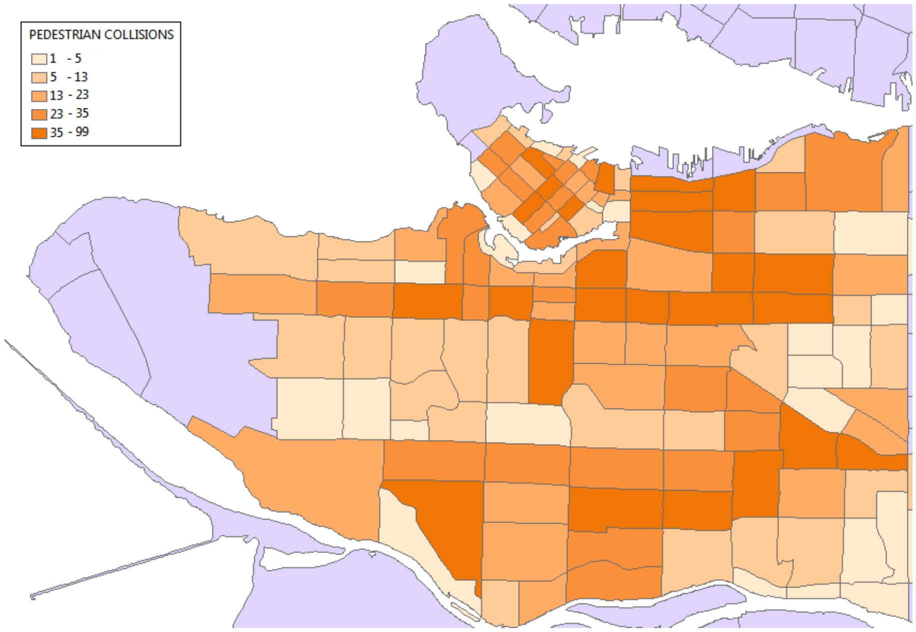


Table B.2 presents the models developed in the four main themes discussed above. All the models and the explanatory variables are significant at the 5% level. The summary statistics of all the models including the dispersion parameters, the t-ratios and the goodness of fit measures are provided in Appendix B.2.

Table B.2

Pedestrian CPZs for the City of Vancouver

Model Theme	Model
Exposure	*PedCol/6yrs* = $1.486\ VKT^{0.489} Exp(-1.964\ VC)$
Infrastructure	*PedCol/6yrs* = $2.352\ VKT^{0.222} Exp(0.215\ SIG - 0.0111\ I3WP)$
Socioeconomic	*PedCol/6yrs* = $0.0582\ VKT^{0.652} Exp(1.33\ COMM + 0.043\ PEDC)$
Transit Network	*PedCol/6yrs* = $0.889\ VKT^{0.413} Exp(0.0016\ AMF - 0.236\ MB - 2.588\ IS)$

Where:

VKT= Vehicle and transit kilometers travelled (EMME)

VC= Volume to capacity ratio (avg. Congestion, EMME)

SIG = No. of signals in a zone

IW3P = Percentage of 3-way intersection per intersections

COMM =% of commercial area in a zone

PEDC = Number of pedestrian commuters = Total commuters* %Pedestrian

AMF = Sum of bus frequencies (AM Peak)

MB = Number of stops midblock

IS = Average spacing between stops

The models show that collisions are positively associated with the main exposure variable (transit and vehicle kilometers travelled *VKT)*. As well, the following observations can be made:

1. Exposure Variables refer to variables related with traffic collision probability. The exposure model shows that decreased pedestrian collision occurrence is related to increases in the average congestion level (VC). This can be explained as the higher level of congestion, the lower the traffic speed, which reduces the risk of pedestrian collisions.
2. Infrastructure Variables include variables describing the physical elements in the road network. The model shows that pedestrian collisions are positively correlated with the number of signalized intersections (SIG). This result is logical as the higher the number of signalized intersections the higher the chance of vehicle/pedestrian conflicts. As well, the model shows decreased pedestrian collisions are related to increases in the percentage of three way intersections (I3WP). This confirms earlier findings and facilitates analyses on street network patterns (e.g. grid versus discontinuous).
3. Socioeconomic Variables include variables based primarily on the census data, such as population, employment, commuting mode choice and land use. The model shows that increases in the number of pedestrian collisions is related to increases in both the percentage of commercial areas (COMM) and the number of pedestrian commuters (PEDC). This result is logical and is similar to the results obtained in the pedestrian models developed by Fernandes et al, which found that pedestrian collisions were positively correlated with the number of entrances/exits to commercial property in close proximity (within 25 meters) of signalized intersections.
4. Transit Network Variables refer to bus elements physically present in the road network. The model shows that increased collisions are related to an increase in the bus frequency. The positive parameter for bus route frequency suggests that an increased flow of transit vehicles can increase the risk of conflicts between transit users boarding/unloading the bus and other vehicles. In the case of inter-station spacing the inverse relationship with pedestrian collisions is intuitive, as a small spacing between bus stops raises the frequency of transit users boarding and unloading by walking.

Identification of Collision Prone Zones in the City of Vancouver

The four CPMs developed in the previous section were applied to identify collision prone zones using the Empirical Bayes technique (explained in Appendix B.1). Collisions prone zones present the highest risk for collisions. The collision prone zones are presented in Figure B.2. Collision prone zones are located mostly in the downtown area (along Burrard Street, Georgia Street and Davie Street), along Broadway (from MacDonald Street to Renfrew Street), Kingsway (between Knight Street to Boundary Road), Hastings Street (between Main Street to Nanaimo Street) and 41st Avenue (between Knight Street and Boundary Road and between Granville Street and MacDonald Street). The collision prone zones identified from each model are shown in Figures B.2 – B.6.

Figure B.2
Pedestrian Collision Prone Zones in the City of Vancouver

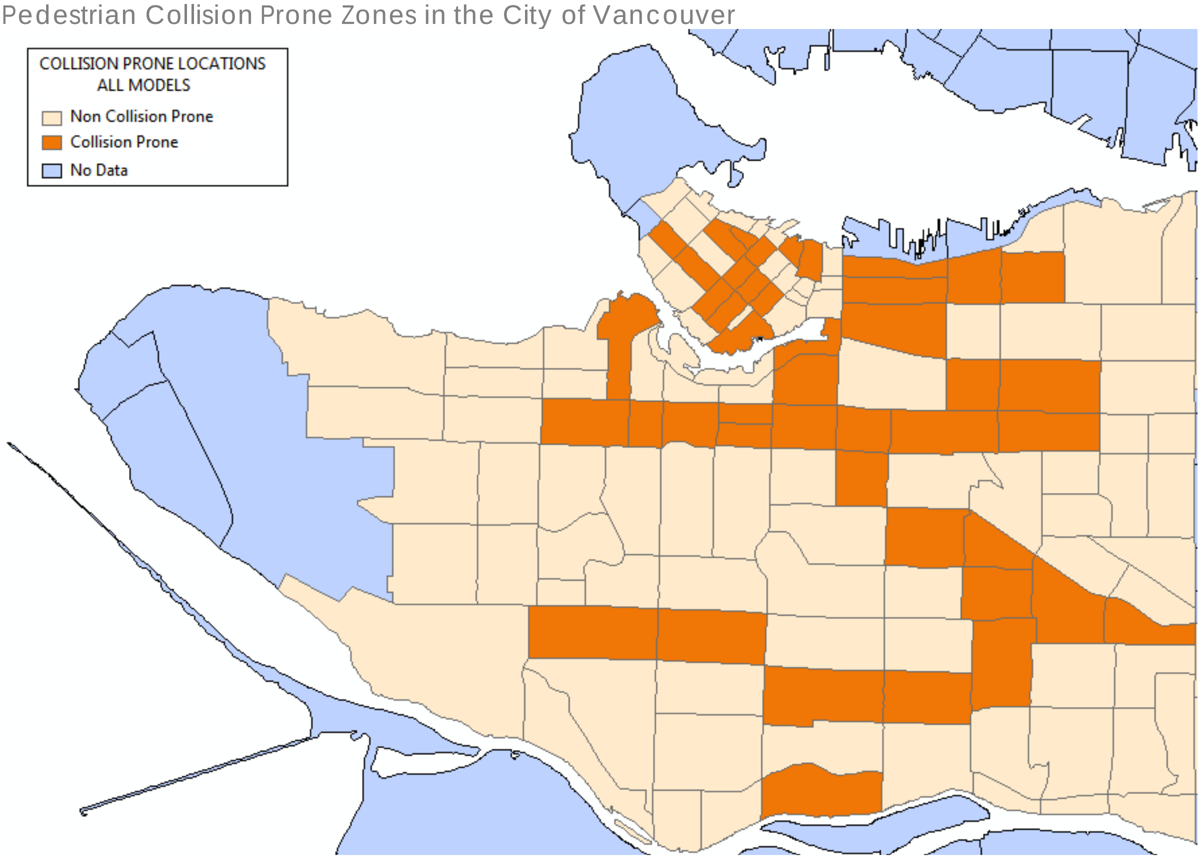


Figure B.3
Pedestrian Collision Prone Zones in the City of Vancouver – Exposure Model

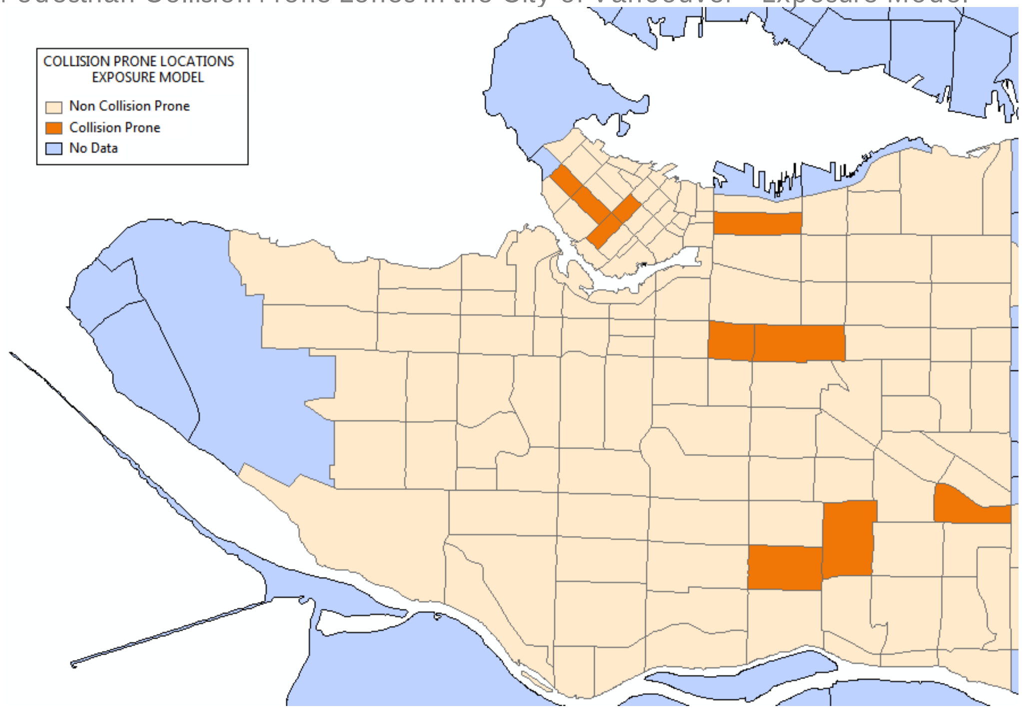


Figure B.4
Pedestrian Collision Prone Zones in the City of Vancouver – Infrastructure Model

