

**THE EFFECT OF PEDESTRIAN COUNTDOWN SIGNALS ON  
PEDESTRIAN WALKING SPEED**

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by

Alexandra Campbell, B.Sc., EIT

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Department of Civil Engineering  
University of Manitoba  
Winnipeg, Manitoba

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## **ABSTRACT**

This research investigates the effect of pedestrian countdown signals (PCS devices) on crossing walking speed of pedestrians at urban signalized intersections. The research considers two age groups: (1) younger pedestrians (ages 20 to 64); and (2) older pedestrians (ages 65 and older).

Two pedestrian walking speeds were used for this research: (1) *crossing* walking speed (speed pedestrians walk crossing a signalized intersection); and (2) *normal* walking speed (speed pedestrians walk a segment of sidewalk).

The research found that PCS devices have an effect on a pedestrians' crossing walking speed, regardless of age, by decreasing the speed. Older pedestrians alter their walking speed after the installation of PCS devices more than younger pedestrians. Furthermore, after the installation of PCS devices the walking speed of pedestrians shifts from a faster crossing walking speed towards a slower normal walking speed.

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# 1 INTRODUCTION

## 1.1 PURPOSE

The purpose of this research is to investigate the crossing walking speed of pedestrians at urban signalized intersections using pedestrian countdown signals (PCS devices). The research focuses on investigating the effect of PCS devices on crossing walking speed of pedestrians. *Crossing* walking speed is defined for this research as the speed at which pedestrians walk when crossing a signalized intersection, and is compared to *normal* walking speed defined as the speed at which pedestrians walk when they go about their daily activities without needing to cross a given intersection. Before installation of PCS devices, data were collected by Arango (2008) for crossing and normal walking speed. This research focuses on the before and after study investigating the effect of PCS devices on crossing walking speed. The research considers two pedestrian groups: (1) younger pedestrians (ages 20 to 64); and (2) older pedestrians (ages 65 and older).

## 1.2 BACKGROUND AND NEED

Pedestrian walking speed is an important input for many transportation engineering applications. Typically, the 15<sup>th</sup> percentile walking speed is used for pedestrian signal timing or for determining required gap sizes (ITE, 2002).

The U.S. Manual on Uniform Traffic Control Devices (FHWA, 2009) assumes a pedestrian walking speed of 0.91 m/s (3.0 ft/s) for the WALK phase and clearance interval of 1.07 m/s (3.5 ft/s) for traffic signal timing purposes. In areas with a high number of older pedestrians or pedestrians using mobility assisting devices, a lower

walking speed should be considered for the pedestrian clearance interval (FHWA, 2009). Prior to the U.S. MUTCD 2009 edition, a pedestrian walking speed of 1.2 m/s (4 ft/s) was assumed for traffic signal timing (FHWA, 2003). In January 2006, the U.S. MUTCD National Committee approved a proposal by the Pedestrian Task Force of the National Committee on Traffic Control Devices to change the pedestrian walking speed assumption in the U.S. MUTCD to 3.0 ft/s or 0.91 m/s for the WALK phase and clearance interval. A draft revision of the U.S. MUTCD was published for public comment as the U.S. Federal Register Docket No. FHWA-2007-28977. The Federal Highway Administration (FHWA) adopted the MUTCD revisions for walking speed in December 2009 (FHWA, 2008). There were two changes related to the pedestrian walking speed: (1) when calculating pedestrian clearance times a value of 3.5 ft/s or 1.07 m/s is used; and (2) when calculating the time required for the pedestrian to walk from one side of the traveled way to the other, the WALK phase and pedestrian clearance interval of 3.0 ft/s or 0.91 m/s is used (FHWA, 2009).

It is common practice in Canada to assume a pedestrian walking speed of 1.2 m/s (4 ft/s) (TAC, 1998). However, as a result of the changes in the U.S. MUTCD, the Transportation Association of Canada (TAC) conducted a national study on pedestrian walking speed. The study's findings were released in March 2013 with the Pedestrian Walking Speed for Traffic Operations and Safety in Canada Technical Report (Montufar et al. 2013). The recommendations will be implemented in the next Canadian MUTCD update expected in 2015. The recommendations for pedestrian walking speed introduce a range of values depending on the percentage of older pedestrians or pedestrians using mobility assistive devices such as canes, walkers and manual wheelchairs. The new recommendation on walking speed ranges from 0.8 m/s to 1.0 m/s. In locations with a low percentage of older pedestrians, the general population will be accommodated

using the walking speed of 1.0 m/s. A walking speed of 0.9 m/s is used when 20 percent or more of pedestrians at the location are 65 years of age or older (i.e., older pedestrians). At locations with 20 percent or more of pedestrians using mobility assisting devices a walking speed of 0.8 m/s is used. The proportion of the population at the intersection can be found from locations around hospitals or nursing homes, and proportion of the population in the areas adjacent to the intersection. Engineering judgement and standard practices are used to determine if the walking speeds are used for the pedestrian clearance interval only or both the pedestrian clearance intervals and the walk interval (Montufar et al., 2013).

The updated pedestrian walking speed for the U.S. MUTCD and the Canadian MUTCD continues to have significant implications in design and traffic operations. Groups of the population have been impacted by the modifications to the assumed walking speed such as older pedestrians, pedestrians with physical disabilities and mobility restrictions, and children. Older pedestrians and pedestrians using mobility assistive devices are better accommodated with the introduction of a lower walking speed. In Canada, the range of 0.8 m/s to 1.0 m/s was introduced in the Canadian MUTCD to accommodate older pedestrians and pedestrians using mobility devices. Previous research indicates that older pedestrians are better accommodated with a walking speed of 0.9 m/s, and pedestrians with mobility impairments are better accommodated with a walking speed of 0.8 m/s (Arango et al. 2009) (Montufar et. al 2013). The accommodation of older pedestrians and pedestrians using mobility assisting devices is increasingly important with the increasing older population. According to Statistics Canada (2013a), in 2013 people 65 years of age and older accounted for 15 percent of Canada's population, and 14 percent of Manitoba's population. In Canada, the trend is towards an aging population, with an estimated 25 percent of Canada's population of 65 years of age or

older by the year 2036, using a medium growth scenario, which combines assumptions of fertility and immigration similar to recent years along with a moderate growth in life expectancy. The largest growth in the population from 2006 to 2011 was between the ages of 60 and 64 years (29 percent), indicating the continued trend of rapid growth of seniors in the country (Statistics Canada, 2013a).

In regards to traffic operations, there has been research studying the possible effect of the new changes to walking speed on traffic operations and signal operations. It is expected that there could be an effect on different system components. The effect on traffic flow is not expected to have a negative impact if the signal cycle length is greater than or equal to 90 sec., the crossing distance is not extremely wide, and the intersection is not operating at capacity currently. Likewise, negative impacts are not expected at locations that are narrow intersections, or locations that have high vehicular demand and low pedestrian demand. At intersection locations where the intersection is currently operating at capacity, the effect of the lowering in walking speed is expected. Significant delays could occur when the walking speed is lowered and there is no change in the cycle length. Looking at a corridor as a whole, corridor progression may be delayed at locations with a high pedestrian demand along with low vehicular demand (Montufar et al., 2013).

Pedestrian walking speed has been a topic of extensive research over the years. Research over the years has addressed characteristics such as age, gender, and other characteristics of the pedestrian population such as physically impaired pedestrians. Little research has investigated the before and after effect of PCS devices on a pedestrian's crossing walking speed. In the past 20 years, the installation of PCS devices has increased greatly. Research has been conducted on the understanding of the devices, collisions at sites where PCS devices are installed, and the perceived level

of safety of the devices. This research designs and applies a methodology to conduct a before and after study to investigate the effect PCS devices have on pedestrian crossing walking speed in urban areas. Winnipeg has not had any PCS devices installed prior to July 2012, and therefore provides an ideal site for the research.

### **1.3 OBJECTIVES AND SCOPE**

Specific objectives of this research are to:

1. Determine the *crossing* walking speed of younger and older pedestrians at signalized intersections with a pedestrian countdown signal.
2. Analyze the effect of the pedestrian countdown signal from Week 0 (i.e., before installation) to Week 22 on the *crossing* walking speed of pedestrians.
3. Analyze the effect pedestrian countdown signals have on pedestrian walking speed.
4. Compare the change in pedestrian *crossing* walking speed at locations with pedestrian countdown signals to *normal* walking speed of pedestrians.

This research was conducted in Winnipeg, Manitoba, Canada from July 2012 to October 2014. Winnipeg is a city located in Southern Manitoba in the Canadian Prairie Region with a population of 730,000 for the Winnipeg Census Metropolitan Area according to Statistics Canada 2011 Census report (2013b). The location to conduct this research is ideal since Winnipeg has never had an installed PCS device prior to July 2012. The fact that the technology is new to the City and its citizens provides insightful results of how PCS devices affect the crossing walking speed of pedestrians.

## 1.4 THESIS ORGANIZATION

This thesis is organized into five chapters.

Chapter 2 summarizes a literary review regarding walking speed of pedestrians and PCS devices. The chapter addresses the following: (1) demographic issues relating to pedestrian's walking speeds (age and gender); (2) walking speed of pedestrians in other jurisdictions and countries discussing the effect of age, and gender; (3) the effect of pedestrian countdown signals on walking speed and pedestrian countdown signal studies; and (4) human factors and pedestrian countdown signals.

Chapter 3 discusses the methodology developed and followed for this research. The chapter discusses the characteristics of the two study groups, as well as the types of pedestrians excluded to prevent biases. The methodology used for determining the sample size required and the site location is also presented in Chapter 3. The chapter then describes the preparation and data collection required for the research.

Chapter 4 details the data analysis for the pedestrian walking speed. The data were analyzed from Week 0 (i.e., before installation) to Week 22 after installation for both younger and older pedestrians to determine the effect of the PCS devices on pedestrian walking speed. The analysis compares the crossing walking speed of pedestrians before and after PCS devices were installed at the chosen locations. The before installation data set was collected by Arango (2008), and compared to data collected for this research after the installation of PCS devices. The *crossing* walking speed of the pedestrians is then compared to the *normal* walking speed of pedestrian's based on data collected by Arango (2008).

Chapter 5 presents the research findings and conclusions reached for the effect of PCS

devices on pedestrian walking speed. Future research opportunities are also presented.

## 1.5 GLOSSARY OF TERMS

**15<sup>th</sup> percentile:** In relation to walking speed, the 15<sup>th</sup> percentile refers to the walking speed at which 15 percent of pedestrians are not able to surpass. (I.e. The speed at which 85 percent of the pedestrians are able to walk at or faster than).

**Compliers:** In relation to pedestrian traffic signals, it represents pedestrians who cross the street at the designated crossing zone while the appropriate pedestrian signal or traffic signal indication is displayed.

**Crossing walking speed:** the speed at which a pedestrian travels while crossing a signalized intersection.

**Normal walking speed:** the speed at which pedestrians walk on a sidewalk as they go about their daily life without having to cross a crosswalk or intersection.

**Older pedestrians:** for this study it will refer to the population of pedestrians 65 years of age or older.

**Pedestrian Countdown Signal (PCS):** A type of pedestrian signal which displays a descending numerical value in the pedestrian signal head. This provides information to pedestrians the number of remaining seconds for the pedestrian interval (FHWA, 2009).

**Week 0:** for this study Week 0 is the data obtained prior to installation from Arango (2008).

**Younger pedestrians:** for this study it will refer to the population of pedestrians between the ages of 20 and 64 years of age.

## **2 LITERATURE REVIEW**

This chapter summarizes the findings from the literature review on the subject of pedestrian walking speed. The chapter begins with an introduction into (1) demographic issues related to pedestrians which effect the walking speed including the age and gender of the pedestrian. From there this chapter discusses (2) walking speed of a pedestrians in other jurisdictions and countries with an emphasis on the effect of age, gender and weather, and (3) pedestrian countdown signal studies and the effect on walking speed.

### **2.1 DEMOGRAPHICS**

#### **2.1.1 Age**

According to Statistics Canada, between 2006 and 2011 the percentage of 65 years of age or older increased 14 percent to nearly 5 million people. The growth rate for the senior population is double the growth rate of the entire population of Canada at 6 percent. In 2011, people aged 65 years or older accounted for 15 percent of the total population of Canada. Between the census years 2006 and 2011, the 60 to 64 year old age group was found to have the highest growth rate at 29 percent. This indicates that the current trend in Canada will continue and the population will see an accelerated growth rate of seniors in the coming years (Statistics Canada, 2013a). It has been estimated that 25 percent of Canada's population will be 65 years of age or older by the year 2036, using a medium growth scenario which combines assumptions of fertility and immigration similar to recent years along with a moderate growth in life expectancy. In Manitoba, the population distribution is following a similar trend to Canada. People ages 65 years of age and older increased from 14 percent of the total population in 2006 to 14

percent of the total population in 2011 accounting for a percent change of 7 percent in 5 years. From the 2006 census to the 2011 census Manitoba has experienced a growth of 16 percent in the population ages 55 to 64 years old, indicating the next decade will experience an increased number of seniors (Statistics Canada, 2013a).

The U.S. Census Bureau (2010) estimates that the population 65 years and older will account for 21 percent of the total population in 2050 – corresponding to a population growth of 150 percent from 2000 to 2050 (NCHS, 2005).

The *Pedestrian Crossing Control Guide: Technical Knowledge Base* states that the “aging process can also result in reduced strength, flexibility and range of motion in the upper arm, shoulder lower leg and the neck and upper torso” (Montufar et al., 2011). As the population ages and their range of motion, strength and flexibility decreases, their speed and ability to perform ordinary tasks becomes more difficult. The need to accommodate pedestrians with decreased mobility becomes more crucial as the percentage of total population over the age of 65 years of age increases. In addition, as older pedestrians are better accommodated, other groups such as children or parents traveling with young children will also be better accommodated

The World Health Organization has launched the “Global Network of Age-friendly Cities and Communities” Network. Their aim is “to create physical and social urban environments that promote healthy and active ageing and a good quality of life for their older residents.” (WHO, 2013) The Network promotes the exchange of ideas and experience, and provides learning opportunities for the cities and communities who have joined. Canada has joined the network, with research conducted in Portage La Prairie, MB, Halifax, NS, Sherbrooke, QC, and Saanich, BC. The *Global Age-Friendly Cities: A Guide* report was released in 2007. The guide includes a section on safe pedestrian

crossings, which discuss the traffic signal timing is not long enough for older pedestrians. One older pedestrian in Halifax is quoted in the guide saying “cross lights are made for Olympic runners” (WHO, 2007). Pedestrian countdown signals are discussed as a possible improvement to allow older pedestrians more information during the crossing.

