Analysis of Pedestrian Travel Paths along Frontage Roads for Transit Planning and Engineering Applications

By

Aldo Núñez García, B.Sc., (CE)

A Thesis
Submitted to the Faculty of Graduate Studies
In Partial Fulfilment of the Requirements of the Degree of

MASTER OF SCIENCE

Department of Civil Engineering
University of Manitoba
Winnipeg, Manitoba

ACKNOWLEDGEMENTS

I wish to thank the precious time, patience and support of my advisor Dr. Jeannette Montufar, P.Eng. The learning opportunities that she opened for me became a milestone in my professional career.

I want to express my gratitude to Professor Alan Clayton, P.Eng. for his invaluable advice throughout my graduate studies, to Ms. Judy Redmond for her priceless assistance throughout this research, and to all the people who belong to the University of Manitoba Transport Information Group.

I want to thank Winnipeg Transit for providing funding for this research, to University of Manitoba and Manitoba Advanced Education and Literacy for providing funding for my graduate studies, and to the City of Winnipeg Public Works Department for providing valuable information, relevant to this research.

To the three women who made this journey possible: my mother Eva, my wife Lissette, and my daughter Alejandra. You are the reason why I wake up every morning.

To all the people who believe that high quality public transportation systems, regardless of the technology, can significantly improve our lifestyle.

ABSTRACT

This research investigates the travel paths of pedestrians along residential frontage roads in the immediate vicinity of bus stops. This investigation was performed to characterize association between seasonality, age, gender, physical impairments and travel path selection. For the purposes of this research, a pedestrian travel path is defined as the physical route chosen by transit users on their walking journey immediately before boarding or after alighting the transit bus, along residential frontage roads in the immediate vicinity of bus stops.

In Winnipeg, there are 126 residential frontage roads with no sidewalks being used as pedestrian facilities for transit users who want to access 190 bus stops. The majority of these roads (57%) have low snow clearance priorities and bus stops with no accessible connections to the nearest sidewalk.

A review of the literature found that there are no clear ‘sidewalk warrants’ regarding the accommodation of pedestrians along residential frontage roads. However, the literature states that residential arterials and collectors serve the largest pedestrian volumes since they connect important origins and destinations. Policies and guidelines state that sidewalks are highly desirable on both sides or should be placed at least on one side of residential arterials and collectors. After interviewing 24 transportation professionals from 15 selected jurisdictions in Canada and the U.S., Winnipeg was found to be the only jurisdiction with the combination of a large number of frontage roads (more than

one hundred), with no sidewalks, low snow clearance priorities, and transit service on the main road.

A study site screening process that encompassed multiple site visits, Automated Passenger Counting / Automatic Vehicle Location and Geographic Information Systems data analyses identified four study sites (with two bus stops each). At these sites, unaware bus stop users were observed and their travel paths were classified into one of three categories: (a) pedestrian walking on the frontage road; (b) pedestrian walking on the outer separation; or (c) pedestrian walking on the main road. The required sample was collected during eight months, and was divided into ‘no-snow’ and ‘snow’ seasons.

After performing statistical tests of association to the travel path selections of bus stop users, the research found that seasonal effects are statistically significant, indicating that there is a higher number of people walking on the main road during the ‘snow’ season. There was also a statistically significant difference in pedestrian path choices regarding site characteristics. When comparing the study sites, the only site that provided a splash strip was found to have a significantly higher amount of people walking along the outer separation, where the splash strip is provided, and which is used by pedestrians as a sidewalk. This finding indicates that if pedestrian facilities were provided along outer separations, they may have an impact on the path chosen by pedestrians when traversing frontage roads.

There was not enough evidence to find a statistically significant relationship between pedestrian walking paths and gender, age or ambulatory capabilities.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1 THE RESEARCH

This research investigates the travel paths of pedestrians along residential frontage roads in the immediate vicinity of bus stops. For the purposes of this research, a pedestrian travel path is defined as the physical route chosen by transit users on their walking journey immediately before boarding or after alighting the transit bus, along residential frontage roads in the immediate vicinity of bus stops. The research is particularly interested in: (1) seasonal differences in travel paths; (2) age and gender differences; and (3) the effect of physical impairments on travel path selection. This research provides engineers and planners with specific information that can assist in the design, operation and maintenance of facilities that accommodate pedestrians along residential frontage roads.

1.2 BACKGROUND AND NEED

Over the next decade, cities are expected to experience accelerated urban growth, aging population, mounting congestion, and environmental challenges. Decision makers have the opportunity to mitigate these issues by putting transit at the centre of communities through government policy, community planning, and community design (CUTA, 2009). The assessment of pedestrian accommodation along residential frontage roads is of interest to engineers and planners who want to put transit at the centre of communities, and put pedestrians at the centre of road design, maintenance and operations. This is because there are hundreds of bus stops being located in residential frontage roads with no sidewalks, and low snow clearance priorities.