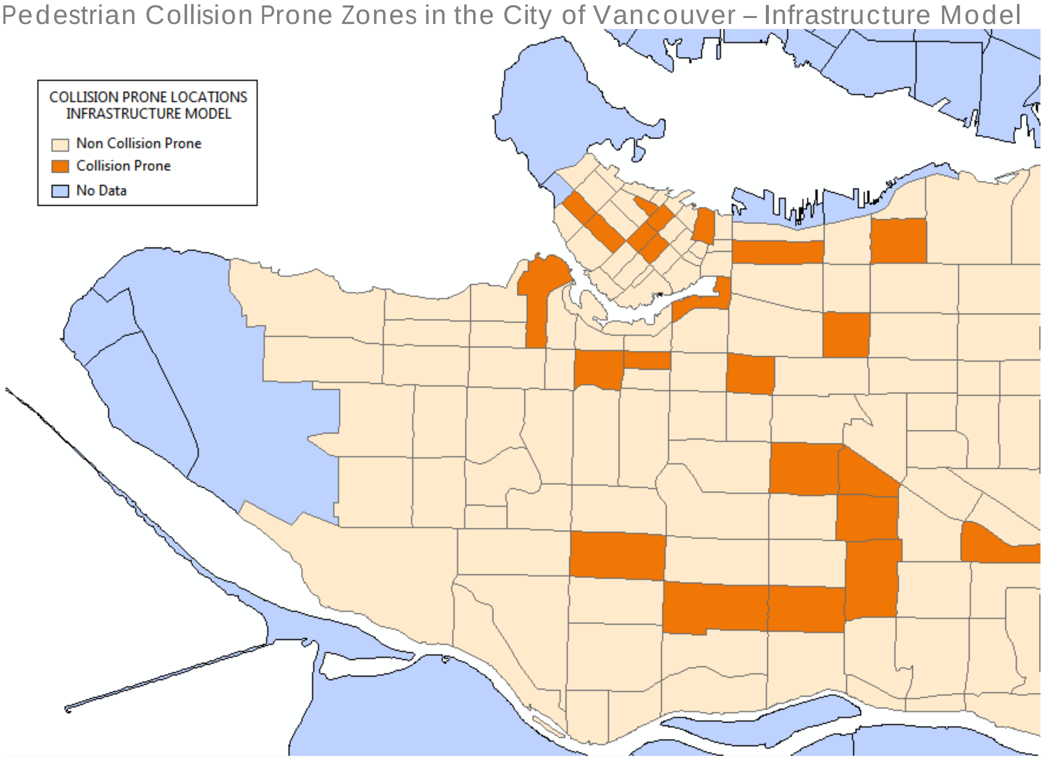


Figure B.5

Pedestrian Collision Prone Zones in the City of Vancouver – Socioeconomic Model

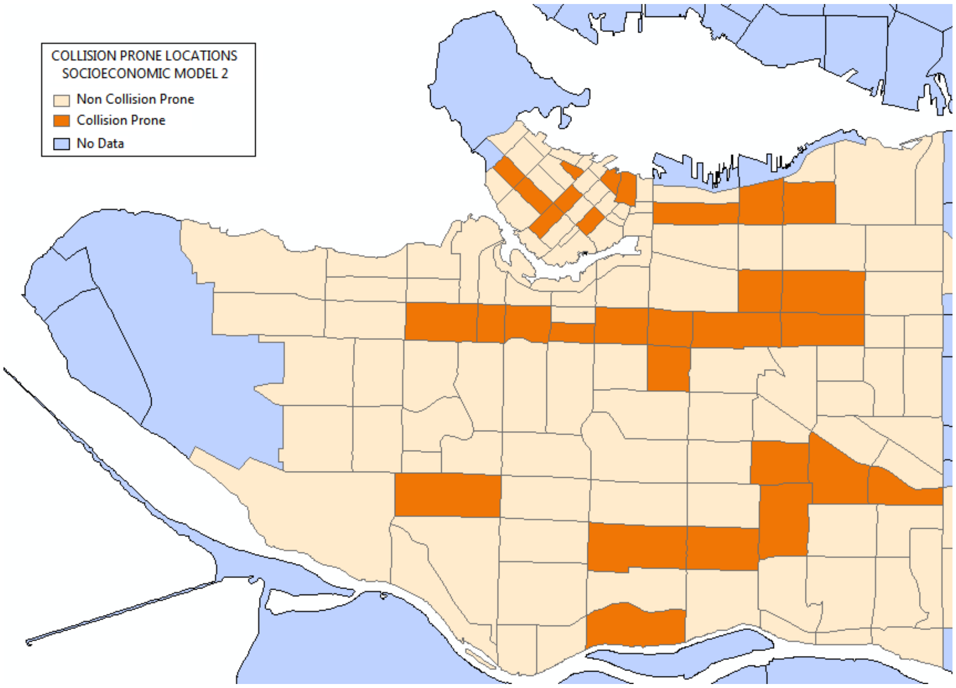
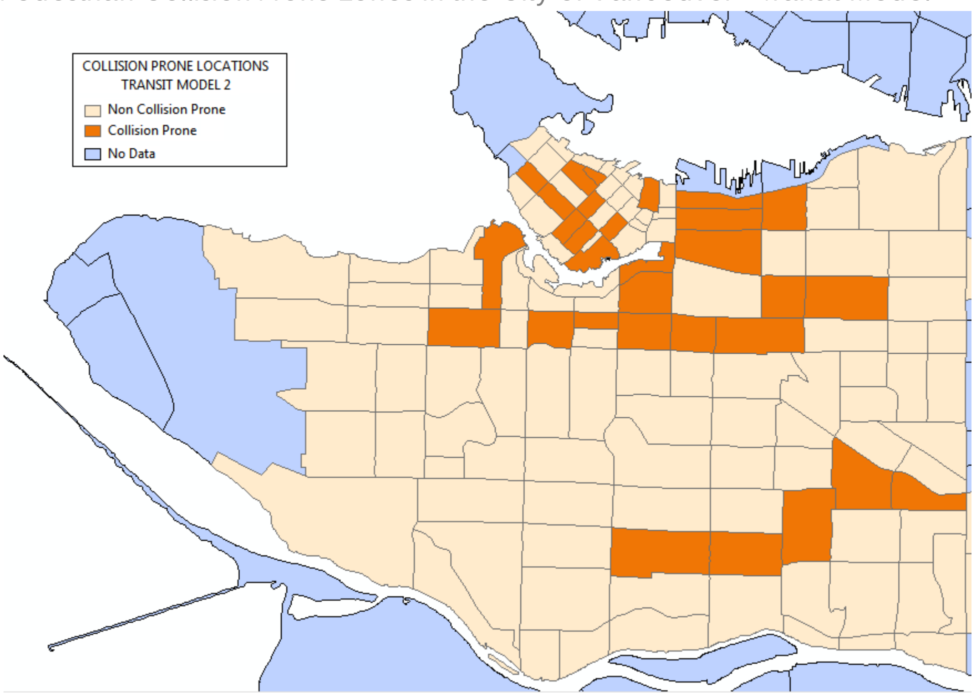


Figure B.6

Pedestrian Collision Prone Zones in the City of Vancouver – Transit Model



Collision Prone Locations

For many years, the prevailing measure of safety was the collision rate, which is the number of collisions per unit of exposure as most commonly expressed by number of collisions per million vehicles entering an intersection. Two reasons were most likely behind this practice. First, the collision rate reflects exposure, which safety analysts have always believed to be the major road-related factor affecting collision occurrence. Second, the collision frequency is not a stand-alone measure of safety.

However, although collision rates do consider exposure, the use of collision rates to gauge the safety of a location can be misleading, as it has been shown the relationship between collision frequency and exposure is non-linear. This finding has led most safety analysts to use collision prediction models (CPM) as the primary tool for estimating road safety. A CPM is a regression model that produces an estimate of the collision frequency for a location based on the site-specific characteristics of the location. For intersections, the CPM utilizes the number of vehicles entering the intersection from the major and minor legs of the intersection, which produces a collision frequency estimate that represents "normal" safety performance for the location.

The use of CPMs allows for an improvement in the accuracy of safety measurement, and can facilitate the establishment of acceptable safety performance benchmarks and thresholds. The use of CPMs for safety analysis is also consistent with evolving safety evaluation techniques. In fact, CPMs serve as the foundation for the standard practice for road authorities in evaluating highway safety. For example, the FHWA's Highway Safety Manual (HSM) will also dictate the use of CPMs for safety analysis and evaluation. As well, the CPMs can be used for network screening and identifying locations that have a high potential for improvement.

This section describes how a pedestrian collision prediction model was developed for this study in order to identify and rank pedestrian collision prone intersections in the city.

Methodology

The data required was extracted and compiled from two main sources:

- The ICBC files of pedestrian collisions for the years 2005 to 2010. The pedestrian collisions data was found for 1076 intersections and 192 midblock locations.

- Intersection vehicle and pedestrian volumes were obtained from the City of Vancouver VanMap website.

The model form used for the development of the CPMs is show in Equation 1 below:

$$PedCol/6yrs = a_0 Z_1^{a_1} Z_2^{a_2} \quad (1)$$

Where:

- $a0$, $a1$ and $a2$= parameters of the model
- *PedCol/6yrs*= the number of pedestrian collisions per intersection in 6 years (2005-2010)
- *Z*= Exposure variable. In this study, Z_1= Average Daily Traffic (ADT) of all approaches and Z_2= Peak hourly pedestrian volume (ped/hr).

Is important to mention that the model was developed for a sample of 80 out of the 1076 intersections. The methodology and statistical measures required to develop collision prediction models are described in more details in Appendix B.1. Collision-prone locations (CPLs) are defined as locations that exhibit a significant number of collisions compared to a specific norm. Because of the randomness inherent in collision occurrence, statistical techniques that account for this randomness should be used when identifying CPLs. An Empirical Bayes methodology using collision prediction models is utilized to identify pedestrian CPLs. The process is described in detail in Appendix B.1.

Results

Equation 2 shows a model that predicts pedestrian collisions at signalized intersections. All variables in the model are statistically significant and the scaled deviance SD and Pearson $\chi 2$ goodness of fit measures show that the model has a good fit to the data.

$$PedCol/6yrs = 0.0391\ ADT^{0.402} PedVol^{0.22} \quad (2)$$

Identification of Collision Prone Locations the City of Vancouver

The developed CPM was applied to identify and rank collision prone locations using the Empirical Bayes technique (explained in Appendix B.1). Collisions prone intersections present the highest risk for collisions. Seven pedestrian collision prone locations were identified and their ranking is presented in Table B.3.

URBAN systems

Table B.3
Ranking of collision prone intersections in the City of Vancouver

Primary Street	Cross Street	Total Pedestrian Collisions (2005 – 2010)	CPL Ranking
East Hastings Street	Main Street	41	1
Davie Street	Burrard Street	25	2
Kingsway	Joyce Street	20	3
East Broadway	Commercial Drive	22	4
East 49th Avenue	Victoria Drive	16	5
East Broadway	Fraser Street	15	6
East 49th Avenue	Main Street	13	7

APPENDIX B.1 Development of Collision Prediction Models

The model form used for the development of CPMs is:

$$E(\Lambda) = a_0 Z^{a_1} \exp\left(\sum b_i x_i\right) \quad (1)$$

Where:

$E(\Lambda)$= Predicted collision frequency (over a period of six years).