### **2.1.2 Gender**

According to Statistics Canada (2013a), women represent the majority of the population in Canada and Manitoba. In 2006 and 2011 the female population was 51 percent and the male population was 49 percent. Looking at the population over the age of 65, the percentage of male and female is changing with the increasing years. In 2006 the male and female population were identical to the total population with 51 percent female and 49 percent male. Five years later, from the 2011 census, the female population was 56 percent of the total population and the male population was 44 percent of the total population. This indicates the life expectancy of women is higher than the life expectancy of men. Statistics Canada estimated in 2009 that the life expectancy at birth for men was 79 years and 83 years for women. This is an increase from the 2007 numbers which estimated the life expectancy at birth of men at 75 years and 81 years for women (Statistics Canada, 2013a).

## **2.2 PEDESTRIAN WALKING SPEED**

Pedestrian walking speed is a required value for a number of traffic engineering applications including signal timing. Pedestrians often require more time to cross a given intersection than the vehicular demand, and vehicular clearance time. According to the Signal Timing Manual (Koonce, P. et al., 2008) the minimum green time, at locations

without pedestrian push buttons, is determined by the time it takes a pedestrian to cross the intersection; therefore pedestrian crossing speed is important for signal timing. Before 2009 the U.S Manual of Uniform Traffic Control Devices (FHWA, 2003) assumed a pedestrian walking speed of 4 ft/s (1.2 m/s) or slower in areas where slower pedestrian are present such as seniors or people using assistive devices (i.e., canes or walkers). The pedestrian walking speed was updated in the U.S. Manual of Uniform Traffic Control Devices released in 2009 in two ways: (1) when calculating pedestrian clearance times a value of 3.5 ft/s or 1.07 m/s will be used; and (2) when calculating the time required for the pedestrian to walk from one side of the traveled way to the other, the WALK phase and pedestrian clearance interval of 3.0 ft/s or 0.91 m/s will be used (FHWA, 2009). The Traffic Operations and Management Standing Committee (TOMSC) were made aware of the changes to the U.S. MUTCD and implications on Canadian jurisdictions in April 2009, with a funding request issued. In 2012 the Canadian study on the pedestrian walking speed began in cities throughout the country. The final report was released in March 2013 with recommendations for the inclusion of a range of pedestrian walking speeds to be included in the upcoming Canadian MUTCD. In subsequent MUTCDC, the crossing time for an intersection will use a walking speed between 0.8 m/s and 1.0 m/s depending on the amount of older pedestrians and pedestrians requiring the use of mobility devices at the location. In areas with more than 20 percent of pedestrians requiring mobility assisting devices such as canes and walkers, a walking speed of 0.8 m/s will be used. A walking speed of 0.9 m/s will be used for locations with 20 percent of pedestrians 65 years of age or older. At locations with less than 20 percent of pedestrians' considered older pedestrians, a walking speed of 1.0 m/s will be used to accommodate the general population (Montufar et al. 2013).

Arango (2008) conducted research on the crossing and normal walking speed of

pedestrians in Winnipeg. A total of 1,792 pedestrians were timed for their walking speed. An average and 15<sup>th</sup> percentile crossing walking speed for older pedestrians were found to be 1.36 m/s (4.46 ft/s) and 1.08 m/s (3.54 m/s) respectively. Younger pedestrians were found to have an average crossing walking speed of 1.61 m/s (5.28 ft/s) and a 15<sup>th</sup> percentile walking speed of 1.33 m/s (4.36 ft/s). Compared to the design value of 1.2 m/s (4.0 ft/s) it was found that nearly 40 percent of older pedestrians would be excluded from design at signalized intersections. Of pedestrians requiring walkers, canes or other mobility devices 90 percent would be excluded. The research states that the changes made to the U.S. MUTCD, lowering the pedestrian walking speed to 0.91 m/s (3.0 ft/s), would decrease the excluded older pedestrians to 10 percent, and 55 percent when requiring walkers or canes.

In addition, Arango's (2008) research found a significant difference between normal and crossing walking speed of both younger and older pedestrians. It was found that the same pedestrian travels at different speeds whether crossing an intersection or traveling along a segment of roadway (i.e., along a sidewalk). The average and 15<sup>th</sup> percentile normal walking speed were 1.36 m/s and 1.10 m/s respectively for younger pedestrians. Similarly, the normal walking speed of older pedestrians were 1.14 m/s and 0.88 m/s for the average and 15<sup>th</sup> percentile walking speed respectively. Both age groups studied were found to significantly alter their walking speeds depending on where they are walking. Arango (2008) found that for both younger and older pedestrians their crossing walking speed were higher than their normal walking speed.

Figure 1 and Figure 2 show the cumulative distribution of pedestrian walking speed for normal and crossing walking speed. The assumed design speed of 1.20 m/s with the corresponding cumulative percent is labeled in red on the figures. The graphs illustrate the difference between crossing and normal walking speed for both age groups.

Additionally, it demonstrates the differences between the walking speed of younger and older pedestrians.

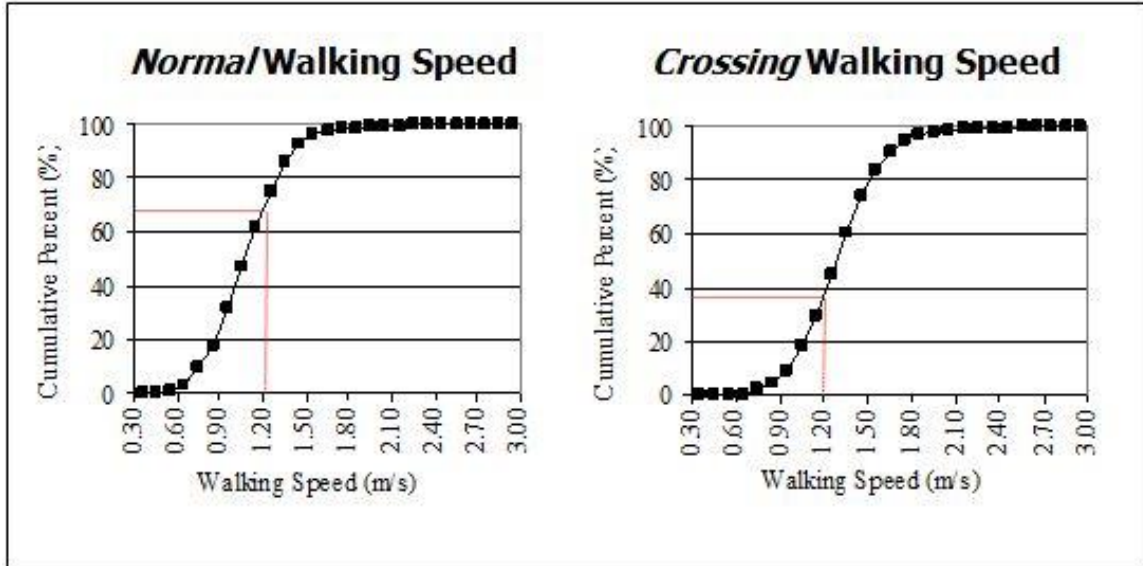


Figure 1: Older Pedestrian Walking Speed (Arango, 2008)

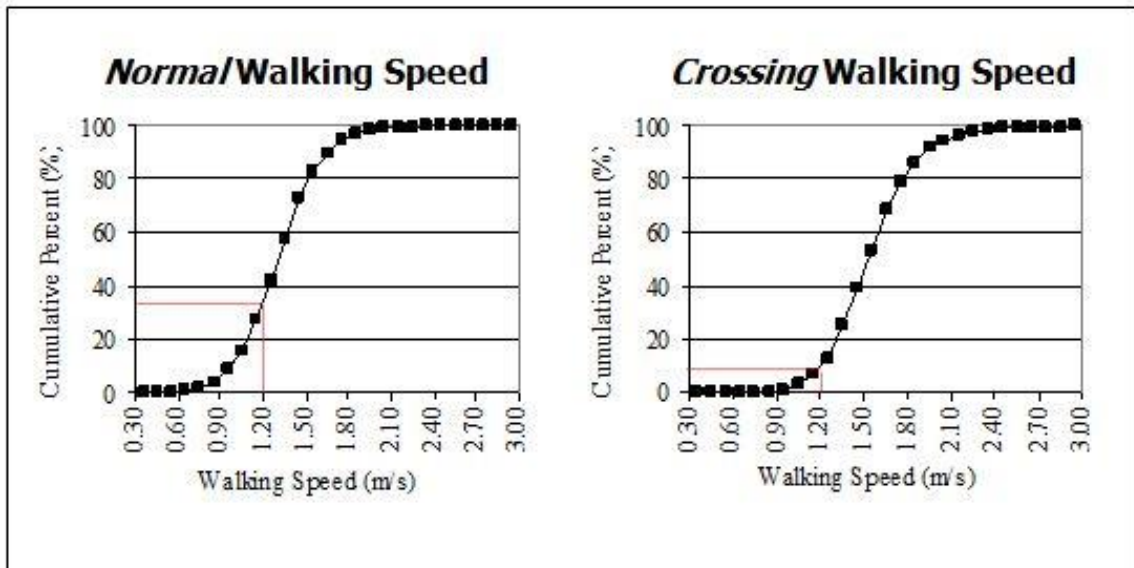


Figure 2: Younger Pedestrians Walking Speed (Arango, 2008)

Research conducted in China by Zhou et al. (2011) timed 6,628 pedestrians to find their crossing speed. The research found that only 24.4 percent of pedestrians have a

crossing speed lower than 1.2 m/s, indicating that 75.6 percent of pedestrians would be excluded with a design speed of 1.2 m/s. Table 1 shows the percent of pedestrians in a given crossing speed range for the research.

**Table 1: Crossing speed by percentage**

<b>Crossing Speed (CS) (m/s)</b>	<b>Percentage (%)</b>
< 1.0	5.9%
$1 \leq CS < 1.2$	18.5%
$1.2 \leq CS < 1.5$	51.4%
$1.5 \leq CS < 2.0$	15.9%
$2.0 \leq$	8.3%

Source: Zhou et al. (2011)

In Zhou et al.'s study (2011), the average crossing speed was 1.4 m/s. The authors interviewed pedestrians for the study and found that "older road users express greater appreciation for the traffic signals at controlled pedestrian crossings and signalized intersections than younger pedestrians". The research found that the older pedestrians have a slower walking speed and prefer to wait at the curb when they believe the green time is not sufficient for crossing. The study found that female pedestrians walked slower than male pedestrians, and indicated that female pedestrians may have more difficulty crossing the crosswalk safely before the light turns red.

Research conducted by Dommès and Cavallo (2011) in France studied street crossing decisions for different age groups. The study investigated the perceptual, cognitive, and motor ability differences as the population ages. The majority of fatal road collisions in France are people aged 65 years or older (51 percent), however are less than 15 percent of the total population. The purpose of the research was to determine if the

decline in perception and cognitive and motor abilities affect the decision making of seniors when they are crossing at intersections. Walking speed has been found to be a predictor of safe crossing decisions. The study found the mean walking speed for the three age groups tested ranged from 1.00 m/s in young (20-30 year olds), 0.90 m/s in younger-old (61-71 years old), and 0.92 m/s in older-old participants (72-83 years of age). The 15<sup>th</sup> percentile walking speed for pedestrians provides access to an acceptable amount of the population (85 percent of the population walks at that speed or higher). The current use of 1.2 m/s as a walking speed is significantly higher than the mean for all three age groups, therefore indicating the 15<sup>th</sup> percentile of the study would also be significantly lower. The authors recommend that splitter islands should be implemented in the middle of two-way roads to allow seniors to cross the intersection in two stages because of their slower walking speed.

### **2.3 PEDESTRIAN COUNTDOWN SIGNALS**

The addition of pedestrian countdown signals at signalized intersections has been extensively studied in regards to pedestrian behaviour, pedestrian compliance and vehicle behaviour. There are six countdown timing pattern options for the installation of PCSs (TAC, 2008):

1. WALK to flashing DON'T WALK - Countdown begins at start of WALK phase and ends after the flashing DON'T WALK phase.
2. WALK to Amber- Countdown begins at start of WALK phase and ends after the amber phase.
3. WALK to All Red- Countdown begins at start of WALK phase and ends after the all red phase.

4. Flashing DON'T WALK - Countdown begins at the start of flashing DON'T WALK phase and ends at the end of flashing DON'T WALK phase.
5. Flashing DON'T WALK to Amber- Countdown begins at the start of flashing DON'T WALK phase and ends after the amber phase.
6. Flashing DON'T WALK to All Red- Countdown begins at the start of flashing DON'T WALK phase and ends after the all red phase.

The Transportation Association of Canada (TAC) released “An Information Report on Pedestrian Countdown Signals (PCS)” (TAC, 2008) in February 2008 which included a jurisdictional survey of existing or proposed PCS use in Canada and the United States. There were 263 ITE members surveyed in Canada from Federal, Provincial, County and local governments. A total of 2396 ITE members from the U.S were surveyed from the Federal, State, County and local governments.

The TAC report identified nine major issues regarding pedestrian crossings and PCSs. The nine issues identified were (TAC, 2008):

1. Do pedestrians understand conventional pedestrian signal displays?
2. Do pedestrians understand pedestrian countdown signal displays?
3. Do pedestrians prefer pedestrian countdown signals or conventional pedestrian signals?
4. Do pedestrian countdown signals reduce pedestrian related crashes?
5. Do pedestrian countdown signals lead to increases in vehicle speeds and acceleration to “beat the light”?
6. Do pedestrian countdown signals result in pedestrians running, hesitating, or turning around?
7. Do pedestrian countdown signals result in the abuse of the pedestrian signal crossing intervals?

8. Are pedestrian countdown signals beneficial for seniors or teens?
9. How do pedestrian countdown timing strategies affect pedestrian signal performance?

The following were found to answer the nine issues identified above (TAC, 2008):

1. In the studies found, the understanding of conventional pedestrians signals ranged from 26 to 80 % of pedestrians did not understand.
2. The understanding of PCS displays ranged from 50 to 97% understood, and 78 to 94% believed it was clearer to understand than conventional displays.
3. It was found that pedestrians prefer PCS displays compared to conventional displays.
4. Past studies indicate there does not appear to be an increase in crashes or conflicts with PCS displays, and that they can reduce pedestrian-vehicle conflicts. It is suggested that this needs to be researched more and in different cities.
5. PCS devices were not found to have a noticeable change in the speed, acceleration and general vehicle behaviour.
6. Studies looking at the effect on pedestrians running, hesitating or turning around were found to be inconsistent.
7. Changes were found for pedestrians entering during the flashing HAND phase and exiting during steady HAND phase only.