In the U.S., the Policy on Geometric Design of Highways and Streets (AASHTO, 2004a) states that sidewalks should be provided along both sides of urban collectors that are used for pedestrian access to schools, parks, shopping areas and transit stops. Regarding pedestrian facilities on urban arterials, the policy states that arterial streets may accommodate both vehicles and pedestrians; therefore the design should include sidewalks, explaining how the justification for the construction of sidewalks depends on vehicle-pedestrian conflicts, not on the street functional classification.

In Canada, the Geometric Design Guide for Canadian Roads (TAC, 1999) states that most urban streets, with the exception of controlled access facilities such as freeways, expressways and high speed arterials, carry pedestrian traffic and are often provided with sidewalks. The Guide recommends pedestrian accommodation on both sides of residential collectors, on one side of residential local streets, and that such accommodation “may be provided” along arterials. When addressing pedestrian accommodation on these roads, the TAC guide illustrates examples where sidewalks are located on the land use side of frontage roads along divided arterials. It does not provide clear examples for undivided arterials or collector streets, where engineering judgement plays an important role in the design of the pedestrian facilities.

The current practice in Winnipeg does not require sidewalks on local residential streets, including residential frontage roads. However, collectors and arterials with residential frontage roads are different from local residential streets (i.e., cul de sacs) because they have higher pedestrian volumes, since they contain a higher amount of attractions (AASHTO, 2004B), and are where transit service operates (Winnipeg Transit, 2006).

The lack of contiguous sidewalks on residential frontage roads, which have low snow clearance priorities, creates several challenges. It does not adhere to the principles of Universal Design nor the City of Winnipeg Accessibility Design Standards, since it imposes challenges on the visually impaired, and creates an environment where pedestrians are expected to walk behind parked vehicles (City of Winnipeg, 2006a). The absence of a complete sidewalk network along residential roads also creates a pedestrian environment that adversely affects transit availability and discourages pedestrian travel (TCRP, 2003).

Based on the jurisdictional survey conducted as part of this research, and which is included in detail in Chapter 2, it was found that there has been controversy amongst transportation professionals on whether or not by requiring a sidewalk along residential frontage roads the city would create a redundant pedestrian facility that would not considerably benefit the public. Some of the reasons for this controversy are that travel paths around these facilities have not been studied, and there is no clear understanding on practices from other similar jurisdictions. There is also a lack of understanding regarding how many of these residential frontage roads with transit service exist.

For this reason, the analysis of pedestrian travel paths along residential frontage roads in the immediate vicinity of bus stops can help engineers and planners to understand the current scenario and to better accommodate pedestrians in an equitable way.

1.3 OBJECTIVES AND SCOPE

Specific objectives of this research are to:

- Obtain an understanding about the literature and current practices pertaining the accommodation of pedestrians along frontage roads (all types), with particular emphasis on transit accessibility.

- Determine relevant design guidelines, standards and policies in use in Winnipeg regarding the accommodation of pedestrians along residential roads, particularly those with residential frontage roads.

- Understand the criteria used for the provision of sidewalks on residential arterials, collectors and local roads in Winnipeg and compare it with other selected Canadian and U.S. jurisdictions.

- Understand the extent and characteristics of the sidewalk and transit networks along residential frontage roads in Winnipeg.

- Design and apply a data collection methodology to understand the travel paths of pedestrians in the immediate vicinity of bus stops along residential frontage roads.

- Determine the related characteristics of pedestrian travel paths in terms of gender, age, ambulatory capabilities and season.

- Identify opportunities for future research.

This research takes place in Winnipeg, a midsize city in the Canadian Prairie Region, with a population of about 650,000 inhabitants.

1.4 THESIS ORGANIZATION

This thesis is divided into six chapters:

Chapter 2 presents the findings from the environmental scan regarding the accommodation of pedestrians along frontage roads (all types), with particular emphasis on pedestrian access to bus stops. The environmental scan comprises a literature review and a survey of selected North American jurisdictions.

Chapter 3 discusses the extent and characteristics of the sidewalk and transit networks along residential frontage roads in Winnipeg. This is based on field visits and Geographic Information System (GIS) Data provided by Winnipeg Transit and the Public Works Department of the City of Winnipeg.

Chapter 4 discusses the methodology developed and applied in this research to perform the data collection and the characterization of pedestrian travel paths along residential frontage roads in the immediate vicinity of bus stops. The chapter explains how the pedestrian paths were classified, and provides a description of the processes followed for both the selection of relevant study sites and the performance of onsite pedestrian path surveys.

Chapter 5 discusses the analysis of the data collected in Chapter 4. The analysis is oriented towards the characterization of the pedestrian travel paths of transit users in their journey to and from bus stops located on residential frontage roads.

Chapter 6 summarizes the research findings, draws conclusions, and comments on opportunities for future research.

1.5 TERMINOLOGY

The following terms are used in this research:

Ambulatory Capabilities: the characteristics of the users as they relate to their ability to traverse a pedestrian facility and their needs for special mobility aids, also referred as mobility capabilities.