Z= External exposure variable. *Z* refers to variables required in order for pedestrian collisions to happen. At a zero exposure collisions must be zero as well.

xi= Additional explanatory variables, which can also explain pedestrian collision occurrence.

*a*0, *a*1 and *bj*= parameters of the model

The methodology considered the following:

- A negative binomial error structure (with an overdispersion parameter κ) .
- The procedure for the selection of model variables was a forward stepwise procedure. The order in which variables are added was based on their t-stat, from highest to lowest.
- Whether to keep or remove a variable in a model was decided based on three conditions. First, the parameter t-statistic is significant (*t* >1.96 for a confidence level of 95%). Second, the addition of a new variable generated a significant drop in the scale deviance (SD) for a 95% level (>3.84). Third, the variable exhibits a low correlation with other independent variables already in the model.
- Once all variables are evaluated, the overall model fit is assessed using two statistical measures: the Pearson χ2 and the scaled deviance *SD*. A model with proper fit will have a Pearson χ2 and *SD* statistics lower than the chi- squared distribution table value for (*n*−*p*−1) degrees of freedom and for a 95% confidence level. First, the Pearson χ2 is defined as:

$$Pearson\ \chi^2 = \sum_{i=1}^{n} \frac{(y_i - E(Y))}{Var(Y_i)} \quad (2)$$

Where *Y i* is the observed number of accidents on section *i*, *E*(*Y*) is the predicted frequency of accidents by the model in section i and *V ar*(*Y i*) is the variance of the frequency of accidents for section *i*. The scaled deviance *SD* represents the likelihood ratio test statistic between twice the difference of the maximized log-likelihoods of the studied model and the complete saturated model. If the error structure is Poisson distributed then the scaled deviance is calculated as:

$$SD = 2\sum_{i=1}^{n} y_i ln\left(\frac{y_i}{E(Y_i)}\right) \quad (3)$$

Finally, the fit of the model was improved by performing an outlier analysis based on the Cook's distance method.

Model form *PEDCOL* =	κ	df	SD	χ^2	$\chi^2_{0.05,df}$	t-statistics
Exposure:						
$1.486VKT^{0.489}exp(-1.964VC)$	2.84	130	141	171	158	a_0=0.67 *VKT*=8.95 *VC*=4.83
Infrastructure:						
$2.352VKT^{0.222}exp(0.215SIG-0.0111I3WP)$	3.12	130	141	136	158	a_0=1.60 *VKT*=3.22 *SIG*=7.48 *I3WP*=3.96
Socioeconomic:						
$0.058VKT^{0.652}exp(1.331COMM+0.0431PEDC)$	2.29	130	141	134	158	a_0 =3.50 *VKT*= 6.75 *PEDC*=2.36
Transit Network:						
$0.889VKT^{0.413}exp(0.0016AMF—0.2361MB-2.588IS)$	2.07	128	141	142	155	a_0=0.18 *VKT*=5.21 *AMF*= 4.00, *MB*= 3.02, *IS*=2.97

Appendix B2: Identification of Collision Prediction Models (collision location model)

Collision prone locations (CPLs) are defined as the locations that exhibit a significant number of collisions compared to a specific norm. Because of the randomness inherent in collision occurrence, statistical techniques that account for this randomness should be used when identifying CPLs. The EB refinement method can be used to identify CPLs according to the following process:

1. Estimate the predicted number of collisions and its variance for the intersection, using the appropriate CPM model. This follows a gamma distribution (the prior distribution) with parameters α and β, where:

$$\beta = \frac{E(\Lambda)}{Var(\Lambda)} = \frac{\kappa}{E(\Lambda)} \text{ and } \alpha = \beta \cdot E(\Lambda) = \kappa \quad \text{(B.1)}$$

2. Determine the appropriate point of comparison based on the mean and variance values obtained in step (B.1). Usually the 50th percentile (P50) is used as a point of comparison. P50 is calculated such that:

$$\int_0^{P_{50}} \frac{(\kappa / E(\Lambda))^{\kappa} \cdot \lambda^{\kappa-1} \cdot e^{-(\kappa / E(\Lambda))\lambda}}{\Gamma(\kappa)} d\lambda = 0.5 \quad \text{(B.2)}$$

3. Calculate the EB safety estimate and its variance from equations 17 and 18. This is also a gamma distribution (posterior distribution) with parameters $\alpha 1$ and $\beta 1$:

$$\beta_1 = \frac{EB}{Var(EB)} = \frac{\kappa}{E(\Lambda)} + 1 \text{ and } \alpha_1 = \beta_1 \cdot EB = \kappa + count \quad \text{(B.3)}$$

Where count is the observed number of collisions in the same time period.

Then, the probability density function of the posterior distribution is:

$$f_{EB}(\lambda) = \frac{(\kappa / E(\Lambda) + 1)^{(\kappa + count)} \lambda^{\kappa + count - 1} e^{-(\kappa / E(\Lambda) + 1)\lambda}}{\Gamma(\kappa + count)} \quad \text{(B.4)}$$

4. Identify the location as collision-prone if there is a significant probability that the intersection's safety estimate exceeds the P50 value. Thus, the location is identified as collision prone if:

$$\left[1 - \int_0^{P_{50}} \frac{(\kappa / E(\Lambda) + 1)^{(\kappa + count)} \lambda^{\kappa + count - 1} e^{-(\kappa / E(\Lambda) + 1)\lambda}}{\Gamma(\kappa + count)} d\lambda \right] \geq \delta \quad \text{(B.5)}$$

where δ represents the confidence level desired (usually 0.95)

Appendix C

Review of Pedestrian Treatments

This section provides a summary of the effectiveness of a range of types of engineering treatments that can be considered to improve pedestrian safety. This includes a review of measures commonly used in Vancouver as well as measures with limited or no current use in Vancouver, as shown below.

The pedestrian treatments included in the following sections include:

1. Pedestrian Activated Signals
2. Corner Bulges
3. Speed Reader Boards
4. Pedestrian Countdown Timers
5. Crosswalks
6. Pedestrian Scrambles
7. Audible Pedestrian Signals
8. Left Turn Bays
9. Greenways
10. Leading Pedestrian Interval
11. Crossing Guards
12. Yield to Pedestrian Signs for Right Turning Vehicles
13. Raised Intersections
14. Midblock Crossings
15. Raised Crosswalks
16. Separate vs. Mixed Modes on Roadway
17. New or Upgraded Intersection Lighting

The effectiveness of each treatment was assessed based on a comprehensive literature review and by contacting staff at five peer cities in Canada and the Pacific Northwest (Calgary, Toronto, Seattle, Portland, and San Francisco). A detailed assessment of each pedestrian treatment is provided for each treatment in the following section, including:

- Description
- Current Use in Vancouver
- Application Guidance
- Benefits
- Costs / Impacts
- Research
- Case Studies
- Lessons Learned

1. Pedestrian Activated Signals

Description

Pedestrian activated signals are used to assist pedestrians in crossing major streets in areas where there is high pedestrian demand, but where a full traffic signal is not warranted. Standard traffic signals are installed on the major street, while the minor street is stop-controlled. Standard Walk/Don't Walk signals are installed for the major street crosswalk.

Pedestrian activated half signals are typically used at intersections or other mid-block locations with high pedestrian demand. When pedestrians activate the signal using a push button, motor vehicles receive a solid red that indicates a requirement for motor vehicles to stop for pedestrians. In British Columbia, between activations pedestrian signals flash green for traffic on the major street. If located at an intersection, there is no phase assignment for the minor street.

Another example of a pedestrian half signal that is used in the United States is the High-Intensity Activated Crosswalk (HAWK), now known as a Pedestrian Hybrid Beacon, which rests in dark and progresses through flashing yellow and red to notify the driver of the upcoming stop condition.

Current Use in Vancouver

Pedestrian activated signals are commonly used in Vancouver where local streets cross collector or arterial streets in areas with high pedestrian demand. Pedestrian activated signals are also frequently used on local street bikeways in conjunction with bicycle activated pushbuttons. The majority of the pedestrian activated signals in the City are half signals, which are located at 343 locations. There are also 9 “special crosswalks” (crosswalks with flashing yellow lights overhead) throughout the City although the City has been converting these to half signals in recent years as they have not found these to be effective at improving pedestrian safety.

Application Guidance

- Appropriate on higher speed/volume roadways at mid-block locations or at unsignalized intersections where pedestrian crossing demand is high and distant from an existing crossing.

Benefits

- Provides a signal-protected pedestrian crossing phase.
- Reduces motor vehicle delay as compared with a fully signalized crossing.
- Improves pedestrian safety.

Costs

Approximately $200,000 for the type of pedestrian activated signal commonly used in British Columbia.

Research

- The HAWK pedestrian signal was originally created in Tucson, Arizona and is currently used at 114 locations in the city. A 2009 study of the effectiveness of HAWK pedestrian signals at 21 locations in Tucson found that pedestrian crashes were reduced by approximately 58 percent. The study warned that the treatment may be less effective if overused.[14]
- A 2010 study comparing four mid-block HAWK signals with traditionally signalized mid-block crossings found the HAWK effective in decreasing excessive driver delay.[15]

Case Studies

The City of Seattle uses a pedestrian half signal that is similar to BC's pedestrian signal, but displays a solid green light between activations. Because the city has found this application effective, it has chosen to continue with its version of the half signal instead of adopting the HAWK technology in order to maintain consistency.

The City of Toronto has implemented pushbutton activated flashing beacons (yellow overhanging lights) at some intersections. The city no longer recommends the treatment, known as a Pedestrian Cross Over, as it found that motor vehicles do not always stop for pedestrians entering the crosswalk when the yellow lights flash. In addition, current laws do not require cars traveling in the inside lanes to stop. The city found issues of multiple threat where the outside vehicle would stop but vehicles in the inside lane would not. Twenty-four of the 77 Pedestrian Cross Overs on major arterials have been converted to fully signalized intersections.

Calgary occasionally uses a pedestrian activated half signal. The traffic signal rests at green until activation. Once activated, the signal progresses through yellow to red so pedestrians gain the right of way to cross the street. The side streets are typically stop controlled. There is a safety concern with traffic on the side streets because drivers cannot see when the traffic signal switches between red and green and thus may pull out in front of oncoming traffic that has the right-of-way. The city also uses "pedestrian corridors," in which overhanging yellow beacons flash when activated by a pedestrian push-button. The city prefers pedestrian corridors over half signals due to the safety concern identified above.

Lessons Learned

Recent studies show the HAWK pedestrian half signals reduce pedestrian crashes and motor vehicle delay (as compared with a signalized mid-block crossing). Peer communities have taken different approaches to installation. Seattle utilizes a half signal, Toronto has converted many of its flashing beacons to full signals, and Calgary prefers the yellow flashing beacon. Complementary warning signs providing direction to motorists to stop when the signal is activated may improve effectiveness.

2. Corner Bulges

Description

Corner bulges, also known as curb extensions, are an extension of the curb into the parking lane at intersections to reduce pedestrian crossing distances, and improve visibility between motorists and pedestrians. They may have the effect of lowering through motor vehicle speeds due to roadway narrowing. Corner bulges are typically installed with curb ramps to increase accessibility for persons with disabilities and in combination with marked crosswalks to increase the visibility between pedestrians and motorists.