8. Teens and seniors were found to be positively affected by PCS devices in regards to understanding and their influence on behaviour.
9. A number of studies were found researching how PCS devices affect pedestrian signal performance. It was found that technical difficulties were found if countdowns were started from the WALK period of the pedestrian display.

A number of studies and research in Canada and the United States have focused on the understanding of the conventional pedestrian crossing display versus PCS displays.

A study conducted in Hampton, Virginia in 1999 found that 26% of pedestrians do not understand the traditional pedestrian display correctly. The installation of a PCS device provided a better understanding of pedestrian crossing control devices. It was found that 92 percent of those interviewed find it clearer to understand and 85 percent interviewed stating it was an improvement to the traditional display (Allsbrook, 1999). Another study performed in Boulder, Colorado obtained similar findings. A sample size of 830 pedestrians was interviewed the week after a PCS device was installed in the downtown area. Of the pedestrians who noticed the PCS device, 97 percent understood the number indicated a countdown of how much time there was left to cross. Slightly higher than the Hampton, Virginia study, 88 percent of the pedestrians believed that PCS devices were useful for pedestrians. The results indicated that 8 percent of people also believed that the technology was unsafe for reasons including people may try to beat the signal to cross and it was a waste of money (Baron et al. 1998). Studies conducted in Salt Lake City, Utah, Fountain Valley, California and Clackamas County, Oregon experienced similar positive results to preferring PCS displays instead of the traditional pedestrian display with results ranging from 80 percent to 90 percent (Bergenthal, 2000) (City of Fountain Valley, 2003) (Christofferson, 2003).

A number of studies have also looked at the effect of PCS technology on driver behaviour. In Monterey, California two technicians were placed at the maximum sight distance from the PCS devices to observe changes in driver behaviour. It was found that no car had a rapid acceleration when the countdown indicated 6 seconds or less to beat the light. The study investigated the probability of a driver using the PCS display to beat the light and found it to be a low probability. It was found that when a driver is approaching at 30 mph (48.2 km/hr), the driver is able to see the countdown display numbers at 107 ft to 238 ft (32.6 to 72.5m) from the stop line. For signal timing, the United States provides a 4.5 sec clearance interval corresponding to a distance of 353 ft (107.6m), which exceeds the 107 ft to 238 ft range visible by the countdown signal. The Montgomery County study results indicated that PCS installation had no effect on the mean speed and 85<sup>th</sup> percentile speed of vehicles. Conflict data collected at the intersections during the pedestrian peak hours before and after installation indicated that the number of conflicts between vehicles and pedestrians decreased after PCS devices were installed given a 95 percent confidence interval (Eccles et al. 2003).

Canadian studies results were consistent with the United States studies with respect to pedestrians' feeling of safety and vehicle-pedestrian conflicts. A Saint-Laurent, Quebec study found that pedestrian feeling of safety improved with PCS installation; however, the study also found that PCS did not improve pedestrian understanding of the WALK, flashing HAND and steady HAND phases (FHWA, 1999). A public opinion study on PCS technology in Edmonton, Alberta found that 90% of the phone comments on the technology were extremely positive. The research indicated that an increased number of pedestrians entered the crosswalk while the display showed a flashing HAND, however a decreased number of pedestrians entered the crosswalk while a steady HAND was displayed (City of Edmonton, 2003).

TAC's (TAC, 2008) outlines proposed additional sections to MUTCDC regarding "PCS Effectiveness Information". In the proposed section it indicates that there are no evident changes in vehicle behaviour including speed, acceleration and signal violations. The Pedestrian Countdown Signal Project Steering Committee suggested three major locations categories that would have added value from the installation of PCS devices (TAC, 2008):

- a) Locations that have a high percentage use by seniors, children, and other mobility challenged pedestrians
- b) Locations with a history of high pedestrian and vehicle conflicts
- c) Locations that generate high pedestrian and/or vehicle traffic

Huang and Ma (2010) conducted research at signalized crosswalks in Shanghai, China on walking speeds at signalized intersections. A portion of the study considered at one intersection with a PCS device installed compared to a regular pedestrian signal. Three separate parts were looked at for each intersection: "first 5 seconds of pedestrian green time (1), last 5 seconds (2), and interim time (3)" (Huang, 2010). It was found that both younger and older pedestrians had a different walking speed with a PCS installed, however the effect is dependent on at what time the pedestrian started their crossing. During the first situation of the first 5 seconds of the pedestrian phase the walking speed for both younger and older pedestrians decreased, however it was found that pedestrian walking speed increased for both pedestrian groups if the pedestrian began their crossing after 5 seconds and in the last 5 seconds (Huang, 2010).

Xiong et al. (2014) collected data from a questionnaire and by video recording at two signalized intersections: one with a PCS device installed and one without a PCS device. It was found that 92 percent of people questioned believed that PCS devices are helpful

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in determining when to enter the crosswalk, and 96 percent prefer the countdown signal compared to the traditional signal. In addition 63 percent of people questioned believed the installation of PCS devices is a necessary step.

Research in Saint-Laurent, Quebec found that PCS devices increased the feeling of safety at an intersection. Similar studies in the U.S. found that both teens and seniors especially find PCS devices increase their understanding and improves their level of safety (FHWA, 1999).

The majority of PCS devices literature has focused on the effect PCS devices have on safety, and the effect PCS devices have on pedestrian and vehicular behavior. There has been little research, with no major study, looking at the effect of PCS devices on walking speed.

### 3 RESEARCH METHODOLOGY

This chapter discusses the methodology used for data collection and the determination of pedestrian walking speed. The research methodology is based on previous research conducted by Arango (2008).

For this research, the *crossing* walking speed is defined as the speed at which pedestrians cross a given signalized intersection. *Normal* walking speed is defined as the speed at which pedestrians walk when they go about their daily activities, without needing to cross any intersection, and without having external pressures, such as exposure to vehicular traffic, as a result of having to cross the intersection.

Pedestrian walking speed data used in this research were collected under two different scenarios. The first is comparing the crossing walking speed of younger and older pedestrians at signalized intersections with PCS devices installed over a 22 week period since installation of PCS devices against the crossing walking speed of pedestrians before PCS devices were installed. The second scenario involves comparing the normal walking speed of pedestrians, collected by Arango (2008) along a road segment between signalized intersections, to the crossing walking speed of both age groups after the installation of PCS devices found for this research.

The five elements of this research methodology, as per Arango (2008) are: (1) determining the characteristics of the study group researched; (2) determining the required sample size; (3) selecting the signalized intersection sites for field investigation; (4) preparing for data collection for field investigation; and (5) collecting the data.

### **3.1 CHARACTERISTICS OF THE STUDY GROUP**

Two study groups were identified for the data collection at the signalized intersection with a PCS device. The two groups were classified based on the age of the pedestrian: one group contained older pedestrians (i.e., pedestrians who appear to be 65 years of age and older), and the other group contained younger pedestrians (i.e., pedestrians who appear to be between ages of 20 and 64 years of age).

To prevent and exclude biases during the analysis, as well as for consistency with the research by Arango (2008), the following situations and/or types of pedestrians were avoided during the data collection process:

- Pedestrians walking with children.
- Pedestrians walking with elderly people.
- Pedestrians walking with people using mobility assistive devices.
- Pedestrians pushing wheelchairs or assisting people in need.
- Pedestrian pushing strollers or shopping carts.
- Pedestrians walking with dogs or other pets.
- Pedestrians walking with a bicycle.
- Pedestrians using rollerblades, skateboards or similar devices.
- People using mobility assistive devices including walkers and canes.
- People for which gender or age were difficult to determine.
- Pedestrians who showed a significant change in speed while crossing the intersection (i.e., speeding up, slowing down or running a portion of the crossing distance).
- Pedestrians running across the entire distance.
- Pedestrians not following the crosswalk alignment (i.e., crossing diagonally).

- Pedestrians not completing the crossing (i.e., stopping midway at median) for unknown reasons but not because they did not have enough time to cross.
- Pedestrians not completing the crossing due to turning around and not reaching the opposite sidewalk.
- Pedestrians who cross away from the intersection.
- Pedestrians crossing illegally (i.e., non-compliers).
- Pedestrians accompanied by another person or a group of people, who were distracted by conversation.
- Pedestrians distracted by technology (i.e., on their cell phone as they walk).
- Pedestrians not starting during the WALK phase of the signal cycle.

The following situations and types of pedestrians were avoided to ensure that a pedestrians crossing walking speed is not altered by extraneous situations. For example, by avoiding pedestrians changing their speed mid crossing and running across the intersection it allowed for the pedestrians day-to-day crossing walking speed to be consistent. Situations that affect their walking speed were therefore avoided.

### **3.2 SAMPLE SIZE**

A total sample of 26,439 pedestrians crossing walking speeds was collected for statistical significance. Of these, 13,176 records corresponded to older pedestrians and 13,263 to younger pedestrians. This sample was collected over a period of 22 weeks from the installation of each PCS device, at 5 sites in Winnipeg. The data was collected over a 22 week period to collect the initial and long term effect on behaviour. After the introduction of a new technology to the population there is an initial shift in behaviour, followed by a shift towards the new normal for the population. Collecting over the 22

weeks, insured both the initial and long term shift were collected. A minimum sample size of 60 older and younger pedestrians was required for each week of data collection. However, between 86 to 142 pedestrian walking speeds were collected per week to allow for more confidence in the results and allow for disaggregation of the data. Table 2 illustrates the distribution of sample size by site, age and gender.

**Table 2 Sample Size**

Site	Site 1 Donald St and Portage Ave	Site 2 Edmonton St and Portage Ave	Site 3 Fort St and Portage Ave	Site 4 Garry St and Portage Ave	Site 5 Osborne St and River Ave	Total
<b>Age</b>						
Younger	1947	2661	2800	2846	3008	13,263
Older	1861	2660	2802	2846	3008	13,176
<b>Gender</b>						
Male	1872	2386	3091	3376	2674	13,399
Female	1936	2935	2511	2316	3342	13,040
<b>Total</b>	3808	5321	5602	5692	6016	<b>26,439</b>

A confidence level of 99 percent was used to determine the K value of 2.58. The standard deviation was set to 0.3 m/s as found by Arango (2008). Finally, to be conservative, the permitted error was set to be 0.1 m/s. The resulting sample size, as perviously mentioned, was found to be 60 pedestrians per week for each site.

The process to determine the sample size used the following equation:

$$N = \left(S \frac{K}{E}\right)^2$$

- where:  $N$  = minimum number of measured speeds
- $S$  = standard deviation (m/s)
- $K$  = constant corresponding to the desired confidence level
- $E$  = permitted error in the average speed estimate (m/s)

### 3.3 SELECTION OF SITES FOR FIELD INVESTIGATION

The research took place at five sites with PCS devices in Winnipeg. These locations were some of the first sites chosen by the City of Winnipeg engineers to have PCS devices installed. Four of the sites are located in downtown Winnipeg, and one is located just south of the Assiniboine River in the Osborne Village area. These locations maximized exposure to pedestrians, and especially older pedestrian activity.

Figure 3 shows the five locations selected for data collection: (1) Portage Avenue at Donald Street; (2) Portage Avenue at Edmonton Street; (3) Portage Avenue at Garry Street; (4) Portage Avenue at Fort Street; and (5) Osborne Street at River Avenue.

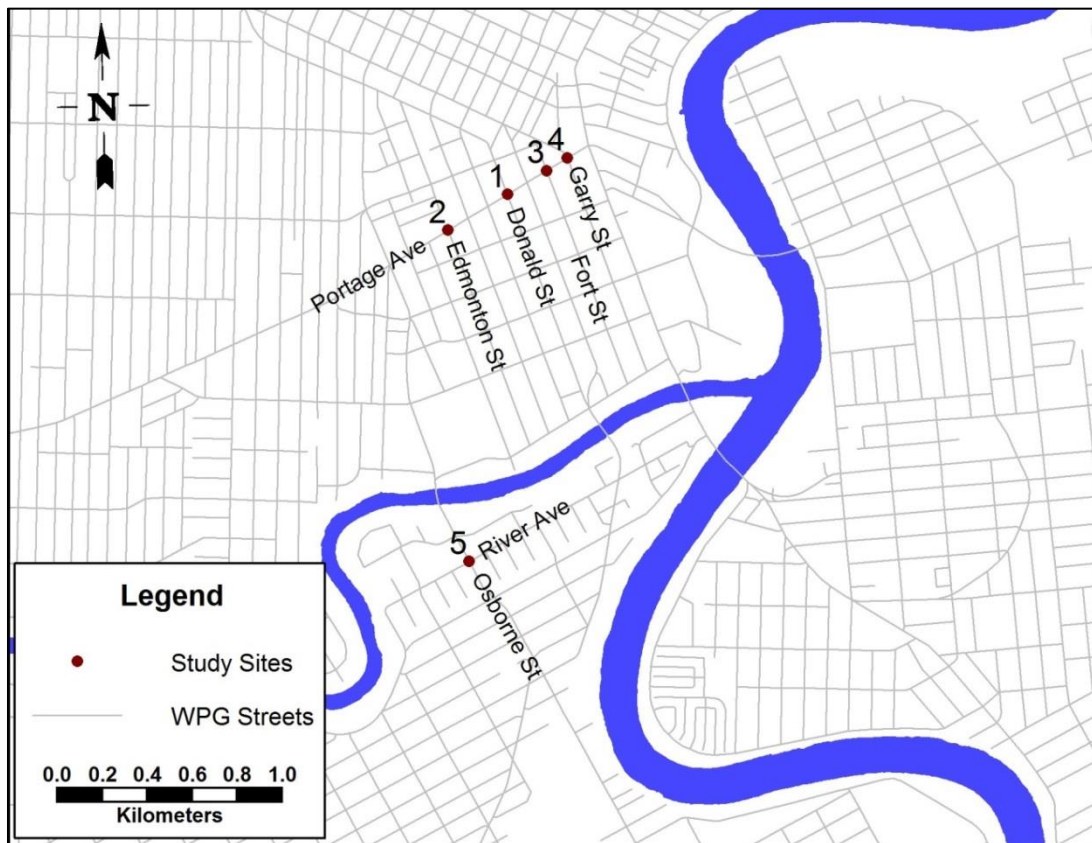


Figure 3 Data Collection Sites

These are the general characteristics of these intersections:

- All are signalized intersections with traffic volumes ranging from 8,300 to 36,600 vehicles per day, and pedestrian activity ranging from about 1,000 to 12,000 pedestrians per day.
- Intersection widths range from 7.60 m (24.90 ft) to 33.50 m (109.91 ft) at roads with or without medians.
- The number of lanes to cross range from two to six.
- All intersections allow the operation of busses and trucks.
- Pedestrian countdown signals are installed at each pedestrian signal of the intersections.
- All intersections have four legs with sidewalks on all legs with the exception of Portage Avenue and Edmonton Street which is a T-intersection.
- Four of the intersections are pre-timed pedestrian crossings with Osborne Street and River Avenue the only intersection with accessible pedestrian pushbuttons. If the pedestrians do not activate the button, no WALK signal will appear.
- Minimum WALK/ DON'T WALK times are from the current Canadian MUTCD standards at the time of data collection.
- The countdown timers use a walking speed of 1.2 m/s for the clearance interval.
- The countdown timers use the separate housing configuration as seen in Figure 4 and all intersections use the Flashing Don't Walk to all Red strategy.