Automated Passenger Counting / Automatic Vehicle Location (APC/AVL) data: the data collected through automated devices located inside of the transit bus, and gathered by public transportation agencies summarizing boardings and alightings per bus stop, per route, over a given period of time.

Captive Sidewalk User: People whose ambulatory needs impose a greater dependency on sidewalks than the average able bodied user to safely traverse a given location (e.g., people walking with crutches, parents walking with young children, etc.). This category of users is further explained and exemplified in section 4.2.

Frontage Roads (or Service Roads): Public roads adjacent to, and generally parallel to major roads. The primary function of a frontage road is to serve the circulation and access needs of the adjacent lands, while controlling access to the parallel major road (TAC, 1999). When frontage roads are located on residential neighbourhoods they are referred as residential frontage roads.

Outer separation: Area between the edge of the traveled lanes of the major road and the adjacent parallel street. This space may accommodate bridge piers, lighting poles, barriers or fences or grassed boulevards (TAC, 1999).

Pedestrian Level of Service (Pedestrian LOS): A qualitative assessment of a pedestrian facility's operating conditions, based on the freedom to select desired walking speeds and the ability to by-pass slower-moving pedestrians (TCRP, 2003).

Pedestrian Travel Path: The physical routes chosen by pedestrians to traverse a road segment. In the case of transit users, this term refers to the path or route followed immediately prior to boarding or after alighting the bus.

Snow Clearance Priority: The priority established by the City of Winnipeg Street Maintenance Division to remove snow from the street network (City of Winnipeg, 2008).

Sidewalk Warrant: The situations or criteria that authorize the construction of a sidewalk on a given road (e.g., pedestrian volumes, vehicle-pedestrian conflicts, collisions, and others).

2. ENVIRONMENTAL SCAN

This chapter presents the findings from the environmental scan regarding the accommodation of pedestrians along frontage roads (all types), with particular emphasis on pedestrian access to bus stops. The environmental scan comprises a literature review and survey of different jurisdictions. The research is particularly interested in the following: (1) criteria for the provision of sidewalks on urban residential roads; (2) design guidelines, standards and policies regarding the accommodation of pedestrians on frontage roads (all types); (3) previous research addressing pedestrian access to bus stops, taking into account ambulatory capabilities, age, gender or seasonal differences; (4) current practices regarding the accommodation of pedestrians on residential frontage roads with particular interest on transit users; and (5) characteristics of pedestrian walking paths when accessing transit.

2.1 LITERATURE REVIEW

A comprehensive search of literature published in the last 15 years worldwide was conducted. The literature search entailed the following: (1) engineering periodicals and journals; (2) readily-available papers and texts; (3) conference proceedings; (4) special interest groups; (5) special government reports; and (6) documents on the World Wide Web. The search reviewed library catalogues, research centres, transportation agencies, and resources of:

Government Agencies

- Transport Canada
- U.S. Federal Highway Administration (FHWA)
- U.S. Federal Transit Administration (FTA)

Journals

- U.S. Journal of Public Transportation
- Transportation Research Record (TRR)
- Institute of Transportation Engineers (ITE) Journal
- Canadian Journal of Civil Engineering

Professional Associations/Affiliations

- Transportation Research Board (TRB)
- American Public Transportation Association (APTA)
- Canadian Urban Transit Association (CUTA)
- Transportation Association of Canada (TAC)
- American Association of State Highway and Transportation Officials (AASHTO)

Research Centres

- National Center for Transportation and Industrial Productivity (NCTIP)
- National Center for Transit Research at the University of South Florida

Special Library Catalogues

- Transportation Research Information Services (TRIS Online)
- The U.S. National Transportation Library (NTL)
- Transport Research Board Publications Index

- University of Manitoba Bison Catalogue

Other Organizations

- Easter Seals Disability Services
- World Road Association (PIARC)

2.1.1 Accommodation of Pedestrians along Frontage Roads

In Canada, the Transportation Association of Canada (TAC, 1999) defines frontage (service) roads as public roads parallel to major roads such as freeways, expressways, and arterials. The primary function of a service road is to serve the circulation and access needs of the adjacent lands, while controlling access to the parallel major road. Regarding functional classification, where frontage roads are only a few blocks long, follow irregular patterns, border the rear and side of buildings or serve scattered development, frontage roads normally operate as local roads, with operating speeds between intersections in the order of 60 km/hr or less (TAC, 1999; NCHRP, 1999).

There are different types of frontage roads in urban settings, typically located adjacent to freeways, expressways or arterials. They may be provided on one or both sides of the main roadway. Frontage roads may be continuous or they may extend for short sections only, and they may operate one or two-ways (NCHRP, 1999). Figure 2-1 illustrates the different types of frontage roads.