Current Use in Vancouver

Corner bulges are commonly used throughout the City of Vancouver.

Application Guidance

- Should only be used where there is a full-time on-street parking lane.
- Should only be used where bicycles and transit vehicles will travel outside of the curb edge for the length of the streets.
- Care should be taken to ensure landscaping or furniture do not obstruct visibility.
- Design should ensure adequate drainage.
- Can be used to enhance mid-block crossings.

Benefits

- Improves motorist visibility of pedestrians.
- Improves motorist yield compliance.
- Reduces speed of turning vehicles.
- Encourages pedestrians to cross at designated crossings.
- Increases sidewalk space
- Decreases crossing distances for pedestrians.
- Can increase green space.
- Improves sight lines for pedestrians.

- Can be combined with beautification elements and rainwater management treatments.
- Improves safety for pedestrians, cyclists and motorists by restricting parking within corner clearance area.

Costs

Approximately $10,000 - $30,000, depending on landscaping, drainage, lighting, etc.

Research

- A 1993 New York City study of crash rates at six intersections found that corner bulges reduced severity rates in four out of six surveyed areas but do not reduce collision frequency. The authors suggest corner bulges minimize the space available for disobedient driving and that the smaller curb radius reduces collision severity by reducing vehicle speeds.[16]
- A 2005 study evaluated the safety of corner bulges in Albany, OR at two intersections along one-way streets adjacent to the downtown shopping area. The study determined that corner bulges contribute to a significant reduction in the average number of vehicles that drive past a pedestrian waiting to cross before yielding, indicating that corner bulges increase the visibility of pedestrians.[17]
- A 2012 Montreal Study found that curb extensions significantly decrease pedestrian crashes but no direct crash reduction was estimated. However, a reduction of 25% was implied from a sensitivity analysis of a regression equation.[18]

Case Studies

The City of Toronto's use of corner bulges is generally popular with the public, though they are not favored by all municipal staff. Corner bulges are installed on a case by case basis, often near employment centers. Truck and transit representatives are not always in favor of this treatment because the reduced turning radius and available roadway width requires a more careful and slow turn, making it more difficult to stay in the assigned travel lanes during a turn. The city is looking to create a street design manual in order to present technical design guidelines for the use of corner bulges.

The City of Calgary installs corner bulges at marked crosswalks on collector roads to address speeding concerns and to improve the visibility of pedestrians. Calgary believes corner bulges to be effective at reducing speeds. The city has received positive feedback from pedestrians. Negative feedback has been received from some motorists regarding the reduced available right-of-way and because of the loss in availability of the right most (parking) lane for passing or for turning.

Lessons Learned

The research indicates that corner bulges tend to reduce vehicular speeds, improve pedestrian visibility, improve motorist yield compliance, and reduce pedestrian collisions. The specific geometry and landscaping of a given intersection must be considered with care to ensure its visibility to motorists, even when pedestrians are not queuing. Corner bulges can also be problematic for drivers of heavy vehicles due to reduced turning radii, and therefore the heavy vehicle volume should be considered during design.

3. Speed Reader Boards

Description

A speed reader board is a sign placed adjacent to a roadway that displays oncoming motorist speeds. Light-emitting diodes (LED) flash the traveling speed near a regulatory speed limit sign as feedback to motorists that they are driving in excess of the posted limit.

Current Use in Vancouver

Speed reader boards have recently been installed at several locations throughout the City, including Oak Street at West 33rd Avenue (both directions), Hastings Street at Columbia Street (eastbound), Gore Avenue (westbound), and Cambie Street Bridge. The City has found that speed reader boards are initially effective in reducing vehicle speeds, but traffic speeds tend to revert to their previous levels unless there is enforcement.

Application Guidance

- Occasional enforcement required to complement this measure.
- Boards should not obstruct pedestrian travelway or sightlines.
- This measure is a complement rather than a substitute for engineering measures.

Benefits

- Enhances enforcement through public education and awareness.

Costs

Approximately $10,000 to $25,000.

Research

- A 1983 study in Nova Scotia found that speed reader boards reduced speeding on a portion of a “limited-access highway” with a non-variable speed limit. Although the effect diminishes as vehicles travel beyond the sign, some degree of effect persists for up to 6 km.[19]
- A 2008 study of speed reader signs at two pilot locations in Singapore found a 12 percent increase in motorist compliance to the speed limit. 72 percent of motorists surveyed through the study reported that the speed reader boards influenced their driving speed.[20]

Case Studies

Although the City of Toronto rotates portable speed reader boards throughout the city, staff questions their effectiveness for a number of reasons. First, drivers tend to speed up after passing the speed reader board, which indicates their effect is temporary. Second, the city finds speed enforcement subsequent to placement is necessary to affect a change in driving speed. Therefore, city staff believes speed reader boards are ineffective unless used in combination with other measures or improvements.

The City of Seattle uses speed reader boards and finds that they are effective at reducing speeds where the signs are placed. There are some corridors where the city has installed more than one speed reader board.

The City of Portland has installed speed reader boards and has found them to be effective at reducing speeds in the short-term. The city has not studied the long-term effects.

Lessons Learned

Speed reader boards reduce the incidence of speeding for a short distance after the sign, making them most appropriate for installation at specific locations where speeding contributes to safety issues. Speed reader boards may be more effective at reducing speeds when used in combination with other treatments, including enforcement, or at multiple locations along a corridor as a continual reminder to drivers.

4. Pedestrian Countdown Timers

Description

Pedestrian countdown timers are used to provide information to pedestrians about how much time is left to cross the street at a signalized intersection. A pedestrian countdown timer includes a display on the pedestrian head indicating the time remaining for a pedestrian to cross during the pedestrian phase of a traffic signal. Countdown timers may be installed with or without pedestrian push button actuation.

Current Use in Vancouver

The City has installed pedestrian countdown timers at Carrall Street and Pender Street, Kingsway and East 10th Avenue, and at the top ten pedestrian collision locations in the City. In addition, the City equips all new traffic signals with pedestrian countdown timers, and includes pedestrian countdown timers with any signal replacements or upgrades.

Application Guidance

- Pedestrian Countdown signals should be considered at any signalized intersection where pedestrian displays are provided. This treatment will likely have the greatest benefits in highly urbanized environments with high pedestrian activity.

Benefits

- Provides pedestrians with valuable information regarding the amount of time left to complete their crossing.
- Contributes to pedestrian safety by reducing the number of pedestrians remaining in the crossing after the crossing interval ends.

Costs

Approximately $4,000 per intersection (8 units).

Research

- A 2000 report on the effectiveness of countdown pedestrian indicators in the Minneapolis-St. Paul urbanized area found that countdown timers: reduced the percentage of pedestrians beginning to cross during pedestrian clearance interval (the flashing hand) and who remained crossing after the hand became fixed from 6 percent to 4 percent; reduced the percentage of pedestrians crossing on the red hand from 15 to 13 percent; and increased the portion of pedestrians who successfully completed their crossing during the pedestrian phase from 67 to 75 percent.[21]

- In a 2003 study in Maryland, pedestrian vehicle conflicts (defined as an interaction where either a pedestrian or a vehicle takes an evasive action to avoid a collision) significantly decreased at four observed intersections.[22]
- The San Francisco case study below, reports a 25% pedestrian crash reduction factor associated with countdown timers.

Case Studies

The City of Seattle has retrofitted more than 30% (130) intersections with pedestrian countdown timers to date. The city is updating 25 to 30 signals per year to reach its ultimate goal of having countdown timers on all signals. Installation locations are based on priorities presented in the pedestrian master plan, using collision, traffic speed, and volume criteria. The city reports that, generally, the public is strongly in favor of the countdown timers.

The City of San Francisco's Department of Parking and Traffic conducted a pilot program to gauge the effectiveness of 14 pedestrian countdown signals in a variety of physically and socio-culturally distinct locations. The study found that the percentage of pedestrians remaining in the crosswalk after the signal turned red declined with the installation of the countdown timers and that the timers were associated with a pedestrian crash reduction factor of 25%.[23]

The City of Toronto has equipped approximately 2,040 intersections with countdown signals.

Lessons Learned

The research and experiences of peer cities indicate that countdown timers improve pedestrian safety by providing information to help judge how much time is remaining for the crossing. Countdown timers are now required for new pedestrian signal head installations in the United States. The timers seem to reduce the confusion associated with the walking man and flashing hand indicators previously used in the United States.

5. Crosswalks

Description

Marked crosswalks are the simplest crossing treatment, which involves pavement markings indicating the crosswalk, and accompanying signs. Crosswalk pavement markings such as “ladder” and “zebra” markings illustrate the circulation area for pedestrians crossing the street and increase the visibility of the crosswalk to approaching motorists. Paint, thermoplastic, decorative pavers, or other materials delimit the area in the right-of-way where motorists should expect pedestrians to cross.

Current Use in Vancouver

Crosswalks are common throughout the City of Vancouver.

Application Guidance

- Crosswalks should be marked at all signalized intersections.
- Crosswalks can be provided at mid-block locations when there is demand for a crossing and no nearby crossing. Additional measures may be required depending on size and speed of the roadway.
- Crosswalks alone are unlikely to improve pedestrian safety. Under most conditions safety is increased in combination with other measures such as curb extensions and median refuge islands.
- Crosswalks can increase pedestrian visibility in areas where there is poor motorist awareness of an existing crossing or at high-use locations. Crosswalks are particularly important along routes to school to improve visibility of school children.

Benefits

- Alerts motorists to expect pedestrians.
- Indicates preferred pedestrian crossing location.

Costs

Minimal costs, simply involves painting the crosswalk and erecting signage where applicable.

Research

- A 2005 FHWA study of marked crosswalks at uncontrolled crossings found that a marked crosswalk on two-lane roads without other treatments was associated with no difference in the pedestrian crash rate as compared to an unmarked crosswalk at the same type of location. The study also found that a marked crosswalk without other treatments on multi-lane roads where traffic volumes were more than 12,000 vehicles per day was associated with a higher pedestrian crash rate compared to an unmarked crosswalk.[24]

Case Studies

The City of Toronto has been working to increase the number of zebra crossings and now has them at approximately 300 intersections. City staff believes these are a way to increase visibility of pedestrians quickly throughout the entire city. Locations for marked crosswalks are determined by a pedestrian safety analysis, which includes vehicle volumes, total collisions, and injury/fatal collisions. Public response indicates that marked crosswalks are popular. Toronto finds that drivers are more likely to stop for pedestrians with zebra crossings as opposed to other types of marked crosswalks. Zebra crosswalks do however present a maintenance challenge as trucks/transit cause damage to striping, due to wear from tires. Toronto is experimenting with longer lasting paint.

The City of Calgary typically uses parallel line crosswalks, but has begun installing zebra crosswalks at schools and other locations. Calgary prefers zebra crosswalks over parallel line crosswalks because they make pedestrians more noticeable. Calgary's recent pedestrian safety study found crosswalks to be one of the top locations for pedestrian collisions. To address this issue, the city has begun a pilot program that installed advance yield lines in five locations on multilane roads. Calgary's initial impression is that motorists are stopping farther back from the crosswalks with this additional countermeasure.

The City of Portland installs zebra crosswalks at unsignalized crossings and school crossings. Zebra crosswalks are preferred by the city for these applications because they provide a more prominent visual cue to motorists. Parallel line crosswalks are used at signalized crossings.