**Figure 4 Pedestrian Countdown Housing Configuration**

### **3.3.1 Portage Avenue and Donald Street**

The intersection of Portage Avenue and Donald Street is a four-leg signalized intersection with sidewalks on all legs. It is located in the core of Winnipeg's downtown district with close proximity to businesses, commercial and entertainment areas as well as residential apartment and condominium buildings.

Portage Avenue is an east-west arterial. At this intersection, Portage Avenue is a six-lane divided roadway with traffic volumes ranging approximately from 34,000 to 37,000 vehicles per day (City of Winnipeg, 2012). At this intersection Donald Street is a south, three-lane, one-way street undivided arterial. The traffic volume on Donald Street ranges approximately from 12,000 to 18,000 vehicles per day. Figure 5 illustrates the layout of the intersection.

### **3.3.1 Portage Avenue and Edmonton Street**

The intersection of Portage Avenue and Edmonton Street is a three-leg signalized intersection with sidewalks on all legs. It is located in the core of Winnipeg's downtown district with close proximity to businesses, commercial and entertainment areas as well as residential apartment and condominium buildings. The main downtown shopping centre is located on the north side of the intersection, with medical buildings located nearby.

Portage Avenue is an east-west arterial. At the intersection Portage Avenue is a six-lane divided roadway with traffic volumes of approximately 36,000 vehicles per day. Edmonton Street is a northbound four-lane one-way street undivided arterial. At Portage Avenue, Edmonton Street ends at Portage Place Mall, requiring vehicular traffic to turn onto Portage Avenue. Figure 6 shows the layout of this intersection.



Figure 5 Intersection of Portage Avenue and Donald Street



**Figure 6 Intersection of Portage Avenue and Edmonton Street**

### **3.3.3 Portage Avenue and Fort Street**

The intersection of Portage Avenue and Fort Street is a four-leg signalized intersection with sidewalks on all legs. It is located in the core of Winnipeg's downtown district with close proximity to businesses, commercial and entertainment areas as well as residential apartment and condominium buildings. The intersection is located in the major business area in Winnipeg. Fort Street is located a block parallel from Main Street which is a major north-south arterial for Winnipeg. The intersection of Portage Avenue and Main Street is closed to pedestrians, however, underground tunnels allow pedestrians access. The underground tunnels are accessed from the buildings to the east of Fort Street; therefore the intersection can have an increase in pedestrian volume.

Portage Avenue is an east-west arterial. At the intersection, Portage Avenue is a six-lane divided roadway with traffic volumes of approximately 37,000 vehicles per day. Fort Street is a northbound four-lane one-way street undivided arterial. Figure 7 shows the layout of this intersection.

### **3.3.1 Portage Avenue and Garry Street**

The intersection of Portage Avenue and Garry Street is a four-leg signalized intersection with sidewalks on all legs. It is located in the core of Winnipeg's downtown district with close proximity to businesses, commercial and entertainment areas as well as residential apartment and condominium buildings. The intersection is located in the major business area in Winnipeg. Garry Street is located two blocks parallel from a major north-south arterial, Main Street, for Winnipeg.

Portage Avenue is an east-west arterial. At the intersection Portage Avenue is a six-lane divided roadway with traffic volumes of approximately 37,000 vehicles per day. Garry Street is a southbound four-lane one-way street undivided arterial. Figure 8 shows the

layout of this intersection.

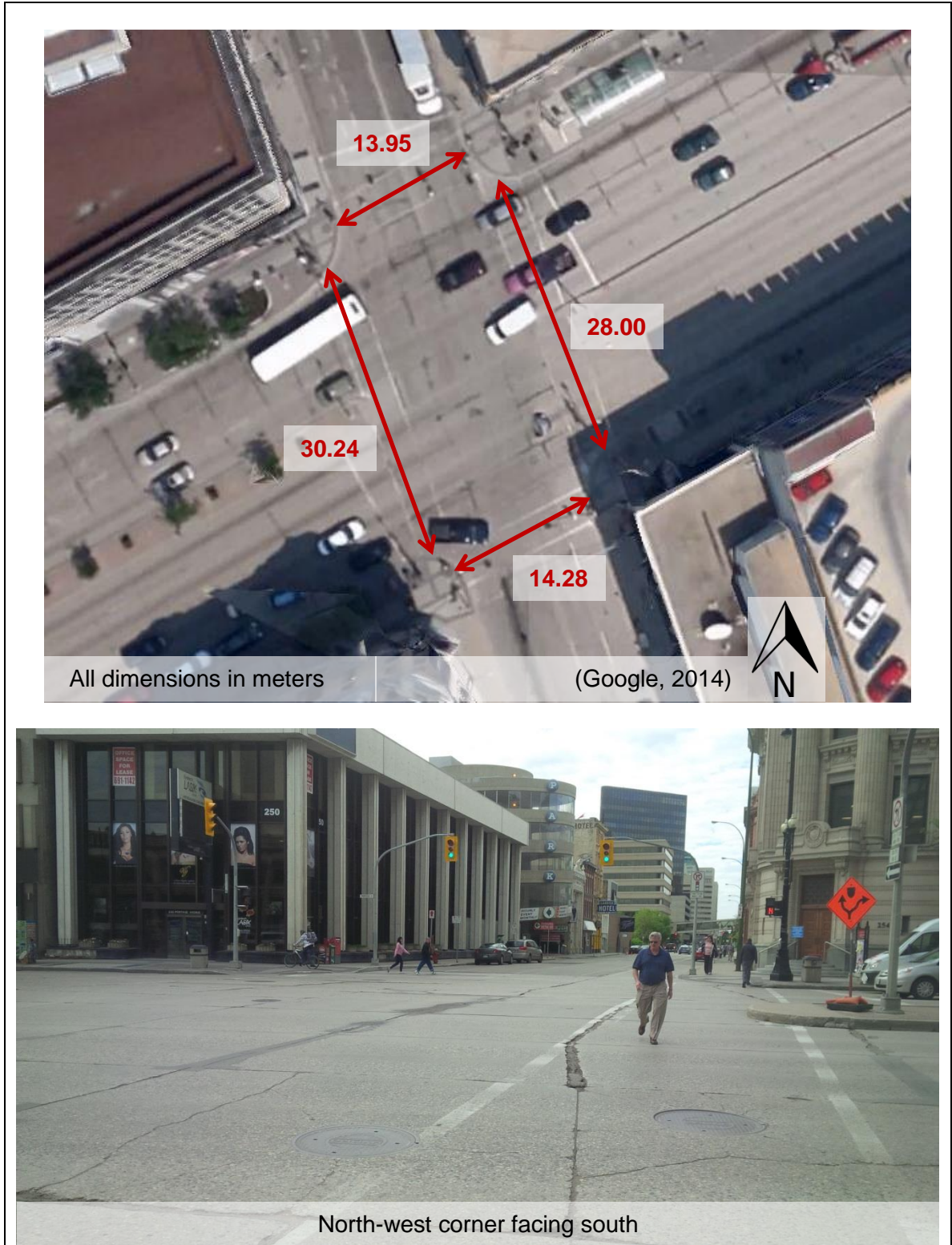
### **3.3.2 Osborne Street and River Avenue**

The intersection of Osborne Street and River Avenue is a four-leg signalized intersection with sidewalks on all legs. It is located in the Osborne Village area of the city which is a mixed land-use area with close proximity to businesses, medical offices, commercial and entertainment areas as well as residential apartment, condominium buildings and single family homes.

Osborne Street is a four-lane undivided north-south arterial with traffic volumes ranging from approximately 35,000 to 38,000 vehicles per day. At the north of the intersection, on the southbound direction, Osborne Street has an additional lane which is a bus priority lane. River Avenue is a one way, two-lane undivided roadway with two additional lanes for right and left turning movements on the east side of the intersection. Traffic volumes on River Avenue are approximately 8,000 vehicles per day. Figure 9 shows the layout of this intersection



**Figure 7 Intersection of Portage Avenue and Fort Street**



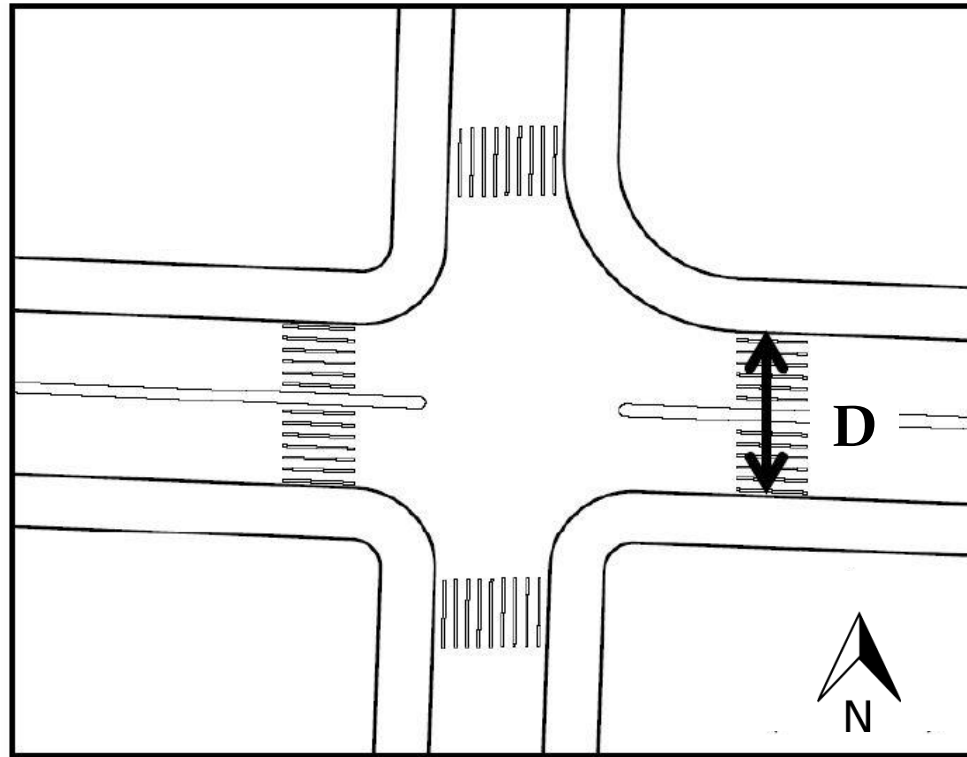
**Figure 8 Intersection of Portage Avenue and Garry Street**



**Figure 9 Intersection of Osborne Street and River Avenue**

### 3.4 PREPARATION FOR DATA COLLECTION

For this research a crossing distance ( $D$ ) was required as illustrated in Figure 10.



**Figure 10 Intersection schematic indicating normal and crossing distance**

The distance ( $D$ ) corresponds to the crossing walking distance. In preparation for the data collection, the crossing distances were measured at the five intersections. The crossing distances of each curb to curb distance, as illustrated in Figure 10, were measured using GIS software. For the four-legged intersections there were four crossing distances measured, whereas for the three-legged intersection there were three crossing distances measured. The crossing distances varied depending on the location from 7.60 m (25 ft) to 33.00 m (108 ft). As previously mentioned, this distance is used to determine the pedestrian crossing speed. The crossing walking speed is the speed at which pedestrians cross the signalized intersection.

### **3.5 DATA COLLECTION PROCESS**

The data collection process required the timing of unaware pedestrians as they traversed the crossing distance ( $D$ ) at each intersection. One data collector (i.e. a person) at each intersection used a stopwatch to time the crossing time of the pedestrians. The crossing time was recorded, keeping track of pedestrian's age (in relation to whether the pedestrian was older or younger), date, weather, temperature, and other information. Appendix A shows the survey form used to record the desired information for data collection.

At crosswalks, pedestrians were timed from the instant they stepped onto the road to the instant they left the road and stepped onto the curb on the other side of the street (i.e., from curb to curb  $D$ ). All pedestrians for which data were collected began walking during the WALK phase of the signal cycle. Considering only pedestrians who started walking during the WALK phase of the signal cycle was important to avoid biases in terms of walking speed. A pedestrian starting their crossing later in the cycle while the numerical countdown is present could influence their crossing speed.

Data collection took place once a week after installation of the PCS device for the first 14 weeks, and every two weeks from Week 14 to Week 22. The data were collected over a 3-hour to 4-hour period in the morning and/or early afternoon. Starting times began at 9:00 AM or 1:00 PM at least until the minimum sample size of younger and older pedestrians was reached. The time frame was chosen to maximize the amount of older pedestrians in the area at the time, and minimize the impact of traffic affecting the study (i.e., cars blocking the crosswalk preventing pedestrians from crossing intersection).

## **4 PEDESTRIAN WALKING SPEED ANALYSIS**

This chapter presents the analysis of pedestrian walking speed for the research. A key element to the analysis is the change in crossing walking speed of pedestrians after the installation of PCS devices; this difference was analyzed for both young and older pedestrians. The analysis compares the data from this research to the normal walking speed determined by Arango's research in Winnipeg (2008). The analysis is divided into six sections: (1) normal walking speed, (2) walking speed of younger pedestrians, (3) walking speed of older pedestrians, (4) comparison of normal and crossing walking speed, (5) statistical significance and OLS regression model, and (6) implications for traffic engineering.

A total of 26,439 pedestrians were timed at the five locations in downtown and central Winnipeg to determine walking speed from Week 1 to Week 22 after of the installation of PCS devices at each location. Of these, 50.2 percent (13,263) were younger pedestrians, and 49.8 percent (13,176) were older pedestrians. A minimum sample size of 60 pedestrians for each age group per week was used to obtain statistically significant data at a 99 percent confidence level, as previously discussed in Section 3.2.

### **4.1 NORMAL WALKING SPEED**

The data of the normal walking speed before PCS devices were installed is from previous research completed by Arango (2008). Younger pedestrians were classified as pedestrians between the age of 20 and 64 years old based on their physical appearance. Older pedestrians were classified as pedestrians 65 years old or older based on their physical appearance. A sample size of 927 was used for normal walking speed of younger pedestrians, and a sample size of 865 was used for normal walking

speed of older pedestrians. Table 3 outlines the average and 15<sup>th</sup> percentile walking speed of both younger and older pedestrians' normal walking speeds. It was found that the average and 15<sup>th</sup> percentile normal walking speed for younger pedestrians were 1.36 m/s and 1.10 m/s, respectively. Older pedestrians' average and 15<sup>th</sup> percentile normal walking speeds were 1.14 m/s and 0.88 m/s, respectively.