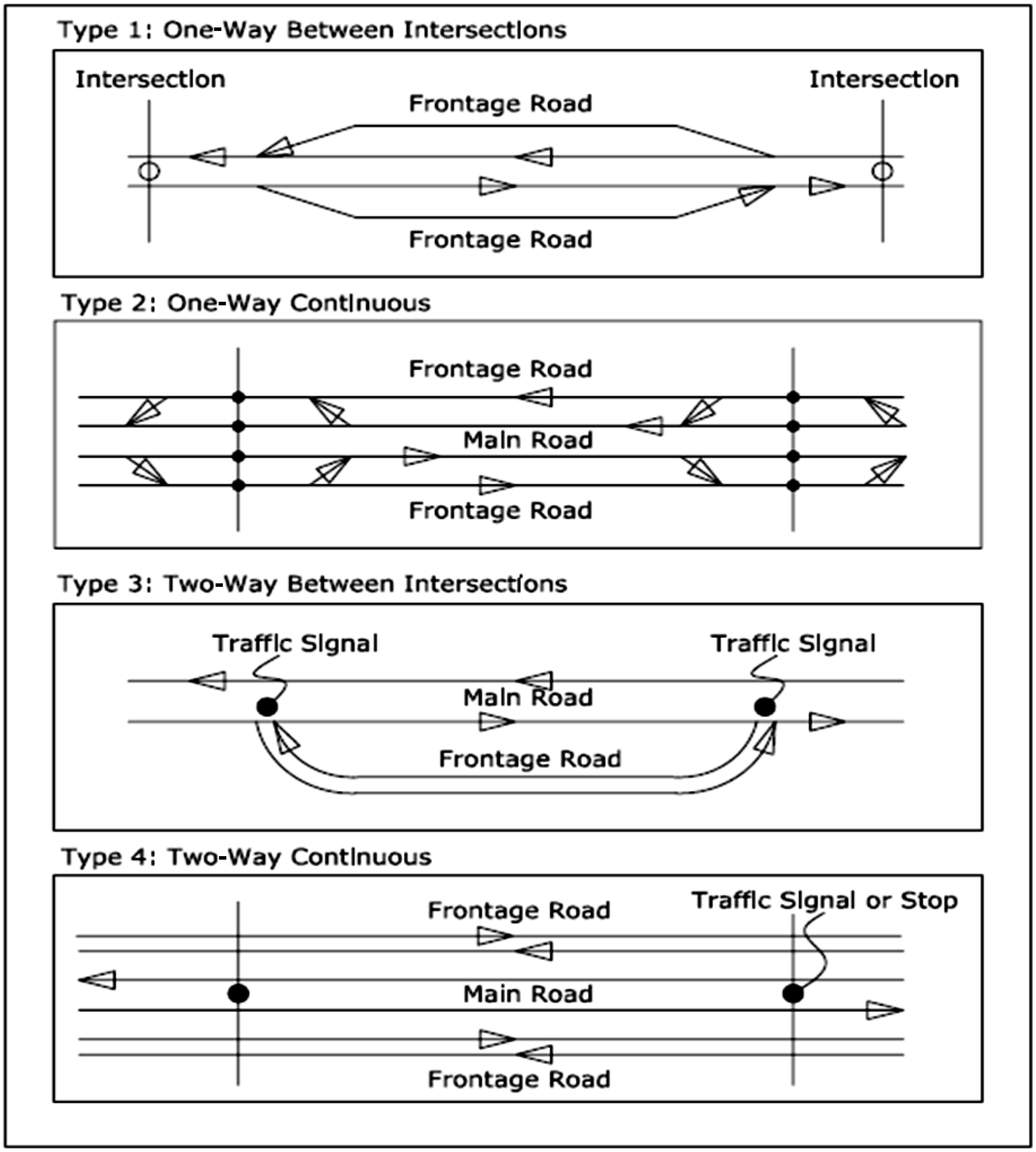


Figure 2-1: Types of Frontage Roads

Source: National Cooperative Highway Research Program (NCHRP, 1999). "Impacts of Access Management Techniques". Transportation Research Board, Washington, D.C.

One-way frontage roads are preferred over two-way frontage roads, and frontage roads confined between intersections are preferred over continuous frontage roads for the following reasons: (1) the safety advantage in reducing vehicular and pedestrian conflicts on intersecting streets often compensates for any inconvenience to local traffic; (2) the use of continuous frontage roads on relatively high speed arterial streets with intersections may be undesirable for both pedestrians and vehicles; and (3) along cross streets, the various through and turning movements at several closely spaced intersections may greatly increase crash potential (NCHRP, 1999; AASHTO, 2004a).

TAC (1999) addresses operational and design issues related to pedestrian travel along one-way frontage roads. The guide depicts a recommended treatment for one-way service roads parallel to divided arterials, where sidewalks are located on the land use side of the service road. Figure 2-2 illustrates the intersection treatment from the TAC guide.