The City of Seattle places advanced stop/yield lines at multilane uncontrolled marked crosswalks.

Lessons Learned

The research suggests that marked crosswalks alone do not unconditionally improve pedestrian safety. At unsignalized intersections, marked crosswalks without additional pedestrian treatments are likely to be most effective on smaller roads with lower traffic volumes. On streets with higher traffic volumes and multiple lanes, marked crosswalks should be accompanied by additional measures, such as pedestrian refuge islands, to improve pedestrian safety. In an attempt to improve safety on multi-lane roads, several of the peer cities are beginning to install advanced yield lines at both controlled and uncontrolled crossings. Many of the peer cities prefer zebra crossings to standard crosswalks due to their increased visibility. Careful striping to increase the probability that motor vehicles will pass over the crosswalk on the non-painted bars of the crosswalk can reduce maintenance costs.

6. Pedestrian Scrambles

Description

A pedestrian scramble is an exclusive pedestrian phase at a signalized intersection where vehicular movements are prohibited at all approaches while pedestrians are permitted to cross diagonally and longitudinally. The separation of vehicular and pedestrian movements is intended to reduce conflicts between the two modes.

Current Use in Vancouver

Pedestrian scrambles are not currently used in the City of Vancouver.

Application Guidance

- Pedestrian scramble phasing is most likely to be successful and have fewer violations at intersections with large volumes of both pedestrians and motor vehicles.
- Pedestrian scramble phase usually creates a longer cycle length and wait between crossings.

Benefits

- Provides an exclusive pedestrian phase with no concurrent traffic movements to reduce conflicts between pedestrians and vehicles.
- The benefits of this treatment may not extend to visually impaired pedestrians.

Costs

Approximately $30,000 – 80,000 based on the experience in Calgary and Toronto. Staff time is required to adjust signal timing if signal heads exist. Additional hardware is also required to provide pedestrian heads for diagonal crossing.

Research

- A 2010 UBC study evaluating pedestrian scrambles implemented in Oakland, California found a significant reduction in the number and severity of pedestrian vehicle conflicts (approximately 50%) following the implementation of the scramble.[25]
- A Calgary study measured the number of pedestrian-vehicle conflicts and pedestrian violations (crossing against signal) and found that pedestrian

scrambles decreased the number of pedestrian-vehicle conflicts occurring at the intersection but slightly increased the number of pedestrian violations.[26]

- A 1998 California study of pedestrian scrambles found a two-thirds reduction in vehicle-pedestrian collisions at intersections with high pedestrian volumes.[27]
- A 1989 study in Sweden determined that safety improved only at intersections where there was high compliance to the signal by pedestrians.[28]

Case Studies

In 2008 the City of Toronto installed a pedestrian scramble at the intersection of Yonge Street and Dundas Street in its downtown core. At this intersection, pedestrians are permitted to cross parallel to vehicles, as well as during the pedestrian-only phase. This type of pedestrian scramble is typically implemented where sidewalks are not wide enough to accommodate waiting pedestrians or there are safety issues with pedestrians gathering.

The City of Calgary installed pedestrian scrambles at the intersections of 3 Street and 2 Avenue SW, and 3 Street and 3 Avenue SW, both located in the pedestrian-oriented Eau Claire Market area. At both intersections, pedestrian movements are prohibited during vehicular phases and only permitted during pedestrian-only phases. This type of pedestrian scramble is typically installed where sidewalk space is wide enough to accommodate waiting pedestrians.

The cities of Toronto and Calgary have found that pedestrian scrambles work best at intersections with high volumes of pedestrians along all approaches at all times of the day. When there are low pedestrian volumes during the pedestrian-only phases, there are more issues of motorists violating the pedestrian scramble. In both cities, pedestrian scrambles increased the delay of vehicular traffic and transit.

Lessons Learned

Pedestrian scrambles appear to offer the greatest safety benefits at intersections with large volumes of both vehicles and pedestrians. Where pedestrian volumes are low, vehicles may violate the pedestrian-only phase. Where vehicle volumes are low, pedestrians are more likely to cross during gaps in traffic rather than wait for the signal. Pedestrian traffic signal compliance is another important consideration, as large numbers of pedestrians who illegally cross during the pedestrian red phase diminish the safety benefit of this treatment. In summary, pedestrian scrambles would be most appropriate at downtown Vancouver intersections with high pedestrian volumes.

7. Audible Pedestrian Signals

Description

Audible pedestrian signals emit a verbal message, an audible tone, or a vibration to indicate to visually impaired pedestrians when they have the right of way to cross the street.

Current Use in Vancouver

Audible pedestrian signals are common in Vancouver. There are 409 audible pedestrian signals in the City, representing over half of the City's traffic signals.

Application Guidance

- Need for audible signal usually demonstrated through a user request. Guidance for installation can be found in TAC Accessible Signal Guide.
- Set at appropriate volume to avoid noise pollution in urban areas.

Benefits

- Provides crossing assistance to pedestrians with vision impairment at signalized intersections.
- Improves safety for visually impaired pedestrians.

Costs

Approximately $7,500 per intersection (8 units).

Research

- A 2008 study of visually impaired pedestrians crossing at accessible pedestrian signals in Charlotte, North Carolina and Portland, Oregon determined that the signals reduced, by two seconds, the delay to the crossing start and significantly increased the proportion of pedestrians who crossed during the "Walk" signal and finishing crossing prior to the release of conflicting traffic.[29]
- A 2005 study of accessible pedestrian signals (APS) in Portland, Oregon found that visually impaired pedestrians were able to determine which of two streets at an intersection had a "walk" signal under the following conditions: when each APS push button was located on a separate post within several feet from the curb; when the posts were close to the line of the associated crosswalk farthest from the center of the intersection; and when the audible

"Walk" indication from each APS was a fast tick (percussive sound) at 10 repetitions per second as opposed to a verbal "Walk" indication.[30]

Case Studies

The City of Seattle installs accessible pedestrian signals when requested by the visually impaired community. To date, all APS requests have been fulfilled. If in the future the city finds that funding is not available to satisfy all requests, it plans to use NCHRP criteria to assist in prioritization of locations. Currently, seven percent of intersections have APS with audible walk indications and four percent of intersections have pushbutton-integrated APS with audible and vibrotactile indications. Neighbourhood complaints about noise from the signals sometimes require a signal adjustment. The City is likely to use MUTCD guidelines for future installations.

The City of Toronto is currently updating approximately 450 intersections to include APS. Guidance is found in the TAC Accessible Signal Guide.

Lessons Learned

Research indicates that audible signals effectively aid visually impaired pedestrians across the street. Research on installation indicates they should be placed close to the curb and on separate poles for each crossing. APS are generally well-received by the visually impaired community, though neighbouring residents or businesses sometimes complain about the noise.

8. Left Turn Bays

Description

A left turn bay is a dedicated left turn lane that can be located at intersections or driveways. This can also refer to a two-way left turn lane. At signalized intersections, there are three different signal alternatives for left turning vehicles in a left turn bay: 1) permissive, where a driver must let oncoming vehicles cross the intersection before making a left-turn; 2) protected, where a driver is provided a specific phase to make the left turn and 3) permissive/protected, where the driver has a protected phase for a portion of the signal that is either led or followed by a permissive phase.

Current Use in Vancouver

Left turn bays are commonly used throughout the City of Vancouver, primarily at arterial street intersections.

Application Guidance

- Left turn bays can be combined with a variety of left turning schemes (permissive, protected or permissive/protected).
- According to the FHWA Traffic Signal Timing Manual, the appropriate turn scheme depends on left-turn and opposing through volumes, number of opposing through lanes, cycle length, speed of opposing traffic, sight distance and crash history.

Benefits

- Provides a dedicated space for vehicles to wait to make a left turn, reducing the pressure turning vehicles feel from vehicles waiting behind them.
- Reduces the frequency of rear end and pedestrian crashes.

Costs

Costs can vary significantly depending on the right-of-way available as well as the hardware requirements.

Research

- A Montreal study of signalized intersections determined that exclusive left turn lanes significantly decrease the number of pedestrian collisions. No direct collision reduction was estimated. However, a reduction range of 3-8% was implied from a sensitivity analysis of a regression equation.[31]

- A 1990 study measured how well drivers understood the different left turn signal alternatives. The study found that the protected signal was by far the best understood, whereas the permissive/protected was the most often misunderstood.[32]

Case Studies

The City of Seattle installs left turn bays with protected left turns for safety reasons and in response to pedestrian requests. Pedestrians typically request protected left turns because of conflicts with motor vehicles. The City finds that those members of the public who have requested the protected left turns are satisfied with the result. On occasion, Seattle installs protected left turns without bays in constrained right-of-ways.

The City of Portland generally adds left turn bays as a countermeasure for crashes or congestion problems. Types of crashes that might trigger a left turn bay include left turn angle crashes and pedestrian involved crashes where the movement preceding the collision was a vehicular left turn. Because protected left turn phases may introduce additional delay, congestion impacts are always considered. To aid in its decision-making, the city uses a cross product method found in FHWA Traffic Signal Timing Manual which multiplies the through volume by the opposing left-turn volume to identify which turning schemes should be considered. However, the cross product method does not consider conflicts with pedestrians and bicycles. To the extent possible, the city prefers to use a protected left turn scheme as it minimizes conflicts between turning motorists and pedestrians and cyclists. To maximize pedestrian safety when a permissive/protected phase is utilized, the city will sometimes delay the permissive phase (flashing yellow arrow) to occur after the pedestrian crossing phase is complete.

Another approach Portland takes to solve crash or congestion problems associated with left turns is to restrict turn movements. The choice to restrict left turns at certain streets relates to the classification of the main street versus the side street and a lack of space for the left turn bay. The connectivity of the street grid may also play a role. Greater connectivity makes it easier to add restrictions near busier intersections.

Lessons Learned

Left turn bays can reduce the frequency of rear end and pedestrian collisions at signalized intersections because an exclusive turn lane provides a waiting area outside of the through travel zone and the pedestrian crosswalk circulation area.

A protected left turn phase for vehicles can reduce potential conflicts with pedestrians by separating the movements of each mode. If a permissive/protected scheme is utilized, the permissive phase can be delayed to occur after the pedestrian crossing phase is complete. The installation of left turn bays may require expensive intersection modifications if the existing roadway right-of-way is constrained.

9. Greenways

Description

Greenways are generally low-volume streets that have been optimized for bicycle and pedestrian travel through traffic calming and diversion, signage and pavement markings, and intersection crossing treatments. A greenway in Vancouver can take the form of one of three classifications: a local street with a parallel multi-use path, a local street with standard sidewalks and traffic calming, or an off-street pedestrian and bicycle pathways.

Current Use in Vancouver

Greenways are located throughout Vancouver and are linear public corridors for pedestrians and cyclists that connect parks, nature reserves, cultural features, historic sites, neighbourhoods and retail areas. Vancouver Greenways can be waterfront promenades, urban walks, environmental demonstration trails, heritage walks and nature trails.

Application Guidance

In Vancouver, while Greenways are generally evenly distributed throughout the City, routes are concentrated in areas with greater population density and a higher number of destinations, such as the downtown peninsula. When the network is complete, a City Greenway will be no more than a 25-minute walk or a 10-minute bike ride from every residence in Vancouver.