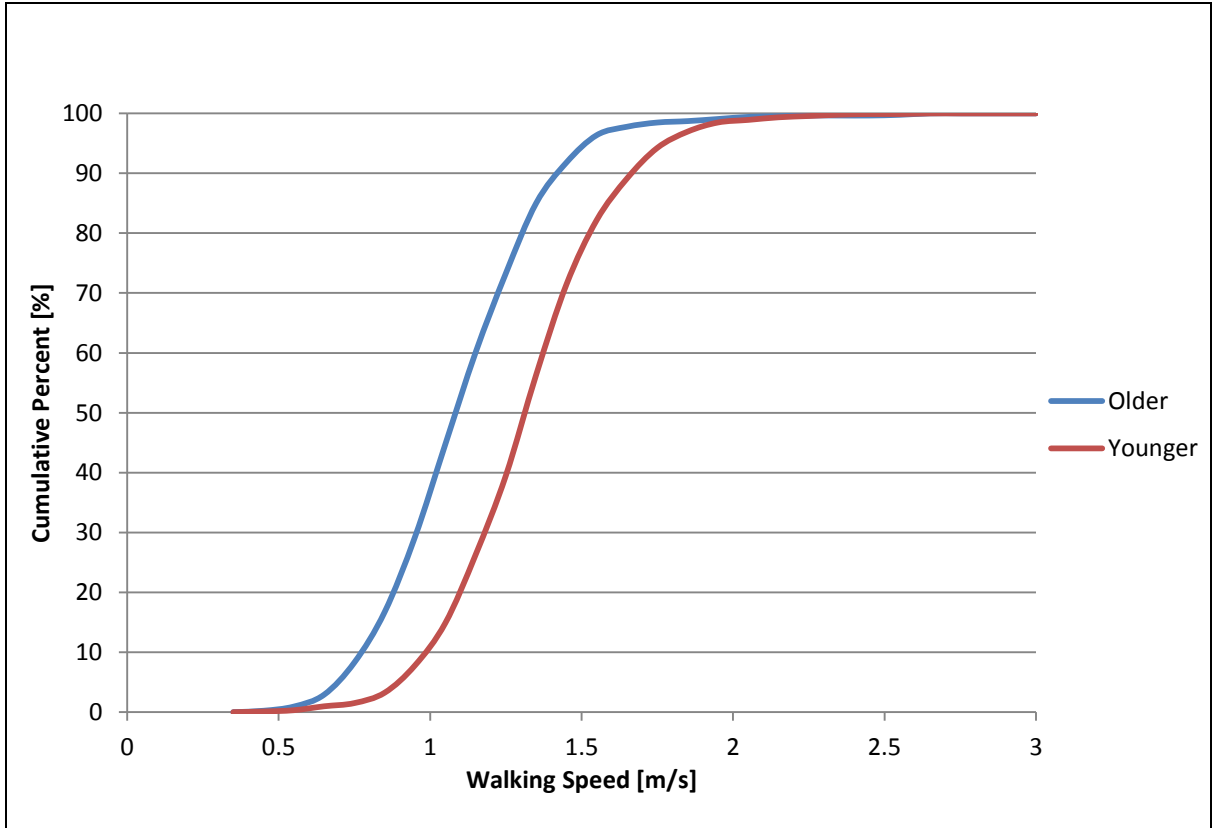
**Table 3 Normal Walking Speed of Pedestrians (Older and Younger) Prior to Installation of PCS Devices**

Description	Number of Records	Average Walking Speed (m/s)	15 <sup>th</sup> Percentile Walking Speed (m/s)
Younger Pedestrians: Normal Walking Speed	927	1.36	1.10
Older Pedestrians: Normal Walking Speed	865	1.14	0.88

Source: Arango 2008

Figure 11 shows the distribution of walking speeds in graphical form. The blue line represents older pedestrians' normal walking speed, and the red line represents younger pedestrians' normal walking speed.

As can be seen in Figure 11, both age groups have a similar distribution shape; however, older pedestrians have a slower normal walking speed than younger pedestrians. This indicates that when pedestrians walk a segment of sidewalk, older pedestrians walk slower than younger pedestrians.



**Figure 11 Normal Walking Speed of Pedestrians (Older and Younger) Prior to Installation of PCS Devices (Arango, 2008)**

#### **4.2 YOUNGER PEDESTRIANS (AGES 20 TO 64 YEARS)**

This section illustrates the effect of PCS devices on younger pedestrians (ages 20 to 64 years) at five signalized intersections in Winnipeg. A sample size of 13,263 younger pedestrians walking speeds was collected for the combined five sites after the installation of PCS devices.

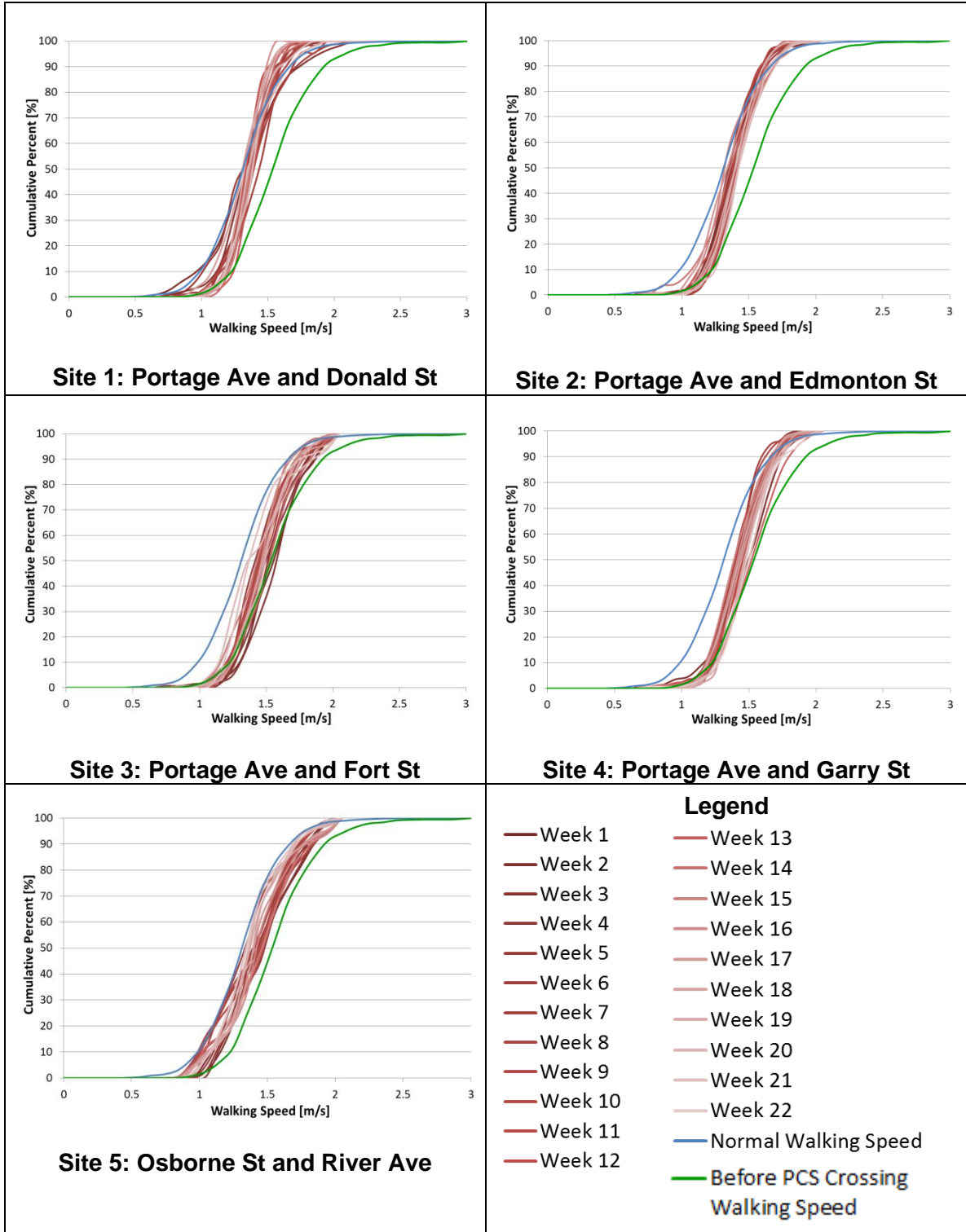
Figure 12 illustrates the cumulative distributions of the crossing walking speed for younger pedestrians' at all five sites. The weeks after the installation of the PCS devices are denoted in red, with the darkest red indicating Week 1 and the lightest red indicating Week 22. The normal walking speed is denoted in blue and the before installation of

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PCS devices crossing walking speed.

In general, a similar pattern is seen for four of the five sites. The crossing walking speed for four sites experienced a shift throughout the weeks towards the normal walking speed in younger pedestrians. In addition, the distribution shapes for the crossing walking speeds were more upright than the normal walking speed for all sites. This indicates more pedestrians were walking at similar speeds when crossing the intersections than when traversing a segment of sidewalk.

Although these two patterns were found for the majority of the five site locations, there were some differences as well. At Site 1 (Portage Avenue and Donald Street) and Site 2 (Portage Avenue and Edmonton Street), the crossing walking speed distributions passed the normal walking speed and reached 100 cumulative percent before the normal walking speed distribution. This was more extreme for Site 1. This indicates that pedestrians were walking slower than their normal walking. Site 3 (Portage Avenue and Fort Street) experienced less of a shift in distribution shape, with the after installation distribution less upright than the other sites. As well, Site 4 (Portage Avenue and Garry Street) did not experience the same degree of shift for the crossing walking speeds towards the normal walking speed. Portage Avenue and Garry Street is located along the same corridor as Site 1 to Site 3; however immediately adjacent to the location are less commercial areas and the location does not have high volume transit stops, therefore, pedestrian generation and numbers of pedestrians were lower. The lower pedestrian generation areas and the lower number of pedestrians could have affected Site 4 and is a possible explanation for the site not experiencing the same degree of shift for crossing walking speed after installation of PCS devices towards the normal walking speed. Finally, the change in distribution shape did not occur as extremely in Site 3 and Site 5, however saw the shift more clearly in the last number of weeks.



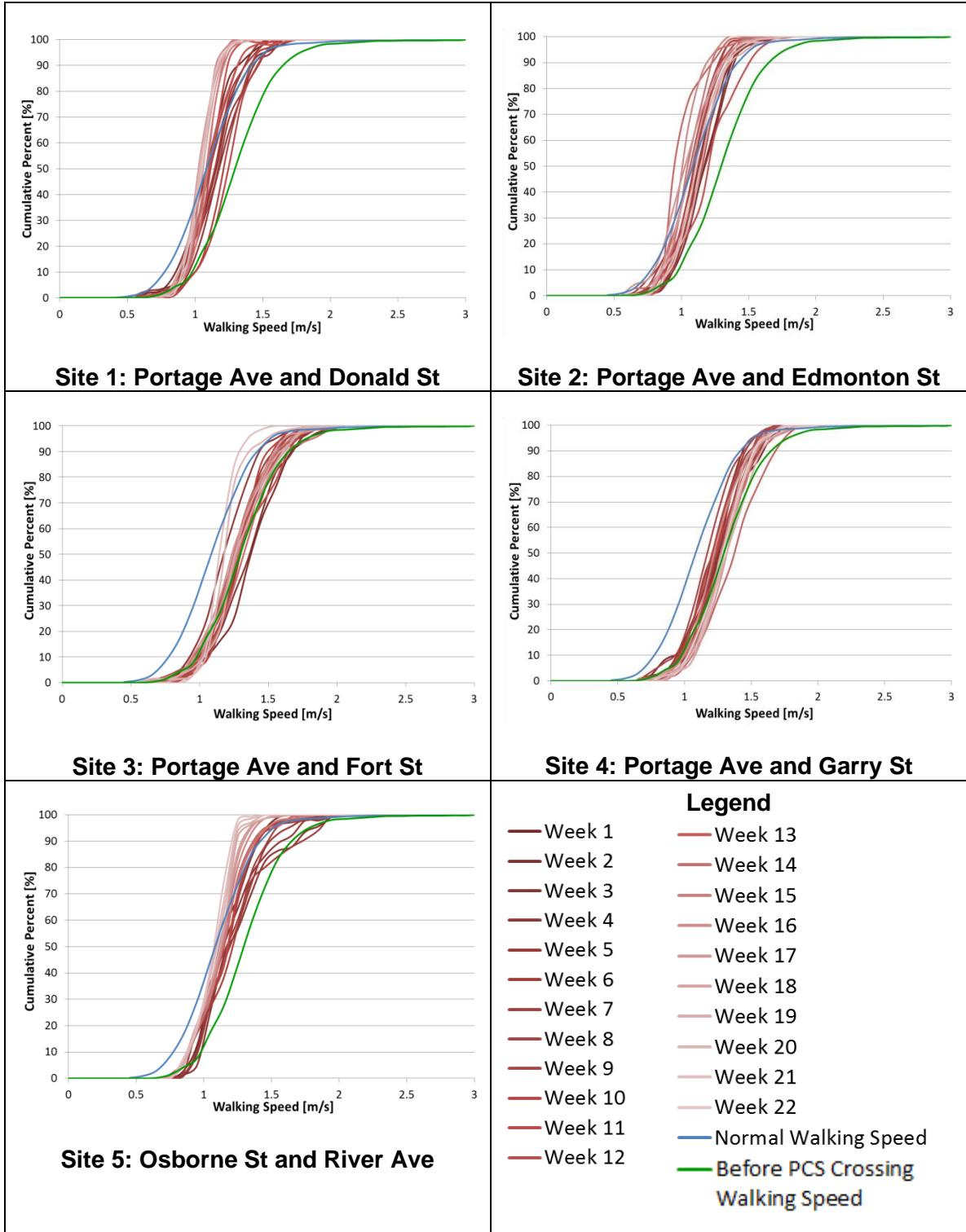
**Figure 12 Walking Speed of Younger Pedestrians Post Installation of PCS Devices**

### **4.3 OLDER PEDESTRIANS (65 YEARS OF AGE AND OLDER)**

This section illustrates the effect of PCS devices on older pedestrians (ages 65 years and older) at five signalized intersections in Winnipeg. A sample of 13,176 older pedestrians crossing walking speeds was collected for the combined five sites after the installation of PCS devices.