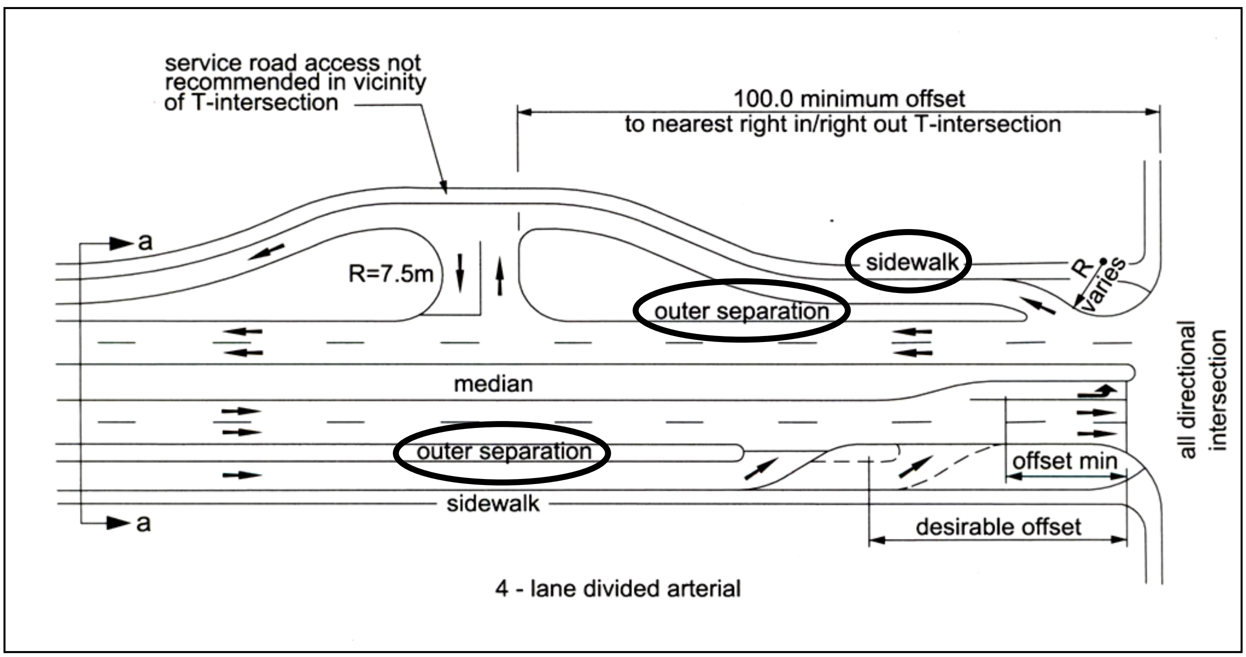


Figure 2-2: One-Way Service Road / Cross Roadway Intersection Treatment

Source: Taken from Transportation Association of Canada (TAC, 1999). "Geometric Design Guide for Canadian Roads". September 1999 with 2007 Updates, Ottawa, Canada, Page 1.3.4.3

As defined in TAC (1999), outer separation is the area between the edge of the traveled lanes of the major road and the adjacent parallel street (see Figure 2-2). The outer separation may accommodate bridge piers, lighting poles, barriers or fences. The TAC guide does not provide any discussion or recommendation regarding the option of accommodating pedestrians by providing a sidewalk inside the outer separation.

In the U.S., AASHTO (2004a) states that frontage roads are street facilities that may be used to control access to arterials serving adjoining properties, while maintaining circulation on the main road. These frontage roads are used most frequently on freeways where their primary function is to distribute and collect traffic between freeway interchanges and local streets. In some cases, frontage roads can be desirable on arterial streets both in downtown and suburban areas, providing better access for commercial and residential uses while preserving the capacity of the main road. AASHTO (2004a) also states that a substantial width of outer separation is advantageous since it provides a refuge for pedestrians, and is especially advantageous when having cross streets, since it minimizes vehicle-pedestrian conflicts. There is no further discussion or recommendation regarding the provision of sidewalks along outer separations.

2.1.2 Criteria for the Provision of Sidewalks on Residential Streets

2.1.2.1 Geometric Design

AASHTO (2004a) indicates that sidewalks are desirable on both sides of a street, but should be provided on at least one side of urban collectors that are used for pedestrian access to schools, parks, shopping areas and transit stops. The policy mentions that "arterial streets may accommodate both vehicles and pedestrians; therefore the design should include sidewalks, crosswalks and sometimes grade separations for pedestrians" (page 484). When addressing the criteria for the provision of sidewalks, the AASHTO policy explains how the justification for the construction of sidewalks depends on vehicle-pedestrian conflicts, since traffic or pedestrian volume warrants for sidewalks have not been established.

To understand the needs of pedestrians, and their conflicts with other modes of transportation, AASHTO published the Guide for the Planning, Design, and Operation of Pedestrian Facilities (AASHTO, 2004b). This publication states that collectors and arterials are typically the roads that serve the largest number of both vehicles and pedestrians, and are the primary location of businesses and attractions. This guide recommends the installation of sidewalks on each side of the road along collectors and arterials whenever the frontage (face of the development) is developed.