Benefits

- Traffic calming on greenways reduces vehicle speeds, which allows vehicles more time to notice pedestrians and reduces injury severity when crashes do occur.
- Traffic calming and diversion reduces vehicle volumes on greenways, reducing potential conflicts between motorists and pedestrians.

Costs

Varies depending on the types and amount of traffic calming, diversion and crossing treatments.

Research

- The project team was unable to identify research specific to greenways and their impact on pedestrian safety. This is partly because a greenway is an overall strategy for a street that is comprised of a number of different measures that serve to improve conditions for bicycles and pedestrians, including traffic calming, diversion, wayfinding and intersection crossing treatments.

Case Studies

The City of Calgary has installed traffic calming on many of its local streets. Studies show that traffic calming decreases the number of vehicles travelling at high speeds. According to the Calgary Citizen Satisfaction Survey, residents prefer walking along the city's extensive network of multi-use pathways to streets. The multi-use paths began as recreational areas, but now are used for utilitarian trips in part because they are so well-connected through the entire city. There are no studies that report the safety of the city's multi-use pathways as compared to local roads with or without traffic calming.

The City of Seattle has begun implementing greenways in order to entice more people to ride their bikes. Pedestrians will also benefit from the traffic calming and crossing improvements.

Other cities with robust greenway networks include Berkeley (CA), Eugene (OR), Palo Alto (CA), Portland (OR), and San Luis Obispo (CA).

Lessons Learned

Traffic calming on local roads tends to enhance the pedestrian environment by reducing vehicle speeds, which allows vehicles more time to notice pedestrians and reduces injury severity when crashes do occur. When multi-use pathways are available and convenient, pedestrians may be more likely to use the separated rights-of-way, which can reduce potential conflicts with motorized vehicles. Elements of greenways such as traffic calming and traffic diversion do offer tangible benefits to pedestrians through reduced exposure to vehicles and reduced speed differentials.

10. Leading Pedestrian Interval

Description

A traffic signal's leading pedestrian interval gives pedestrians the "Walk" symbol several seconds before motor vehicles traveling in the parallel direction are given a green light. This allows pedestrians to get a head start on crossing before vehicles begin turning, making them more visible to motorists.

Current Use in Vancouver

Not currently used in Vancouver.

Application Guidance

- Leading pedestrian intervals should be considered at intersections with a history of conflict between pedestrians and turning vehicles.

Benefits

- Provides pedestrians with a head start to begin their crossing before vehicles begin turning, making pedestrians more visible to motorists.
- Reduces conflicts between pedestrians and turning vehicles.

Costs

No capital costs. Cost is limited to resources for staff time to adjust the signal timing.

Research

- A St. Petersburg, FL before-and-after study of three second leading pedestrian intervals in the downtown found that conflicts were almost entirely removed for pedestrians entering the crosswalk during the beginning of the WALK interval. The study found that there was a smaller reduction in conflicts during the remainder of the WALK interval, which was most likely because pedestrians had already claimed the right-of-way during the first portion of the WALK interval.[33]
- A 1993 New York City study determined that leading pedestrian intervals reduce collisions with pedestrians, especially in locations where there are a high number of turning vehicles. The study found that the increased pedestrian safety occurs regardless of pedestrian volume.[34]

- A 2009 FHWA report based on research conducted in San Francisco and Miami found a significant decrease in the number of motorists turning left in front of pedestrians in two out of the three intersections studied in San Francisco and a significant increase in motorists yielding for pedestrians on left-turns at both study intersections in Miami. The study indicates that leading pedestrian intervals reduce conflicts between pedestrians and left turning motorists, but also determined that the increased yielding to pedestrians does not seem to be true for motorists turning right.[35]

Case Studies

From 2005-2009 the most frequent movement preceding a pedestrian involved collision in the City of Toronto was the vehicular left turn. The leading pedestrian interval is one measure the city has used to address these collisions. While there are currently only a few leading pedestrian intervals in place, staff would like to install more to improve safety. However, some staff members are unsure if drivers and pedestrians will understand the treatment, because some drivers attend to both the pedestrian signal and the motor vehicle signal

The City of Portland installs leading pedestrian intervals of approximately three to five seconds where there are heavy turn conflicts with pedestrian crossings. The city finds that the leading pedestrian intervals seem effective at reducing conflicts.

Lessons Learned

Research indicates that the head start offered to pedestrians to begin their crossing by leading pedestrian intervals is effective at reducing conflicts between pedestrians and turning vehicles. Pedestrians permitted to enter the intersection prior to the release of traffic are more visible to motorists and drivers are less likely to initiate turns when pedestrians are already in the street. Several peer cities have begun using this treatment.

11. Crossing Guards

Description

Crossing guards are paid employees or volunteers that provide assistance to people trying to cross the street. Crossing guards are typically stationed at school crossings to guide children through intersections, though they can also be used at other locations where assistance in judging crossing conditions could improve safety. Crossing guards often use stop paddles, reflective vests, and other devices to alert motor vehicles to the presence of pedestrians.

Current Use in Vancouver

Crossing guards are not frequently used in the City of Vancouver.

Application Guidance

- Typically stationed at school crossings, crossing guards can also be stationed at other locations where people would benefit from assistance in judging the suitability of traffic conditions for street crossings.
- Crossing guard programs are often a combined effort between local traffic officials, police, school officials, parents, and students.

Benefits

- Improves pedestrian safety at school crossings when the crossing guard is on duty.

Costs

Crossing guards are generally volunteers or paid for short intervals during the morning and afternoon peak traffic period; staff time required for coordination.

Research

- A 2006 study evaluating the effectiveness of crossing guards at Israeli elementary schools suggested that crossing guard programs may increase child awareness of safety rules. The study indicated that children attending schools with crossing guard programs may internalize traffic safety rules demonstrated by the crossing guards and engage in safe behaviors outside the presence of a guard. The study also found that the effectiveness of crossing guard programs depends on age, gender, and school location.[36]

- A 1983 crossing guard training program evaluation in Tallahassee, Florida determined that children taught crossing safety using a ‘show and tell’ approach did not consistently cross the street using safe behaviors. However, when children practiced crossing the street safely and received feedback from crossing guards, children consistently crossed the streets using safe behaviors. The study also found that while the program was in place, there were no conflicts between motor vehicles and pedestrians.[37]

Case Studies

Seattle’s crossing guard program is implemented through Seattle Public Schools. Adult crossing guard locations are determined by the Seattle School Transportation Committee, composed of Seattle Department of Transportation, Seattle Police Department, and Seattle Public Schools representatives. Locations must be marked school crosswalks and are prioritized based on roadway characteristics such as posted speed limit, traffic volume, number of vehicle lanes, pedestrian crossing distance, and presence of traffic control devices or warning beacons.

The City of San Antonio has had a “Crossing Guard Program” since 1952. As of 2010, crossing guards work part time for the San Antonio Police Department (SAPD). Most guards work an average of two hours per day on days when school is in session. The School Crossing Guard Supervisor trains new crossing guards in appropriate and effective methods to stop traffic and facilitate safe street crossings by elementary school children. The SAPD provides uniforms, vests, and whistles among other equipment. There are over 260 civilians who make up the SAPD School Crossing Guard program and no child fatalities have occurred at a school crossing while a crossing guard was on duty since the program’s inception.[38]

Lessons Learned

Research and peer city experience suggest that crossing guards can be effective at helping children cross streets safely near schools. Crossing guards may also be useful for aiding specific adult populations that, like children, may have less ability to make safe crossing decisions. Though crossing guards may reduce conflicts between pedestrians and vehicles while the guard is present, unless people are also taught how to behave safely, crossing guard programs may only be effective when the guard is on duty.

12. Yield to Pedestrian Signs for Right Turning Vehicles

Description

"Yield to Pedestrian" signs for right-turning vehicles are used to tell motorists who are executing turns that they need to yield to pedestrians in crosswalks. These signs are typically used at signalized intersections with heavy right turn volumes where right turn on red movements are allowed and there is a history of right turning vehicles failing to yield to pedestrians entering the crosswalk at the start of the green phase.

Current Use in Vancouver

Not currently used in Vancouver.

Application Guidance

- Typically used at signalized intersections with heavy right turn volumes where right turn on red movements are allowed.
- Overuse of signs tends to lead to non-compliance. Too many signs can lead to visual clutter.

Benefits

- May reduce conflicts between pedestrians and turning vehicles, though evidence is limited.

Costs

$400 per sign plus installation cost.

Research

- A 1996 Lincoln, Nebraska study at six intersections reported that installing a "Turning Traffic Must Yield to Pedestrians" sign on the corner opposite right turning vehicles reduced conflicts between pedestrians and vehicles between 15 and 30 percent. The study also noted that conflicts between motor vehicles and pedestrians decreased as pedestrian volumes increased, though this was true without the presence of a sign, as well. [39]

- A 2009 FHWA report based on research conducted in Las Vegas, Miami, and San Francisco determined that there were few quantifiable significant differences in motorists yielding and conflicts with pedestrians, and that the significant findings were inconsistent across the sign installation locations. The study reported that turning driver yielding increased at just two of the eight sign installation locations and conflicts between vehicles and pedestrians also decreased at just two of eight sites where the signs were installed.[40]

Case Studies

As indicated in the FHWA study above, San Francisco is the only peer city contacted that makes use of the 'Yield to Pedestrian' signs. Some of the other cities use right turn on red restrictions to minimize conflicts between pedestrians and right turning vehicles.

Lessons Learned

The research on the effects of yield to pedestrian signs is inconclusive, with one study finding the measure effective at reducing conflicts between pedestrians and turning vehicles while a more recent FHWA study finding no effect. This measure is generally not used by the peer cities; instead several of the peer cities use right turn on red restrictions to reduce conflicts between pedestrians and right turning vehicles.

13. Raised Intersections

Description

Raised intersections are flat elevated areas that span an entire intersection. They are typically either elevated to the same level as the sidewalk or just below so that visually impaired pedestrians can detect the transition from the sidewalk to the road. Raised intersections are often installed with decorative pavers to increase the visibility of the intersection and identify it as a pedestrian zone.

Current Use in Vancouver

There is one raised intersection in the City at Prince Edward Street and East 37th Avenue.

Application Guidance

- Used as a traffic calming treatment.
- May not be appropriate on emergency vehicle or bus routes.
- Can provide accessibility solutions for narrow sidewalks.

Benefits

- Reduces vehicle speeds at intersection.
- Increases pedestrian visibility.

Costs

Approximately $100,000; includes adjusting curb ramps and moving catch basins; dependent on the size of the intersection.

Research

- A 2000 study of a raised intersection in Cambridge, Massachusetts on a one-way residential collector street found that the treatment resulted in more pedestrians using the marked crosswalk, but did not increase the percentage of motorists yielding to pedestrians.[41]

Case Studies

The City of New York constructed a raised intersection to reduce cut-through traffic and increase stop sign compliance at a four-way stop-controlled intersection of two local streets in Brooklyn. The intersection did not warrant signal installation. After construction of the raised intersection, the city found there was a 25 percent increase in the number of motorists that stopped at the stop bar. The number of peak hour vehicles declined by 33 percent, indicating that the treatment made the road less desirable as a cut-through route.[42]

Lessons Learned

The research on raised intersections is inconclusive. Raised intersections may improve safety at stop-controlled or unsignalized intersections by increasing motorist yielding to pedestrians. Raised intersections also slow emergency vehicles and may cause some motorists to select alternate routes.