Figure 13 illustrates the cumulative distributions of the crossing walking speed for older pedestrians' at all five sites. The weeks after the installation of the PCS devices are denoted in red, with the darkest red indicating Week 1 and the lightest red indicating Week 22. The normal walking speed is denoted in blue and the before installation of PCS devices crossing walking speed.

In general, the sites experienced similar changes for both age groups throughout the 22 week period after the installation of PCS devices at the intersections. Older pedestrians' crossing walking speed shifted towards and past the normal walking speed, and the distribution became more upright in shape. Each site experienced different results with the affect PCS devices had on older pedestrians' crossing walking speed, although there was a general pattern found for the crossing walking speed after the installation of PCS devices compared to the before installation of PCS devices crossing walking speed and normal walking speed.



**Figure 13 Walking Speed of Older Pedestrians Post Installation of PCS Devices**

Although the majority of the sites experienced similar patterns, in regards to the shift of crossing walking speed towards the normal walking speed and the change in shape to be more upright, the sites experienced some differences. Site 1 (Portage Avenue and Donald Street) experienced a clear shift of crossing walking speeds past the normal walking speeds and the most in the later weeks. The distribution for Site 2 (Portage Avenue and Edmonton Street) experienced a higher percentage of pedestrians walking at slower speeds, therefore indicating an earlier shift towards the normal walking speed. Site 3 (Portage Avenue and Fort Street) did not experience the shift in shape towards and past the normal walking speed until the last couple weeks. It was not until Week 18 that the distributions for Site 3 began to show the shift from the crossing walking speed before the installation of PCS devices towards the normal walking speed of older pedestrians. Additionally, the shift in shape didn't become upright until Week 18. Site 3 required more time after the installation of PCS devices for older pedestrians to shift and adapt their walking speed. A possible explanation for the increase in time for the older pedestrians to adapt is the increase in crossing distance for the older pedestrians at this location. This increase in crossing distance could have affected the amount of time for the older pedestrians to adapt to the installation of PCS devices. In addition, Site 4 (Portage Avenue and Garry Street) did not shift past the normal walking speed, and the shift towards the normal walking speed was not as apparent as the other sites. Once again, Site 4 had longer crossing distance (similar to Site 3), therefore the increase in distance could have affected the older pedestrians crossing walking speed. Another explanation for the differences in the cumulative distributions seen at Site 4 is immediately adjacent to the location there are fewer pedestrian generation locations and lower number of pedestrians. Site 4 did not experience the shift in shape to becoming more vertical as the other sites. Finally, Site 5 (Osborne Street and River Avenue)

experienced a very extreme change in shape during the later weeks, well past the normal walking speed, however the first weeks after installation did not experience the same shift.

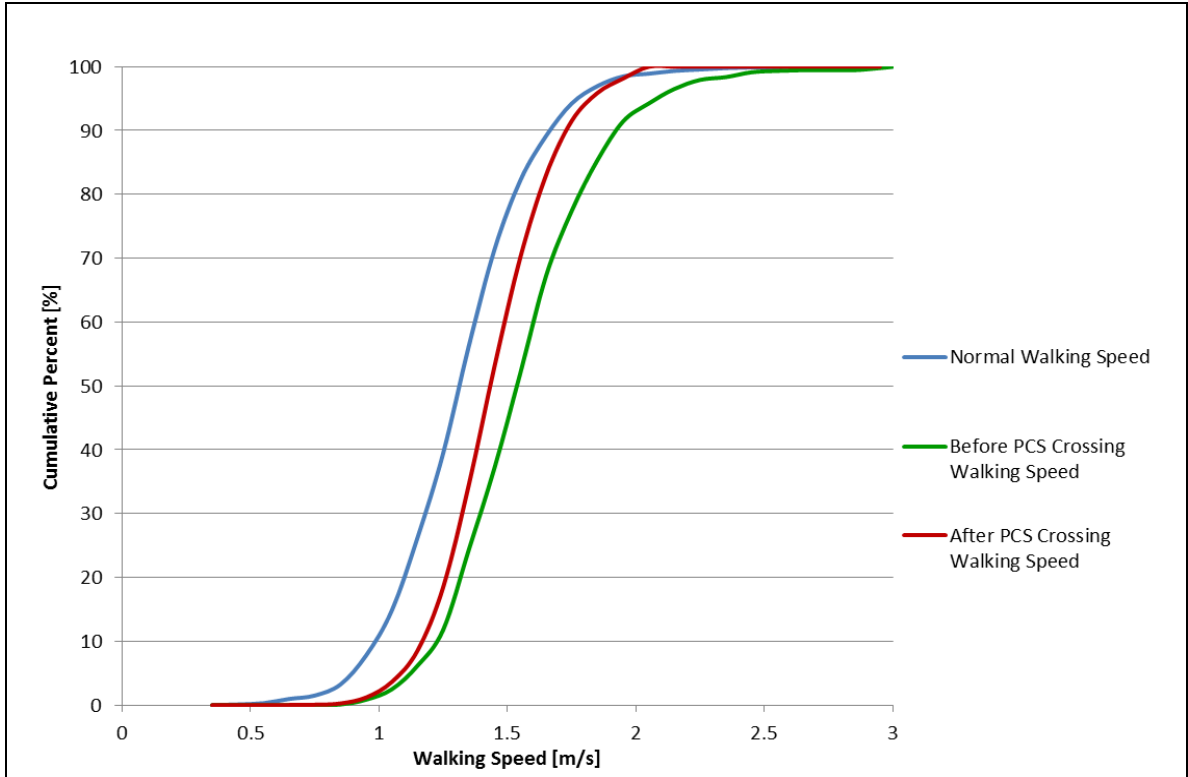
#### **4.4 COMPARISON OF NORMAL AND CROSSING WALKING SPEED**

This section shows the influence of PCS devices on pedestrians' walking speed before and after installation of PCS devices. Three walking speeds are presented in this section: (1) the normal walking speed (Arango, 2008), (2) the before installation of PCS devices crossing walking speed (Arango, 2008), and (3) the combined, after installation of PCS devices, crossing walking speed from all five sites. These three distributions are shown in Figure 14 and Figure 15.

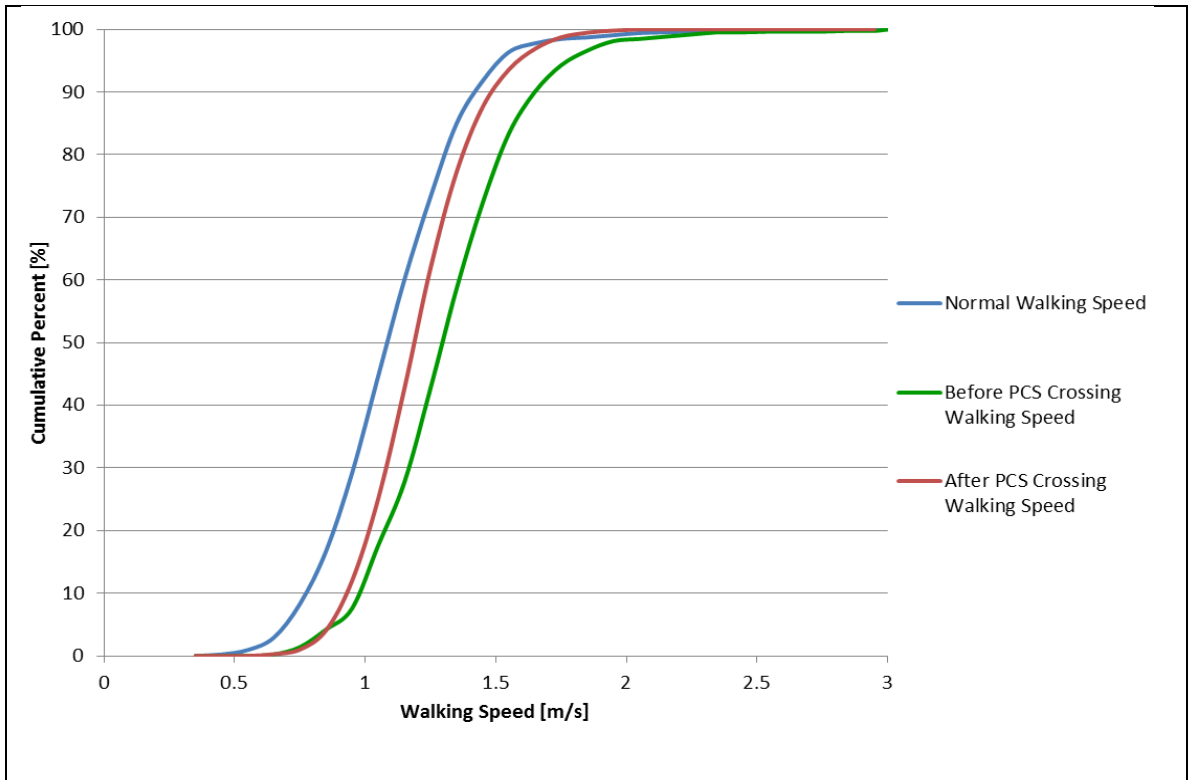
Figure 14 shows the walking speed of younger pedestrians, and Figure 15 shows the walking speed of older pedestrians. The blue line denotes normal walking speed, the green line denotes the crossing walking speed of pedestrians before the installation of PCS devices and the red denotes the crossing walking speed after installation of PCS device. Both figures indicate that after the installation of PCS devices at an intersection, there was a shift in crossing walking speed. The crossing walking speed of pedestrians, regardless of age, shifted closer to the normal walking speed of pedestrians. Figure 15 shows the shift in walking speed was more extreme for older pedestrians. In addition, the shape of the distribution for the crossing walking speed after the installation of PCS devices, for both younger and older pedestrians, was more upright and extreme. This indicates there were more pedestrians in each age group walking at similar speeds after PCS devices are installed.

Table 4 shows the average and 15<sup>th</sup> percentile walking speeds of younger and older

pedestrians. Prior to the installation of PCS devices, the average and 15<sup>th</sup> percentile crossing walking speed for younger pedestrians were 1.61 m/s and 1.33 m/s respectively. At locations with PCS devices installed, the crossing walking speed was found to be 1.43 m/s and 1.21 m/s for the average and 15<sup>th</sup> percentiles. Both the average and 15<sup>th</sup> percentile after installation shifted towards the normal walking speed of 1.36 m/s (average) and 1.10 m/s (15<sup>th</sup> percentile). Older pedestrians' average and 15<sup>th</sup> percentile crossing walking speeds experienced a similar shift towards the normal walking speed. Prior to the installation of PCS devices, older pedestrians' average and 15<sup>th</sup> percentile crossing walking speeds were found to be 1.36 m/s and 1.08 m/s respectively. At locations with PCS devices installed, the crossing walking speed of pedestrians was found to be 1.19 m/s and 0.97 m/s for the average and 15<sup>th</sup> percentile respectively. Both the average and 15<sup>th</sup> percentile after installation shifted towards the normal walking speed of 1.14 m/s and 0.88 m/s for older pedestrians.



**Figure 14 Younger Pedestrians Normal and Crossing Walking Speed**



**Figure 15 Older Pedestrians Normal and Crossing Walking Speed**

**Table 4 Average and 15<sup>th</sup> Percentile Normal and Crossing Walking Speeds**

<b>Description</b>	<b>Number of Records</b>	<b>Average Walking Speed [m/s]</b>	<b>15<sup>th</sup> Percentile Walking Speed [m/s]</b>
<i>Younger Pedestrians (Ages 20 to 64 years)</i>			
Normal Walking Speed	927	1.36	1.10
Before Installation Crossing Walking Speed	927	1.61	1.33
After Installation Crossing Walking Speed	13,263	1.43	1.21
<i>Older Pedestrians (Ages 65 year and over)</i>			
Normal Walking Speed	865	1.14	0.88
Before Installation Crossing Walking Speed	865	1.36	1.08
After Installation Crossing Walking Speed	13,176	1.19	0.97

## **4.5 STATISTICAL SIGNIFICANCE AND OLS REGRESSION ANALYSIS**

### **4.5.1 Analysis of Variance**

A one-way Analysis of Variance (ANOVA) was conducted to determine if there were differences between the mean normal walking speed, mean crossing walking speed before PCS devices were installed and mean crossing walking speed after PCS devices were installed. This was done for three groups: (1) all observations grouped together (i.e. younger and older pedestrian), (2) younger pedestrians; and (3) older pedestrians.

The ANOVA for all observations resulted in an F-value of 342.15, which indicates that there is a statistically significant difference between the three groups at a 99.99 percent confidence level ( $p < 0.001$ ). However, an ANOVA does not tell which groups are different. The Holm-Sidak test was used to determine where the statistical differences lie. The results show that the crossing walking speeds before the PCS devices were

installed were 0.228 m/s higher than the normal walking speed. The results also indicate that crossing walking speeds became closer to the normal walking speed after PCS devices were installed, with a difference of 0.116 m/s. There was a statistically significant difference between crossing walking speeds before and after installation, with speeds being 0.112 m/s lower after installation.

The ANOVA for younger pedestrians resulted in an F-value of 247.47, which indicates that there is a statistically significant difference between the three groups at a 99.99 percent confidence level ( $p < 0.001$ ). Again, the Holm-Sidak test was used to determine where the statistical differences lie. The results show that the crossing walking speeds before the PCS devices were installed were 0.241 m/s higher than the normal walking speed. The results also indicated that crossing walking speeds became closer to the normal walking speed after PCS devices were installed, with a difference of 0.129 m/s. There was a statistically significant difference between crossing walking speeds before and after installation, with speeds being 0.112 m/s lower after installation.

The ANOVA for older pedestrians resulted in an F-value of 189.70, which indicates that there is a statistically significant difference between the three groups at a 99.99 percent confidence level ( $p < 0.001$ ). Again, the Holm-Sidak test was used to determine where the statistical differences lie. The results show that the crossing walking speeds before the PCS devices were installed were 0.214 m/s higher than the normal walking speed. The results also indicated that crossing walking speeds became closer to the normal walking speed after PCS devices were installed, with a difference of 0.108 m/s. There was a statistically significant difference between crossing walking speeds before and after installation, with speeds being 0.105 m/s lower after installation.

The results of the ANOVA and Holm-Sidak test indicate that crossing walking speeds for

all study groups, both younger and older pedestrians, decreased after the installation of PCS devices and were closer to the normal walking speed. All of these differences were statistically significant at the 99.99 percent confidence level ( $p < 0.0001$ ).