In Canada, TAC (1999) states that most urban roads, with the exception of controlled access facilities such as freeways, expressways and high speed arterials, carry pedestrian traffic and are often provided with sidewalks. The guide mentions how in residential areas, sidewalks are desirable on both sides of the road and are normally placed on at least one side of all local roads. The only typical exceptions are short cul-de-sacs where vehicular traffic volumes are very low. The TAC guide presents a chart where pedestrian accommodation is organized by functional classification (Figure 2-3).

	Public Lanes Residential	Public Lanes Commercial	Locals Residential	Locals Indust./Comm.	Collectors Residential	Collectors Indust./Comm.	Arterials Minor	Arterials Major	Expressways	Freeways
traffic service function	traffic movement not a consideration		traffic movement secondary consideration		traffic movement and land access of equal importance		traffic movement major consideration	traffic movement primary consideration	traffic movement primary consideration	optimum mobility
land service / access	land access only function		land access primary function		traffic movement and land access of equal importance		some access control	rigid access control	no access	no access
traffic volume (veh/day) (typical)	<500	<1000	<1000	<3000	<8000	1000 – 12 000	5000 – 20 000	10 000 – 30 000	>10 000	>20 000
flow characteristics	interrupted flow		interrupted flow		interrupted flow		uninterrrupted flow except at signals and crosswalks		uninterrupted flow except at signals	free-flow (grade separated)
design speed (km/h)	30 - 40		30 - 50		50 - 80		50 - 70	60 - 100	80 - 110	80 - 120
average running speeds (km/h) (off-peak)	20- 30		20 - 40		30 - 70		40 - 60	50 - 90	60 - 90	70 - 110
vehicle type	passenger and service vehicles	all types	passenger and service vehicles	all types	passenger and service vehicles	all types	all types	all types up to 20% trucks	all types up to 20% trucks	all types up to 20% trucks
desirable connections	public lanes, locals		public lanes, locals, collectors		locals, collectors, arterials		collectors, arterials, expressways, freeways		arterials, expressways, freeways	arterials, expressways, freeways
transit service	not permitted		generally avoided		permitted		express and local buses permitted		express buses only	express buses only
accommodation of cyclists	no restrictions or special facilities		no restrictions or special facilities		no restrictions or special facilities		lane widening or separate facilities desirable		prohibited	prohibited
accommodation of pedestrians	pedestrians permitted, no special facilities		sidewalks normally on one or both sides	sidewalks provided where required	sidewalks provided both sides	sidewalks provided where required	sidewalks may be provided, separation for traffic lanes preferred		pedestrians prohibited	pedestrians prohibited
parking (typically)	some restrictions		no restrictions or restrictions one side only		few restrictions other than peak hour		peak hour restrictions	prohibited or peak hour restrictions	prohibited	prohibited
min. intersection spacing[1] (m)	as needed		60		60		200	400	800	1600 (between interchanges)
right-of-way width (m) (typically)	6 - 10		15 - 22		20 - 24		20[2] - 45[3]		>45[3]	>60[3]

Figure 2-3: Characteristics of Urban Roads

Source: Taken from Transportation Association of Canada (TAC, 1999). "Geometric Design Guide for Canadian Roads". September 1999 with 2007 Updates, Ottawa, Canada, Page 1.3.4.3

Figure 2-3 shows how that TAC (1999) recommends the installation of sidewalks on both sides of residential collectors, and one side of local residential roads, and that sidewalks “may be provided” along arterials.

The Urban Street Design Handbook (2008) states that sidewalks are “highly desirable” along urban collectors. Collectors are often ideal streets for pedestrians because of their relatively low traffic speeds, their direct routing, and their direct access to a large number of destinations. Continuous sidewalks are also desirable along urban arterial streets. The primary goal of a continuous pedestrian access route is to enable unrestricted access to all potential facility users. A sidewalk initially should be provided along at least one side of an arterial and in regions with existing or proposed pedestrian-friendly development, a sidewalk should be provided on both sides of the street (ITE, 2008).

2.1.2.2 United States Federal Legislation

In the United States, accessibility laws, regulations and standards have been a fundamental element when addressing the provision and design of pedestrian facilities (AASHTO, 2004b). In 1990, the U.S. Congress approved the Americans with Disabilities Act (ADA), which is a law that prohibits discrimination on the basis of disability, and fosters the creation of design standards for accessible routes.