14. Midblock Crossings

Description

A midblock crossing is a pedestrian crossing facility implemented to accommodate pedestrian crossing demand between intersections and away from signalized intersections. Midblock crossings can include a number of additional treatments including pedestrian refuge islands, pedestrian signals, high visibility markings, and signage.

Current Use in Vancouver

Limited use in the City of Vancouver.

Application Guidance

- Consider the posted speed, traffic volume and number of lanes when selecting the appropriate measures to be included in the crossing.
- The mid-block crossings should align with pedestrian 'desire lines' to the extent possible to ensure the crossing is utilized.

Benefits

- Accommodates pedestrian crossing demand between intersections and away from signalized intersections.
- Alerts motorists to expect pedestrian crossing activity.
- Improves pedestrian safety, provided the crossing treatment is appropriate for the roadway.

Costs

Varies; depends on the type of crossing treatment.

Research

- A 2005 study of marked crosswalks at uncontrolled crossings, including midblock crossings, in cities throughout the United States found that a marked crosswalk on two-lane roads at an uncontrolled location without other treatments was associated with no difference in the pedestrian crash rate as compared to an unmarked crosswalk at the same type of location. The study also found that having a marked crosswalk without other treatments on multilane roads where traffic volumes were at least 12,000 vehicles per day was associated with a higher pedestrian crash rate as compared to an unmarked crosswalk at the same type of location. Raised medians provided significantly lower pedestrian crash rates on multilane roads, compared to roads with no raised median.

- A 2009 study in the City of St. Petersburg, Florida found that rectangular shaped rapid flashing LED beacons (RRFB) can increase motorists yielding to pedestrians at multilane, uncontrolled crosswalks. Results from 19 locations in St. Petersburg determined that average yielding behavior increased 2 to 86 percent. A follow-up study two years later found that 85 percent of motorists were yielding to pedestrians crossing where the RRFBs were located.[43]

Case Studies

The City of Portland does not typically install midblock crossings, as it finds that most pedestrians desire to cross at intersections along the existing street grid. There are select examples of both signalized and unsignalized mid-block crossings, however, no research related to safety is available.

There are several midblock crossings throughout the City of Calgary, though they are not common. The existing midblock crossing warrant requires that they be located a certain distance away from an intersection, which limits their installation. Examples of effective midblock crossings on collectors are those that connect pathways to parks or where pedestrian trip generators and attractors are located across from each other along a part of the street segment that is remote from an intersection.

Lessons Learned

Midblock crossings can provide a safety benefit for pedestrians, but the appropriate crossing treatment depends on the local street conditions. In general, roadways with high traffic volumes and multiple lanes need treatments beyond a striped midblock crossing, including measures such as median refuge islands, warning signs, or flashing beacons. It is important that mid-block crossings align with pedestrian 'desire lines' to ensure the crossings are utilized.

15. Raised Crosswalks

Description

Raised crosswalks are elevated pedestrian crossings that extend the sidewalk across the street through the creation of a flat topped speed hump. Raised crosswalks make the pedestrian more visible to drivers, slow driver speed, and provide more convenient crossings for persons using assistive mobility devices.

Current Use in Vancouver

There are several raised crosswalks in the City, including Ontario Street at 27th Avenue, 42nd Avenue, and 58th Avenue; Balaclava Street at West 29th Avenue; East 45th Avenue at Killarney Street, and Earles Street at East 40th Avenue.

Application Guidance

- Consider posted speed of road.
- May not be appropriate on emergency vehicle or bus routes.
- Use detectable warnings at the curb edges to alert vision-impaired pedestrians that they are entering the roadway.
- Care must be taken to manage drainage.

Benefits

- Reduces vehicle speeds.
- Increases pedestrian visibility.

Costs

Approximately $50,000.

Research

- A study of raised pedestrian crossings found that the treatment could reduce fatal and injury pedestrian collisions by 30 to 35 percent.[44]
- Another study of raised pedestrian crossings determined that total pedestrian collisions could be reduced by 8 percent.[45]

Case Studies

The City of Toronto has ten existing raised crosswalks and is looking for opportunities to install more in the downtown area. The city's traffic engineering department is reluctant to install more because they may give pedestrians may a false sense of security; alternatively there maybe an opportunity to provide a design cue that signals to drivers that they need to slow down to increase yield rates to pedestrians. Toronto intends to study the effectiveness of raised crosswalks further. The city has also found that snow/ice causes damage to pavers.

The City of Seattle uses raised crosswalks at both midblock crossings and at intersections, though there are only a few in the city. Seattle installs raised crosswalks as a result of a desire from the community and when there is available funding to honor the requests, but the city does not look for the opportunities to install these. Communities that requested raised crosswalks have been satisfied with them. The city has found raised crosswalks no more difficult to maintain than normal crosswalks and is not aware of any complaints.

The City of Portland has approximately 30-40 raised crosswalks as a form of traffic calming to reduce speeds at pedestrian crossings. Modified crosswalks are striped on 22 foot speed tables. The raised crosswalks resulted in speed reduction from over 35 mph to typical speeds of 25-28 mph. Currently only Local Service or Neighborhood Collector streets are eligible for traffic calming. Major Emergency Response routes are not considered for traffic calming due to potential delays.

Lessons Learned

Research suggests that raised crosswalks can reduce pedestrian collisions by increasing the visibility of pedestrians and reducing vehicle speeds, which tends to reduce the severity of injuries when collisions do occur. Raised crosswalks are generally not used on streets with higher design speeds or on emergency vehicle routes.

16. Separated vs. Mixed Modes on Roadway

Description

Typical roadways separate traffic modes by type, with sidewalks for pedestrians and often bicycle lanes or paths for bicyclists. Roadways that mix modes allow for the shared use of space by motor vehicles, pedestrians, and bicyclists, without lane assignment. There generally are no sidewalks or other features to separate modes and these roadways usually have lower posted speed limits.

Current Use in Vancouver

Though not a completely shared space, the closest example in Vancovuer of a mixed mode space is Granville Island.

Application Guidance

- Special consideration should be given to ensure there are cues that demarcate the travel way for visually impaired pedestrians.

Benefits

- Reduces motor vehicle travel speeds and volumes.
- Increases bicycle/pedestrian activity.
- Improves attractiveness of street.
- Increases social activity amongst neighbours and children.

Costs

Can be very expensive to retrofit; minimal or no extra cost if designed as a shared street from the beginning.

Research

- Oudehaske, Netherlands implemented a mixed-mode roadway in 1985 by creating a “square-like quality” through the installation of bricks in place of asphalt on the roadway and by changing the urban design to highlight the village church and village pub. These changes reduced vehicle speeds by 50 percent, on a street that had an average daily traffic (ADT) of 8,000 vehicles and 2,500 bicyclists.[46]

- In 2000, Drachten, Netherlands installed a shared space at an intersection with 22,000 vehicles per day. The city removed most traffic signals in exchange for a roundabout and redesigned the intersection to look like a public plaza that included water fountains. Because the fountains attract people to the intersection, vehicle speeds have dropped.[47] A study on the intersection reported that collisions decreased after the roundabout was installed.[48]

Case Studies

Though not a completely shared space, the City of Seattle has installed a "woonerf" on Terry Avenue, a lower volume street adjacent to streets that carry higher volumes of traffic. One side of the roadway lacks sidewalks and is overall less defined, blending into public plazas. The main issue that the city has faced on Terry Avenue is the occasional driver entering the public plazas and parking in them.

The City of Calgary has an area where the mixing of modes occurs, though the location is not designed specifically to be a shared space. The Steven Avenue Mall is a pedestrian-only zone from 6 am to 6 pm. The sidewalk is only slightly higher than the roadway and thus hard to distinguish, which leads a few pedestrians to walk in the roadway when motor vehicle traffic is permitted. The visually impaired community has issues with this space as people cannot feel where the curb ends. Because the pedestrian mall has been in place for several decades, pedestrians and motorists generally understand how to use the space and the city reports no other notable safety issues.

The City of Portland reports success with its Chinatown festival streets which are designed to be closed to motorized traffic for special events. Based on observations, these streets work quite well when open to motorized traffic. The city notes that on future installations of this type of street it would recommend installation of detectable warnings for the entire length of the curbless sidewalk area to benefit visually impaired pedestrians.

Lessons Learned

Shared space roadways are often designed to be a civic center where people mix and congregate. Research suggests that these roadways can result in lower vehicle speeds and can reduce collisions. If residents are unfamiliar with the concept of mixed modes, it may be necessary to conduct outreach on how to use the space. While more common in Europe, several of the North American peer cities have implemented some variation of a shared street and generally report success. Special consideration should be given to ensure appropriate cues for visually impaired pedestrians.

17. New or Upgraded Intersection Lighting

Description

Proper illumination at intersections provides greater visibility for both drivers and pedestrians.

Current Use in Vancouver

Varies.

Application Guidance

In Vancouver, there is an overrepresentation of pedestrian collisions occurring during darkness. Improved intersection lighting should be provided at:

- All signalized intersections.
- Intersections where pedestrian volumes are high, especially during the night time.

Benefits

Increases pedestrian visibility.

Costs

$5,000-$10,000

Research

- A 2004 FHWA study reports that providing intersection lighting can result in 78% reduction in injury pedestrian collisions and 42% of fatal pedestrian collisions.[49]

Case Studies

Many municipalities have lighting design guides (e.g., Edmonton) and highly recommend enhanced intersection lighting as a safety measure to reduce pedestrian collisions.

Lessons Learned

Improved lighting should be provided at intersections where pedestrian volumes are high during low light conditions, or where there is a trend of night time collisions.

Appendix D

Example Road Safety Awareness Program References

City/Agency	Campaign Messaging	Description	Reference
RTA (New South Wales)	Speeding Drunk Driving Motorcycles Alcohol and Drugs Driver Fatigue Seat belts Motorcycles Young Drivers Road Worker Safety	Various marketing campaigns aimed at affecting behavioural change in motorists.	http://www.rta.nsw.gov.au/roadsafety/advertisingcampaigns/index.html
Toronto	We're all Pedestrians (current) "Please Drive Carefully – We're all Pedestrians" (2003/04)	Reinforces the theme that everyone needs to take care and be courteous as they make their way around Toronto. The posters are featured on transit shelters and curb side garbage bins throughout the city.	http://www.toronto.ca/transportation/publications/pedestrian_safety/index.htm http://www.toronto.ca/wesads/index.htm#pedsafety
Think! Road Safety (United Kingdom)	Speed – rural Speed – urban Be Safe Be Seen	Comprehensive website includes a wealth of information highlighting Think! campaigns as well as guidance for road safety professionals and educators.	http://think.dft.gov.uk/think/
FHWA	Pedestrian Safety Campaign	Pedestrian safety campaign materials developed by FHWA in 2003 – have been used by over 400 communities in the US.	http://safety.fhwa.dot.gov/local_rural/pedcampaign/
Oakland and San Francisco, California	Tune in to your surroundings – Drivers can't always see you Walk a Child to School Day (annual event) Pedestrian Safety Week (annual event) Safe Moves Town (pedestrian safety training for children) Public relations campaigns (including	Programmatic elements to improve pedestrian safety, including annual events, safety training and public relation campaigns.	http://www.oaklandnet.com/government/Pedestrian/PedMasterPlan.pdf