#### 4.5.2 Ordinary Least Square (OLS) Analysis

Ordinary least square (OLS) linear regression was used to estimate a model to predict pedestrian crossing speeds. OLS regression has the benefits that it is robust, efficient, and simple to estimate. The general functional form used to estimate pedestrian crossing speeds is:

$$V_{x\text{-ing}} = \alpha + \beta X_i + \varepsilon_i$$

where,

$V_{x\text{-ing}}$  = Crossing speed

$X_i$  = vector of exogenous variables influencing crossing speed

$\alpha, \beta$  = vectors of coefficients to be estimated

$\varepsilon_i$  = disturbance (error) terms.

The model estimated is shown below in Table 5. An iterative process was used to determine the independent variables that should be included in the model to predict pedestrian crossing speeds. The variables in the model were chosen based on their statistical significance, coefficient of the variables (i.e. whether or not the coefficient has practical significance), and the change in the predictive power of the model (i.e. RMSE). The model was estimated by adding additional variables to the model and then estimating the model again. If the variable was statistically insignificant, the coefficient had no practical significance, or the RMSE of the model increased, the variable was

removed from the model and another variable was added. This iterative process continued until the predictive power of the model did not improve. All of the variables shown in the model are highly significant, with p-values less than 0.05. How well the model fit the data was based on the coefficient of determination (Adj.  $R^2$ ), with a value closer to one having more predictive power. The adjusted  $R^2$  is relatively low since pedestrians walk at a variety of speeds. Once the model was determined, the residuals were plotted against the different variables to determine if there were any patterns in the residuals. These plots showed there were no obvious patterns; therefore, it was concluded that there was not heteroskedasticity in the model.

**Table 5 Ordinary Least Squares Regression Analysis**

<i>Pedestrian Crossing Walking Speed (m/s)</i>				
<b>Variable</b>	<b>Coefficient</b>	<b>SE</b>	<b>Z-Static</b>	<b>P-value</b>
Gender (1 if female, 0 otherwise)	-0.0619	0.003	-22.99	<0.0001
Senior (1 if senior, 0 otherwise)	-0.2450	0.003	-90.95	<0.0001
Crossing Distance	0.0022	0.0002	11.65	<0.0001
PCS Device (1 if PCS, 0 otherwise)	-0.1191	0.0065	-21.54	<0.0001
Constant	1.6014	0.0065	246.30	<0.0001
Number of observations = 28231				
$R^2 = 0.2470$				
Adjusted $R^2 = 0.2469$				
Root MSE = 0.22567				

As shown in Table 5, the coefficient was negative for the following variables: female, senior, and PCS. A negative value indicates that pedestrian crossing walking speeds decrease if these binary variables are equal to 1. In this case, crossing walking speeds are predicted to be lower for females, seniors, or if there is a PCS device present. The

coefficient was positive for the crossing distance, which indicates that crossing walking speeds increase as the crossing distance increases.

The female variable indicates that crossing walking speeds were lower by 0.062 m/s if the pedestrian was female, holding all other variables constant. This was expected since females generally have a little slower walking speed (Arango, 2008).

The senior variable indicates that crossing walking speeds were lower by 0.245 m/s if the pedestrian was a senior or older pedestrian, holding all other variables constant. This was expected since seniors typically have a slower walking speed compared to the younger population (Arango, 2008).

The pedestrian countdown signal (PCS) variable indicates that crossing walking speeds were lower by 0.119 m/s if a PCS was installed at the intersection. This agrees with this research that has shown pedestrians cross at a lower speed that is closer to their normal speed if a PCS device is present.

The crossing distance variable indicates that crossing walking speeds increased by 0.002 m/s for each additional meter of crossing distance, holding all other variables constant. This corresponds with engineering judgment that indicates pedestrians will walk faster if they have a farther distance to cross.

#### **4.6 IMPLICATIONS FOR TRAFFIC ENGINEERING AND POLICY**

In Canada it was common practice to use a walking speed of 1.2 m/s (4.0 ft/s) when designing for pedestrians. In 2013, a Final Report was released by Montufar et al. recommending the Canadian MUTCD to include a section on pedestrian walking speed. The next update for the Canadian MUTCD in 2015 will include the range of 0.8 m/s to

1.0 m/s for a pedestrian's walking speed (Montufar et al., 2013). Previous studies have indicated that 1.2 m/s is not sufficient for the slower pedestrians, especially older pedestrians and pedestrians using mobility devices (Arango 2008). In 2009, the U.S. MUTCD updated the walking speed used for design to be 0.91 m/s, to provide more inclusive service for pedestrians (FHWA, 2009). This change prompted a Canadian study to look at the need for a change in walking speed for the design of traffic engineering inputs.

This research has found with the installation of PCS devices, the crossing walking speed of pedestrians is expected to decrease and become closer to the pedestrians normal walking speed. This decrease in walking speed allows for a more inclusive design for pedestrians.

The change in walking speed in North America and the effect of PCS devices on pedestrian walking speed has the potential to influence the capacity of the intersection and the level of service (LOS) of the intersection. With the installation of PCS devices, the crossing walking speeds of both age groups were found to decrease. The decrease in walking speed means pedestrians are in the pedestrian crossing for an extended period of time and prevents the movement of other modes of transport such as turning vehicles. Although the installation of PCS devices and a lower walking speed could have an impact on the capacity and LOS of the intersection, previous research on a lower walking speed indicates negative impacts are not seen at locations with 90 sec or great cycle length for the signals, crossing distances that are not overly wide, or locations that have not reached capacity yet. In addition, locations with narrow intersections or low demand for pedestrians would not be affected by pedestrians walking slower. Capacity and LOS issues could arise at locations where capacity has been reached or surpassed without changing the cycle length of the traffic signals. Additionally, corridor movement

could be negatively influenced in areas with high pedestrian volumes and low vehicular volumes (Montufar et al., 2013). Although there are possible negative effects on capacity and LOS, it is important as transportation engineers to remember that the profession focuses on the movement of people and not just vehicular traffic. The installation of PCS devices have been found to have a positive effect on a wide variety of pedestrians, therefore while there is the potential for negative implications it promotes equity in the transportation network especially for older pedestrians, children and pedestrians using mobility assisting devices.

This research has indicated that PCS devices have an influence on different groups of pedestrians. Older pedestrians were affected more significantly than younger pedestrians, with older pedestrians slowing their crossing walking speed more and allowing them to walk closer to their normal walking speed. The knowledge gained from this research has the potential to influence where PCS devices should be implemented. Older pedestrians are able to walk closer to their normal walking speed, and feel more comfortable and safer at locations with PCS devices. Therefore, locations with a high number of older pedestrians could benefit immensely from the installation of PCS devices. In addition, PCS devices have the potential to affect the walking speed of other pedestrian groups such as children and people using mobility assistive devices. This research and further research studying the effect of PCS devices on the walking speed of pedestrian groups could help to provide suggested locations for where PCS devices will have the greatest positive impact and assist jurisdictions deciding where to install PCS devices.

It is essential as transportation engineers to provide service for varied populations, such as different age groups and levels of mobility. As the age of a pedestrian increased the crossing walking speed of the pedestrian decreased. With the aging population there will

be a larger number of pedestrians walking slower or with mobility disabilities. It is important for transportation and traffic engineers to provide facilities that supply safe and equitable services for a wide variety of the population. This research indicates that with the inclusion of PCS devices at signalized intersections the information provided to the pedestrian improves, and allows for a more informed decision to cross signalized intersections. Intersections with PCS devices provide information that enables pedestrians to better decide if they will have adequate time to cross the intersection, and allows them to alter their speed during the crossing accordingly.

## **5 CONCLUSION**

This chapter discusses research findings and conclusions drawn from this study.

The purpose of this research was to examine the effect of PCS devices on the crossing walking speed of pedestrians as a function of age. This research focused on the crossing walking speed, defined as the speed at which pedestrians walk when crossing a signalized intersection. The effect of PCS devices was found by comparing the normal walking speed and crossing walking speed before installation of PCS devices to the crossing walking speed over a period of 22 weeks after the installation of PCS devices. The research considered two study groups: (1) younger pedestrians (ages 20-64); and (2) older pedestrians (ages 65 and older). The findings are discussed in more detail in the subsequent sections.

The following conclusions were drawn from the research:

### **5.1 LITERATURE REVIEW**

A literature review looking at walking speed and PCS devices was conducted. The literature review found the following:

- North America's population is rapidly aging.
- The population in Canada has become more dominantly women from 2006 to 2011, since women have a longer life expectancy than men.
- A major pedestrian walking speed study was conducted in Winnipeg, MB comparing the normal walking speed to crossing walking speed.

- The literature indicates that the average walking speed of pedestrian ranges from 0.90 m/s to 1.51 m/s, and the 15<sup>th</sup> percentile walking speed ranges from 0.84 m/s to 1.25 m/s.
- Studies found that older pedestrians walk slower than younger pedestrians, and women walk slower than male pedestrians.
- The literature indicates that the PCS's increase the feeling of safety of pedestrians.
- Few studies were found on the effect of PCS installation on walking speed of pedestrians.
- Human factors such as personality and pedestrian's perception of safety may affect their intersection behavior.

## **5.2 EFFECT OF PEDESTRIAN COUNTDOWN SIGNALS ON WALKING SPEED**

This research analyzed pedestrian walking speed at signalized intersections. Data were collected after the installation PCS devices from Week 1 to Week 22. A total of 26,439 older and younger pedestrian speeds were collected to understand the effect of PCS devices on a pedestrian's crossing walking speed. After installation data were compared to the data collected by Arango's, which determined the normal and crossing walking speed of pedestrians on a segment of sidewalk and at signalized intersections without PCS devices installed respectively (2008). The following conclusions were drawn from the research:

- Older pedestrians walk slower than younger pedestrians regardless of whether a PCS device is present. This is consistent with findings by Arango (2008).

- After the installation of PCS devices, younger and older pedestrians slow their crossing walking speed. Both age groups were found to clearly shift their crossing walking speed towards their normal walking speed for four of the five sites. Additionally, both age groups had the distribution shape become more upright at varying degrees.
- The installation of PCS devices decreases the younger pedestrian's average crossing walking speed from 1.61 m/s before installation, to as low as 1.27 m/s after installation, whereas the 15<sup>th</sup> percentile decreased from 1.33 m/s to as low as 1.05 m/s.
- The average and 15<sup>th</sup> percentile of younger pedestrians at all sites after installation were 1.43 m/s and 1.21 m/s respectively.
- The installation of PCS devices decreases the older pedestrian's average crossing walking speed from 1.36 m/s before installation, to as low as 1.03 m/s after installation, whereas the 15<sup>th</sup> percentile decreased from 1.08 m/s to as low as 0.84 m/s.
- The average and 15<sup>th</sup> percentile of older pedestrians at all sites after installation were 1.19 m/s and 0.97 m/s respectively.
- The installation of PCS devices affects the crossing walking speed of pedestrians, by allowing pedestrians to slow their crossing walking speed. The installation of PCS devices allowed pedestrians to walk at a speed closer to their normal walking speed when crossing a signalized intersection.
- The crossing walking speed of older pedestrians is more significantly affected by the installation of PCS devices. Older pedestrians slowed their speed more extremely looking at the disaggregated and aggregated data.

- After installation, both the younger and older pedestrian's crossing walking speed shifts closer to the normal walking speed of pedestrians.
- The ANOVA and OLS regression analysis indicate the crossing walking speeds statistically decrease by approximately 0.11 m/s for both younger and older pedestrians, after the installation of PCS devices.

PCS devices provide the users of the system with more information for a more informed decision when crossing at a signalized intersection. This research provides information on the effect of PCS devices on pedestrians' crossing walking speed, filling a gap in the previous research done on PCS devices. The increase in information provided to the pedestrians allows for pedestrians to select a crossing speed which is closer to the normal walking speed; therefore, indicating that pedestrians feel more comfortable with their crossing. These findings could be used to improve the accommodation of all age and mobility sections of the population, through the implementation of PCS devices at a signalized intersection. Although these findings work towards filling a gap in PCS research, there are limitations to the research to be considered. As previously mentioned situations such as pedestrians running or walking with mobility assistive devices were excluded from the research to ensure a consistent data collection, however, this could be seen as a limitation. In addition, four of the five sites were located along the same corridor (Portage Avenue) and all five sites were in similar urban environments. The effect of PCS devices on pedestrian walking speed was studied in an urban, core context; therefore, the effect on a suburban context was not studied. The information gathered from this research could be used to improve urban planning, signal timing, and other transportation engineering applications. Improving the transportation system with the implementation of new devices and knowledge could result in a better and safer quality of life for the population as a whole.

### 5.3 RECOMMENDATIONS FOR FURTHER RESEARCH

This research has resulted in recommendations for continued research:

- Research the effect of PCS devices on children and teenager's understanding and crossing walking speed. This research was limited to 20 years of age and older; however, the effect on people under 20 years of age could be different. Depending on the location of the signalized intersection, this influence may be important for traffic engineers and impact children's crossing safety.
- Research the effect of PCS devices on vehicular movements, such as using the countdown to time whether the vehicle can "beat the light". This has the potential to increase vehicular crashes or vehicular-pedestrian crashes at the location.
- Research the effect of different countdown signal timing and housing configurations on the crossing walking speed of pedestrians.
- Research the effect of PCS devices on pedestrians in different land-uses and areas such as the suburbs.
- Research the effect of PCS devices on pedestrian walking speeds when pedestrians begin their crossing during the "Flashing Don't Walk" and countdown stage.
- Research the effect of PCS devices on pedestrian crossing walking speed including runners and pedestrians who change their walking speed during the crossing.

- Research the effect of PCS devices on people using mobility devices. It is known that people with disabilities that require the use of mobility devices walk at a slower speed. Researching the effect of PCS devices on people requiring mobility devices could aid traffic engineers in accommodating people with disabilities or seniors in target areas such as around hospitals, clinics and assisted living residences.