In 2000, the Federal Highway Administration (FHWA) published a policy statement providing guidance to understand the Transportation Equity Act for the 21st Century

(TEA-21) provisions related to pedestrians and cyclists, and to interpret ADA. Such guidance indicates that pedestrians of all abilities should be accommodated in pedestrian facilities and pedestrian crossings; those features should be considered from the beginning of project planning. With respect to the provision of sidewalks, the guide states (FHWA, 2000):

> *"Bicycle and pedestrian ways shall be established in new construction and reconstruction projects in all urbanized areas unless one or more of three conditions are met:*
>
> - *Bicyclists and pedestrians are prohibited by law from using the roadway. In this instance, a greater effort may be necessary to accommodate bicyclists and pedestrians elsewhere within the right of way or within the same transportation corridor.*
> - *The cost of establishing bikeways or walkways would be excessively disproportionate to the need or probable use. Excessively disproportionate is defined as exceeding twenty percent of the cost of the larger transportation project.*
> - *Where scarcity of population or other factors indicate an absence of need. For example, the Portland Pedestrian Guide requires "all construction of new public streets" to include sidewalk improvements on both sides, unless the street is a cul-de-sac with four or fewer dwellings or the street has severe topographic or natural resource constraints..."*

The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) of 2005 includes two sections that address older pedestrians and safe routes to school as key elements of its road safety agenda. The Act uses TEA-21 as its foundation and continues giving support to the Americans with Disabilities Act of 1990 (FHWA, 2005).

2.1.3 Pedestrian Access to Bus Stops

As recommended by the Guidelines for the Location and Design of Bus Stops (1996), riders should not have to walk through grass or exposed soil to reach the bus. The areas between the bus stop and the curb can become worn and decline to muddy areas during inclement weather. These guidelines propose the coordination of sidewalk design and placement between developers and transit agencies, to ensure riders direct access to the nearest bus stop (TRCP, 1996).

Previous research has compared a number of methods that have been proposed for assessing quality of operations along pedestrian facilities on the basis of pedestrian Level of Service (LOS). Some of these methodologies utilize principles of the Highway Capacity Manual (TRB, 2000) to evaluate pedestrian traffic operations on the basis of the flow-speed-density relationship. Other methodologies are more concerned with the facility design and walking environment than the actual pedestrian flows. One example is the Australian Method, which evaluates three aspects: (1) physical characteristics (path width, surface quality, obstructions, crossing opportunities and support facilities); (2) location factors (connectivity, path environment, and potential pedestrian-vehicle conflicts); and (3) user factors (pedestrian volume, mix of path users and personal security). Each factor has a score which is weighted by using standardized tables to get the final pedestrian LOS (Sisiopiku et al., 2007).

The quality of pedestrian access to bus stops can also be evaluated by the pedestrian LOS in the vicinity of the stop. In the U.S., the Florida Department of Transportation has developed the 2009 Quality/Level of Service Handbook which uses a pedestrian model that accounts for existence of sidewalks, lateral separation of pedestrians from motorized vehicles, traffic volumes, and average running speeds (Florida DOT, 2009).

The Transit Cooperative Research Program has performed extensive research addressing the quality of pedestrian access to transit services. The Transit Capacity and Quality of Service Manual (TCRP, 2003) states:

> *"Transit availability is the most important quality of service category for pedestrians because it determines whether or not transit is even an option, regardless of the quality of the trip."*

To achieve transit availability, the system must provide: (1) service near the rider's origin; (2) service near the rider's destination; (3) service at the times required; (4) information on when and where transit service is provided and how to use the system; and (5) sufficient capacity (TCRP, 2003).

The provision of good pedestrian access affects the first two availability factors, particularly for persons with mobility impairments, who require ADA accessible routes with sidewalks, curb cuts, and bus stop loading areas. Without these facilities, passengers with disabilities depend on paratransit services, which typically provide fewer choices in travel times and cost substantially more for transit operators to provide (TCRP, 2003).

TCRP (2003) states that pedestrian environment plays an important role as part of the availability factors, and mentions how, even when a transit stop is located within a reasonable walking distance, the absence of sidewalks, poor maintenance of sidewalks, and lack of street lighting discourage pedestrian travel.

As stated by the Pedestrian Safety Guide for Transit Agencies, when studying pedestrian access to bus stops it is necessary to understand the characteristics or the range of pedestrians that may be accessing transit to help develop safe alternatives. Table 2-1 shows pedestrian groups arranged by ages and mobility capabilities, and defines important pedestrian walking path characteristics to be considered when designing pedestrian access to transit facilities (FHWA, 2008).

Pedestrian Group	Pedestrian Walking Path Characteristics
Children Pedestrians	- May have difficulty choosing where and deciding when it is safe to cross the street. - May have difficulty seeing (and being seeing by) drivers of all types of vehicles, including buses because of less peripheral vision and shorter stature that adults. - May have difficulty judging the speed of approaching vehicles. - May need more time to cross the speed than adults.
Older Pedestrians	- May have reduced motor skills that limit their ability to walk at certain speed or turn their heads. - May need more time to cross the street than younger adults. - May have difficulty with orientation and understanding traffic signs, so they may need more information about how to access transit and get around safely. - May have difficulty judging the speed of approaching vehicles.
People with Disabilities	- May be more affected by surface irregularities in the pavement and changes in slope or grade. - May need more time to cross a street than people without disabilities. - May have trouble seeing (and being seeing) by drivers of all types of vehicles due to seated position (for people using wheelchairs). - Pedestrians who are blind or who have low vision may have trouble detecting yielding vehicles or communicating visually with drivers in crossing at unsignalized crosswalks.