City/Agency	Campaign Messaging	Description	Reference
	"It's Our Town, Let's Slow it Down")		
Lausanne, Switzerland	"It is better to stop before…"	Campaign encourages motorists to yield to pedestrians at crossings.	http://www.lausanne.ch/view.asp?DocId=29220
New York City, New York	Curbside Haikus (pedestrian safety) Walk Ways (walking to school) Traffic Safety Calendar	Multimedia safety and event campaigns aimed at drivers and pedestrians of all ages.	http://www.nyc.gov/html/dot/html/safety/curbside-haiku.shtml http://www.nyc.gov/html/dot/html/safety/walkingschools.shtml http://www.nyc.gov/html/dot/html/safety/safe_calendar.shtml
Seattle, Washington	See You in the Crosswalk (pedestrian safety for drivers and walkers)	Pedestrian safety campaign for the holiday season. Includes carollers, flash mobs, videos, posters, bus ads, coaster giveaways,	http://www.seattle.gov/transportation/seeyou_mm.htm
Portland, Oregon	I Brake for People	Multimedia campaign aimed at drivers, encouraging yielding to pedestrians. Includes ads on transit vehicles, benches, and shelters, bumper stickers, and drive-time radio blurbs.	http://bikeportland.org/2007/10/15/pdot-to-launch-pedestrian-safety-campaign-5564
Chicago, Illinois	Pedestrian Safety Campaign	Numerous initiatives, including mannequins representing pedestrians who have died in crashes; outreach to schools, senior facilities, and taxi drivers; stencilled messages on sidewalks; and pedestrian crossing flags.	http://blog.zolk.com/post/11914584514/cdot-launches-pedestrian-safety-campaign

Appendix E

References

[1] City of Vancouver. Walking – Vancouver's Top Priority. http://vancouver.ca/engsvcs/transport/cleanGreen/walking/index.htm.

[2] Vodden, K., Smith, Douglas, Eaton, F, and Mayhew, D. Analysis and Estimation of the Social Cost of Motor Vehicle Collisions in Ontario – Final Report. Transportation Canada, August 2007.

[3] Transport Canada. Transport Canada Releases First, Systematic Analysis of Cost of Urban Traffic Congestion in Canada. http://www.tc.gc.ca/eng/mediaroom/releases-nat-2006-06-h006e-2353.htm#table.

[4] http://www.phac-aspc.gc.ca/hp-ps/hl-mvs/oic-oac/index-eng.php

[5] Walking, Cycling, and Obesity Rates in Europe, North America, and Australia, Bassett, Pucher, Buehler, Thompson, and Crouter. Journal of Physical Activity, 2008, 5, 795-814

[6] Statistics Canada, CANSIM table 102-0561 and Catalogue no. 84-215-X. Last modified: 2011-11-01.

[7] http://www.euro.who.int/__data/assets/pdf_file/0003/87573/E72015.pdf

[8] http://vancouver.ca/sustainability/documents/FactSheetCityClimateProtectionCS1.pdf

[9] Fitzpatrick, K. and Park, E.S. Safety Effectiveness of HAWK Pedestrian Treatment. Transportation Research Record: Journal of the Transportation Research Board, No. 2140, Transportation Research Board of the National Academies, Washington, D.C., 2009, pp. 214–223.

[10] Fernandez, D., Miranda-Moreno, L. and Morency, P. (2012) "Pedestrian injury risk at signalized intersections: Exposure measures and geometric designs", TRB 2012 Annual Meeting, Washington DC

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

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

[13] http://www.tc.gc.ca/eng/roadsafety/tp-tp15145-1201.htm

[14] Fitzpatrick, K. and Park, E.S. Safety Effectiveness of HAWK Pedestrian Treatment. Transportation Research Record: Journal of the Transportation Research Board, No. 2140, Transportation Research Board of the National Academies, Washington, D.C., 2009, pp. 214–223.

[15] Godavarthy, R. P. and R. R. Eugene Sr. Effectiveness of a HAWK Beacon at Mid-block 12 Pedestrian Crossings in Decreasing Unnecessary Delay to the Drivers. Presented at 89th 13 Annual Meeting of the Transportation Research Board, DVD, Washington, D.C., 2010, 14 January 10-14.

[16] King, M.R. Calming New York City Intersections. TRB Circular E-C019: Urban Street Symposium. Retrieved from: http://onlinepubs.trb.org/onlinepubs/circulars/ec019/Ec019_i3.pdf

[17] Johnson, R.S. Pedestrian Safety Impacts of Curb Extensions: A Case Study. Oregon Department of Transportation and Federal Highway Administration. 2005. Retrieved from: http://www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/PedestrainSafetyCurbExt.pdf?ga=t

[18] Fernandez, D., Miranda-Moreno, L. and Morency, P. (2012) "Pedestrian injury risk at signalized intersections: Exposure measures and geometric designs", TRB 2012 Annual Meeting, Washington DC.

[19] Van Houten, R. and Nau, P.A. Feedback Interventions and Driving Speed: A Parametric and Comparative Analysis. Journal of Applied Behavior Analysis 16(3). 1983 pp. 253-281.

[20] Your Speed Sign (YSS). Retrieved October 2011 from: http://www.onemotoring.com.sg/publish/onemotoring/en/on_the_roads/road_safety/your_speed_sign__yss.html

[21] Farraher, B.A.B. (2000). "Pedestrian Countdown Indication – Market Research and Evaluation," Proceedings, Institute of Transportation Engineers Annual Meeting (on CD-ROM).

[22] Rousseau, G. and Davis, G. (2003). A comparison of Countdown Pedestrian Signal Display Strategies; Report. Mclean Virginia: US Department of Transportation. Federal Highway Administration.

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

[24] Zeeger, C.V., Stewart, R., Huang, H.H., Lagerwey, P.A., Feaganes, J., and Campbell, B.J. Safety Effects of Marked versus Unmarked Crosswalks at Uncontrolled Locations: Final Report and Recommended Guidelines. Federal Highway Administration. 2005.

[25] Ismail, K., Sayed, T., and Saunier, N. (2010) "Automated Analysis of Pedestrian-vehicle Conflicts: A Context for Before-and-after Studies", Transportation Research Record: Journal of the Transportation Research Board, Vol. 2198, pp.52-64.

[26] Kattan, L., S. Acharjee, and R. Tay. Pedestrian Scramble Operations. Transportation Research Record: Journal of the Transportation Research Board. 2140, 2009, pp. 79-84.

[27] Vaziri, B. Exclusive pedestrian phase for the business district signals in Beverly Hills: 10 years later. Institute of Transportation Engineers. District 6 Meeting (51st : 1998 : San Diego, CA), compendium of technical papers. Washington, D.C.: Institute of Transportation Engineers, 1998.

[28] Garder, P. Pedestrian safety at traffic signals: a study carried out with the help of a traffic conflicts technique. Accident analysis and prevention. Vol. 21, no. 5, October 1989, p. 435-444.

[29] Scott, A.C., Barlow, J.M., Bentzen. B.L., Bond, T.L.Y., and Gubbe, D. "Accessible Pedestrian Signals at Complex Intersections: Effects on Blind Pedestrians", Transportation Research Record: Journal of the Transportation Research Board, No. 2073, Transportation Research Board of the National Academies, Washington, D.C., 2008, pp. 94–103.

[30] Scott, A.C., Myers, L., Barlow, J.M., and Bentzen, B.L. Accessible Pedestrian Signals: The Effect of Push-Button Location and Audible "Walk" Indications on Pedestrian Behavior. Transportation Research Record: Journal of the

Transportation Research Board, No. 1939, Transportation Research Board of the National Academies, Washington, D.C., 2005, pp. 69–76.

[31] Fernandez, D., Miranda-Moreno, L. and Morency, P. (2012) "Pedestrian injury risk at signalized intersections: Exposure measures and geometric designs", TRB 2012 Annual Meeting, Washington DC.

[32] Hummer, J.E., R.E. Montgomery, and K.C. Sihna. Motorist Understanding of and Preferences for Left-Turn Signals. In Transportation Research Record 1281, TRB, National Research Council, Washington, D.C., 1990, pp. 137-147.

[33] Van Houten, R. Leading Pedestrian Interval: St. Petersburg, Fl. Retrieved from: http://www.walkinginfo.org/pedsafe/casestudy.cfm?CS_NUM=66

[34] King, M.R. Calming New York City Intersections. TRB Circular E-C019: Urban Street Symposium. Retrieved from: http://onlinepubs.trb.org/onlinepubs/circulars/ec019/Ec019_i3.pdf

[35] Pedestrian Safety Engineering and ITS-Based Countermeasures Program for Reducing Pedestrian Fatalities, Injury Conflicts, and Other Surrogate Measures Final System Impact Report. Federal Highway Administration. Retrieved October 2011 from:
http://safety.fhwa.dot.gov/ped_bike/tools_solve/ped_scdproj/sys_impact_rpt/chap_2.cfm

[36] Rosenbloom, T., Haviv, M., Peleg, A., and Nemrodov, D. The Effectiveness of Road-Safety Crossing Guards: Knowledge and Behavioral Intentions. Safety Science 46(10). December 2008, pp. 1450-1458.

[37] Yeaton, W.H., and Bailey, J.S. Utilization Analysis of a Pedestrian Safety Training Program. Journal of Applied Behavioral Analysis 16(2). 1983 pp. 203-216.

[38] San Antonio Police Department. School Safety Program. Retrieved October 2011 from: http://www.sanantonio.gov/sapd/schoolpatrol.htm

[39] Abdulsattar, H.N., M.S. Tarawneh, P.T. McCoy, and S.D. Kachman (1996). "Effect on Vehicle-Pedestrian Conflicts of 'Turning Traffic Must Yield to Pedestrians' Sign," Transportation Research Record 1553, Transportation Research Board, National Research Council, Washington, DC, pp. 38-45.

[40] Pedestrian Safety Engineering and ITS-Based Countermeasures Program for Reducing Pedestrian Fatalities, Injury Conflicts, and Other Surrogate Measures Final System Impact Report. Federal Highway Administration. Retrieved October 2011 from:
http://safety.fhwa.dot.gov/ped_bike/tools_solve/ped_scdproj/sys_impact_rpt/chap_2.cfm

[41] Huang, H.F. and Cynecki, M.J. Effects of Traffic Calming Measures on Pedestrian and Motorist Behavior. Transportation Research Record 1706, Transportation Research Board, National Research Council, Washington, DC, pp. 26-31.

[42] City of New York. Raised Intersection. Retrieved October 2011 from: http://www.walkinginfo.org/pedsafe/casestudy.cfm?CS_NUM=58

[43] Shurbutt, J. Van Houten, R. Turner, S. and Huitema, B. Rapid-Flash Beacons on Yielding to Pedestrians in Multilane Crosswalks. Transportation Research Record: Journal of the Transportation Research Board, No. 2140, Transportation Research Board of the National Academies, Washington, D.C., 2009, pp. 85–95.

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

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

[46] Oudehaske (1985). Shared Space. Retrieved October 2011 from: http://www.shared-space.org/default.asp?OBJECTID=18429

[47] Drachten (2000) Laweiplein. Shared Space. Retrieved October 2011 from: http://www.shared-space.org/default.asp?OBJECTID=18436

[48] Noordelijke Hogeschool Leeuwarden. The Laweiplein: Evaluation of the reconstruction of a square with roundabout. Noordelijke Hogeschool Leeuwarden. Leeuwarden, Netherlands, January 2007, pp. 26.

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