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**APPENDIX A**

**PEDESTRIAN WALKING SPEED DATA COLLECTION FORM**

**PEDESTRIAN WALKING SPEED SURVEY**

<b>DATE</b>	<b>TIME PERIOD</b>	
<b>LOCATION</b>		
<b>WEATHER CONDITIONS</b>	<b>TEMPERATURE</b>	

**OTHER COMMENTS:**

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<b>Ped #</b>	<b>Gender</b>	<b>Crossing Time</b>	<b>Senior? ≥ 65</b>	<b>Cross-walk Crossed</b>	<b>Special Comments</b>
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					

## **APPENDIX B**

### **AVERAGE AND 15<sup>TH</sup> PERCENTILE WALKING SPEED YOUNGER AND OLDER PEDESTRIANS**

**Table 6 Walking Speed of Younger Pedestrians: Portage Ave and Donald St**

<b>Description</b>	<b>Number of Records</b>	<b>Average Walking Speed (m/s)</b>	<b>15<sup>th</sup> Percentile Walking Speed (m/s)</b>
<i>Prior of Installation of PCS Devices</i>			
Normal Walking Speed	927	1.36	1.10
<i>After Installation of PCS Devices</i>			
Week 1	116	1.31	1.06
Week 2	116	1.34	1.16
Week 3	102	1.37	1.16
Week 4	120	1.31	1.07
Week 5	109	1.43	1.22
Week 6	112	1.38	1.18
Week 7	107	1.40	1.21
Week 8	106	1.32	1.17
Week 9	110	1.39	1.21
Week 10	110	1.34	1.20
Week 11	105	1.39	1.26
Week 12	104	1.38	1.23
Week 13	103	1.37	1.24
Week 14	101	1.35	1.21
Week 16	117	1.31	1.12
Week 18	103	1.33	1.19
Week 20	102	1.34	1.21
Week 22	104	1.38	1.21

**Table 7 Walking Speed of Younger Pedestrians: Portage Ave and Edmonton St**

<b>Description</b>	<b>Number of Records</b>	<b>Average Walking Speed (m/s)</b>	<b>15<sup>th</sup> Percentile Walking Speed (m/s)</b>
<i>Prior of Installation of PCS Devices</i>			
Normal Walking Speed	927	1.36	1.10
<i>After Installation of PCS Devices</i>			
Week 1	140	1.37	1.19
Week 2	140	1.35	1.18
Week 3	140	1.38	1.21
Week 4	140	1.40	1.20
Week 5	140	1.39	1.21
Week 6	140	1.40	1.26
Week 7	140	1.36	1.21
Week 8	140	1.41	1.22
Week 9	140	1.39	1.22
Week 10	140	1.42	1.25
Week 11	140	1.40	1.18
Week 12	140	1.27	1.07
Week 13	140	1.36	1.13
Week 14	140	1.32	1.16
Week 15	140	1.34	1.14
Week 17	140	1.40	1.20
Week 18	140	1.42	1.22
Week 20	140	1.40	1.23
Week 22	140	1.43	1.28

**Table 8 Walking Speed of Younger Pedestrians: Portage Ave and Fort St**

<b>Description</b>	<b>Number of Records</b>	<b>Average Walking Speed (m/s)</b>	<b>15<sup>th</sup> Percentile Walking Speed (m/s)</b>
<i>Prior of Installation of PCS Devices</i>			
Normal Walking Speed	927	1.36	1.10
<i>After Installation of PCS Devices</i>			
Week 1	140	1.55	1.34
Week 2	140	1.58	1.35
Week 3	142	1.51	1.30
Week 4	140	1.50	1.30
Week 5	140	1.42	1.25
Week 6	140	1.46	1.25
Week 7	140	1.47	1.27
Week 8	140	1.44	1.25
Week 9	140	1.45	1.27
Week 10	140	1.45	1.25
Week 11	140	1.48	1.27
Week 12	140	1.46	1.26
Week 13	140	1.52	1.28
Week 14	140	1.43	1.19
Week 15	140	1.46	1.27
Week 16	140	1.48	1.26
Week 17	140	1.47	1.28
Week 18	140	1.49	1.27
Week 20	140	1.35	1.17
Week 22	140	1.37	1.21

**Table 9 Walking Speed of Younger Pedestrians: Portage Ave and Garry St**

<b>Description</b>	<b>Number of Records</b>	<b>Average Walking Speed (m/s)</b>	<b>15<sup>th</sup> Percentile Walking Speed (m/s)</b>
<i>Prior of Installation of PCS Devices</i>			
Normal Walking Speed	927	1.36	1.10
<i>After Installation of PCS Devices</i>			
Week 1	86	1.50	1.25
Week 2	140	1.44	1.27
Week 3	140	1.46	1.23
Week 4	140	1.42	1.21
Week 5	140	1.43	1.25
Week 6	140	1.41	1.23
Week 7	140	1.43	1.26
Week 8	140	1.40	1.22
Week 9	140	1.40	1.26
Week 10	140	1.46	1.23
Week 11	140	1.46	1.24
Week 12	140	1.47	1.26
Week 13	140	1.52	1.31
Week 14	140	1.42	1.25
Week 15	140	1.39	1.21
Week 16	140	1.41	1.23
Week 17	140	1.44	1.29
Week 18	140	1.43	1.23
Week 19	140	1.48	1.31
Week 20	140	1.47	1.29
Week 22	100	1.50	1.29

**Table 10 Walking Speed of Younger Pedestrians: Osborne St and River Ave**

<b>Description</b>	<b>Number of Records</b>	<b>Average Walking Speed (m/s)</b>	<b>15<sup>th</sup> Percentile Walking Speed (m/s)</b>
<i>Prior of Installation of PCS Devices</i>			
Normal Walking Speed	927	1.36	1.10
<i>After Installation of PCS Devices</i>			
Week 1	104	1.43	1.14
Week 2	104	1.48	1.20
Week 3	140	1.48	1.18
Week 4	140	1.46	1.17
Week 5	140	1.39	1.14
Week 6	140	1.34	1.08
Week 7	140	1.42	1.06
Week 8	140	1.40	1.05
Week 9	140	1.40	1.04
Week 10	140	1.45	1.06
Week 11	140	1.44	1.05
Week 12	140	1.47	1.12
Week 13	140	1.46	1.12
Week 14	140	1.46	1.12
Week 15	140	1.46	1.14
Week 16	140	1.42	1.15
Week 17	140	1.40	1.16
Week 18	140	1.40	1.16
Week 19	140	1.37	1.17
Week 20	140	1.36	1.15
Week 21	140	1.35	1.13
Week 22	140	1.34	1.12

**Table 11 Walking Speed of Older Pedestrians: Portage Ave and Donald St**

<b>Description</b>	<b>Number of Records</b>	<b>Average Walking Speed (m/s)</b>	<b>15<sup>th</sup> Percentile Walking Speed (m/s)</b>
<i>Prior of Installation of PCS Devices</i>			
Normal Walking Speed	865	1.14	0.88
<i>After Installation of PCS Devices</i>			
Week 1	107	1.04	0.89
Week 2	117	1.16	0.93
Week 3	106	1.18	0.99
Week 4	110	1.11	0.93
Week 5	104	1.17	0.97
Week 6	102	1.15	0.94
Week 7	101	1.21	1.05
Week 8	100	1.25	1.06
Week 9	100	1.12	0.96
Week 10	100	1.20	0.95
Week 11	100	1.10	0.96
Week 12	102	1.08	0.96
Week 13	102	1.09	0.97
Week 14	104	1.06	0.95
Week 16	100	1.03	0.90
Week 18	101	1.05	0.90
Week 20	101	1.04	0.95
Week 22	104	1.05	0.92

**Table 12 Walking Speed of Older Pedestrians: Portage Ave and Edmonton St**

<b>Description</b>	<b>Number of Records</b>	<b>Average Walking Speed (m/s)</b>	<b>15<sup>th</sup> Percentile Walking Speed (m/s)</b>
<i>Prior of Installation of PCS Devices</i>			
Normal Walking Speed	865	1.14	0.88
<i>After Installation of PCS Devices</i>			
Week 1	140	1.17	0.98
Week 2	140	1.13	0.95
Week 3	140	1.17	0.97
Week 4	140	1.13	0.95
Week 5	140	1.13	0.97
Week 6	140	1.09	0.92
Week 7	140	1.08	0.87
Week 8	140	1.07	0.87
Week 9	140	1.10	0.92
Week 10	140	1.15	0.92
Week 11	140	1.20	0.94
Week 12	140	0.95	0.87
Week 13	140	1.05	0.89
Week 14	140	1.01	0.87
Week 15	140	1.03	0.84
Week 17	140	1.07	0.89
Week 18	140	1.14	0.93
Week 20	140	1.11	0.94
Week 22	140	1.11	0.96

**Table 13 Walking Speed of Older Pedestrians: Portage Ave and Fort St**

<b>Description</b>	<b>Number of Records</b>	<b>Average Walking Speed (m/s)</b>	<b>15<sup>th</sup> Percentile Walking Speed (m/s)</b>
<i>Prior of Installation of PCS Devices</i>			
Normal Walking Speed	865	1.14	0.88
<i>After Installation of PCS Devices</i>			
Week 1	140	1.37	1.12
Week 2	140	1.36	1.10
Week 3	139	1.18	0.97
Week 4	140	1.30	1.03
Week 5	140	1.26	1.04
Week 6	140	1.27	1.06
Week 7	124	1.29	1.06
Week 8	140	1.26	1.07
Week 9	140	1.29	1.10
Week 10	134	1.27	1.06
Week 11	137	1.29	1.07
Week 12	140	1.29	1.02
Week 13	139	1.32	1.08
Week 14	140	1.25	1.01
Week 15	140	1.28	1.04
Week 16	140	1.24	1.00
Week 17	140	1.26	1.03
Week 18	140	1.26	1.09
Week 20	140	1.19	1.07
Week 22	140	1.14	1.05

**Table 14 Walking Speed of Older Pedestrians: Portage Ave and Garry St**

<b>Description</b>	<b>Number of Records</b>	<b>Average Walking Speed (m/s)</b>	<b>15<sup>th</sup> Percentile Walking Speed (m/s)</b>
<i>Prior of Installation of PCS Devices</i>			
Normal Walking Speed	865	1.14	0.88
<i>After Installation of PCS Devices</i>			
Week 1	86	1.26	1.15
Week 2	140	1.25	1.04
Week 3	140	1.21	0.99
Week 4	140	1.26	1.06
Week 5	140	1.25	1.03
Week 6	140	1.28	1.00
Week 7	140	1.22	1.00
Week 8	140	1.17	0.98
Week 9	140	1.24	1.04
Week 10	140	1.24	1.06
Week 11	140	1.21	1.01
Week 12	140	1.29	1.03
Week 13	140	1.37	1.11
Week 14	140	1.28	1.06
Week 15	140	1.28	1.08
Week 16	140	1.22	1.04
Week 17	140	1.32	1.11
Week 18	140	1.28	1.07
Week 19	140	1.28	1.07
Week 20	140	1.32	1.10
Week 22	100	1.30	1.09

**Table 15 Walking Speed of Older Pedestrians: Osborne St and River Ave**

<b>Description</b>	<b>Number of Records</b>	<b>Average Walking Speed (m/s)</b>	<b>15<sup>th</sup> Percentile Walking Speed (m/s)</b>
<i>Prior of Installation of PCS Devices</i>			
Normal Walking Speed	865	1.14	0.88
<i>After Installation of PCS Devices</i>			
Week 1	104	1.12	0.96
Week 2	104	1.12	0.97
Week 3	140	1.19	1.00
Week 4	140	1.15	0.97
Week 5	140	1.19	0.98
Week 6	140	1.17	0.92
Week 7	140	1.21	0.93
Week 8	140	1.18	0.92
Week 9	140	1.17	0.92
Week 10	140	1.17	0.93
Week 11	140	1.17	0.93
Week 12	140	1.15	0.91
Week 13	140	1.14	0.91
Week 14	140	1.14	0.91
Week 15	140	1.14	0.92
Week 16	140	1.13	0.91
Week 17	140	1.12	0.91
Week 18	140	1.11	0.91
Week 19	140	1.11	0.92
Week 20	140	1.09	0.92
Week 21	140	1.09	0.92
Week 22	140	1.07	0.91

## **APPENDIX C**

### **STATISTICAL ANALYSIS REPORTS ORDINARY LEAST SQUARES REGRESSION MODEL**

**Ordinary Least Squares Regression Model (OLS Model)**

Source	SS	df	MS
Model	471.313378	4	117.828344
Residual	1437.02915	28227	0.050925974
<b>Total</b>	<b>1908.34252</b>	<b>28231</b>	<b>0.067618968</b>

**Number of observations** = 28296  
**F( 4, 28227)** = 2313.72  
**Prob > F** = 0.0000

<i>Pedestrian Crossing Walking Speed (m/s)</i>				
Variable	Coefficient	SE	Z-Static	P-value
Gender (1 if female, 0 otherwise)	-0.0619	0.003	-22.99	<0.0001
Senior (1 if senior, 0 otherwise)	-0.2450	0.003	-90.95	<0.0001
Crossing Distance	0.0022	0.0002	11.65	<0.0001
PCS Device (1 if PCS, 0 otherwise)	-0.1191	0.0065	-21.54	<0.0001
Constant	1.6014	0.0065	246.30	<0.0001
Number of observations = 28231				
R <sup>2</sup> = 0.2470				
Adjusted R <sup>2</sup> = 0.2469				
Root MSE= 0.22567				

**APPENDIX D**

**STATISTICAL ANALYSIS REPORTS  
OLDER AND YOUNGER PEDESTRIANS**

**One Way Analysis of Variance  
Pedestrian Crossing Walking Speed**

**All Observations (Younger and Older Pedestrians)**

**ANOVA Test: All observations**

Source	SS	df	MS	F	Prob >F
Between Groups	46.5338785	2	23.2669392	342.15	0.000
Within groups	2040.86237	30021	0.068001545		
<b>Total</b>	<b>2087.39624</b>	<b>30023</b>	<b>0.069547419</b>		

**Comparison of Speed by Time: All observations (Holm-Sidak method)**

Group	Diff of Means
Before crossing walking speed vs. Normal walking speed	-0.228 m/s
After crossing walking speed vs. Normal walking speed	-0.116 m/s
Before crossing walking speed vs. After crossing walking speed	0.112 m/s

**Older Pedestrians**

**ANOVA Test: Older pedestrians**

Source	SS	df	MS	F	Prob >F
Between Groups	19.7216066	2	9.86080332	189.70	0.000
Within groups	771.563821	14904	0.068001545		
<b>Total</b>	<b>791.285427</b>	<b>14906</b>	<b>0.53303161</b>		

**Comparison of Speed by Time: Older pedestrians (Holm-Sidak method)**

Group	Diff of Means
Before crossing walking speed vs. Normal walking speed	-0.214 m/s
After crossing walking speed vs. Normal walking speed	-0.108 m/s
Before crossing walking speed vs. After crossing walking speed	0.105 m/s

**Younger Pedestrians**

**ANOVA Test: Younger pedestrians**

Source	SS	df	MS	F	Prob >F
Between Groups	27.0972006	2	13.5486003	247.47	0.000
Within groups	830.300813	15115	0.054747515		
<b>Total</b>	<b>857.398014</b>	<b>15117</b>	<b>0.056526768</b>		

**Comparison of Speed by Time: Older pedestrians (Holm-Sidak method)**

Group	Diff of Means
Before crossing walking speed vs. Normal walking speed	-0.241 m/s
After crossing walking speed vs. Normal walking speed	-0.129 m/s
Before crossing walking speed vs. After crossing walking speed	0.112 m/s