Table 2-1: Pedestrian Walking Path Characteristics by Group

Source: Pedestrian Safety Guide for Transit Agencies (FHWA, 2008)

Most of the research on transit accessibility is directed towards the most disadvantaged of the three pedestrian groups: the pedestrian with disabilities (ambulatory impairments). Such pedestrians may use devices such as wheelchairs, crutches, canes, walkers, and/or prosthetic limbs to enhance their mobility. When using such assistive devices, they require sufficient space and proper structures to manoeuvre around barriers (AASHTO, 2004b).

Publications like the Guidelines for the Location and Design of Bus Stops (TCRP, 1996) and the Toolkit for the Assessment of Bus Stop Accessibility and Safety (ESPA, 2006) provide guidance regarding the principles used for the enhancement of bus stop accessibility by helping the designer to determine ADA requirements and to enhance bus stop accessibility using universal design features. These features typically include curb cuts, ramps, landing pads, and small slopes in the accessible routes towards bus stops.

The literature also explains how for people with disabilities, inaccessible bus stops often represent the weak link in the system and can effectively prevent the use of fixed route bus service. Physical, cognitive, and psychological barriers associated with bus stops can severely hamper bus ridership by people with disabilities, thus limiting their mobility and potentially leading to increased paratransit costs (ESPA, 2006).

2.1.4 Characteristics of Pedestrian Walking Paths when Accessing Transit

Pedestrian walking path characteristics and path choices are topics that have been extensively researched in the last decade. It has been found that pedestrians traveling to/from transit are frequently preoccupied with reaching the stop before the bus arrives. Pedestrians who are running late may take more risks than they typically would under normal conditions. For this reason, the understanding of pedestrian walking path characteristics is imperative when promoting pedestrian safety near transit (FHWA, 2008).

Typical pedestrian walking path characteristics when accessing transit are: (1) pedestrians like walking short distances to their bus stops, TCRP (2003) states that most users walk 400 meters or less to bus stops, equivalent to a maximum walking time of five minutes; (2) pedestrians engage in risk-taking behaviour when they experience difficulty crossing streets, particularly when their delay exceeds 30 seconds (TRB, 2000); (3) pedestrians typically take the most direct line possible to minimize the distance and time they must walk to reach their destination (FHWA, 2008); and (4) pedestrians have a basic resistance to changes in grade or elevation when crossing roadways and tend to avoid using special underpass or overpass pedestrian facilities (AASHTO, 2004b).

Pedestrian age is also an important factor that may explain risk-taking behaviour that leads to collisions between motor vehicles and pedestrians. Older pedestrians may be affected by sensory, perceptual, cognitive or motor limitations while very young pedestrians are often careless in traffic from either ignorance or exuberance. Pedestrian collisions also can be related to the absence of sidewalks, which may force pedestrians to share the right of way with motorists. Therefore, sidewalk construction should be considered as part of any urban/suburban street development or improvement (AASHTO, 2004b).

The pedestrian environment can significantly affect a person's walking experience and the utility of walking along a transit user's path (Guo, 2009). Observational studies have helped to understand these relationships. Cervero (2000) analyzed access trips to the rail services in San Francisco, California and Montgomery County, Maryland, showing that urban design, particularly sidewalk provisions and street dimensions, significantly influences whether someone reaches a transit stop by foot or not. Muraleetharan and Hagiwara (2007) performed a study where the LOS of walkways and crosswalks was related to actual path choices in the vicinity of the Hokkaido University Campus and its transit facilities, in the city of Sapporo, Japan. The research results indicated that pedestrians walking short distances minimized their travel time, but more importantly, those traversing longer paths chose their routes not only based on travel time, but also accounting for the overall sidewalk and crosswalk level of service.

Other research approaches have developed mathematical tools to model pedestrian walking path choices. The latest literature in this area shows consensus on two points: (1) pedestrians tend to maximize their walking utility, which is a trade-off between factors like physical contact with other pedestrians, energy usage, walking time and distance (Campanella et al; 2009); and (2) walking path choice is also associated with the walking environment (Smith, 2009).

2.1.5 Seasonal Considerations

The effects of road design and road maintenance on pedestrian mobility have been studied in northern Japan, particularly in the city of Sapporo, the snowiest city in the country. Shintani et al. (2002 and 2003) conducted three pedestrian walking experiments. The first experiment was particularly focused on pedestrian mobility at crosswalks, where pedestrians' mobility worsens in winter because of slippery road surface conditions. The outputs of the experiment show how barrier-free (properly designed and maintained) intersections improve pedestrians' mobility. The second experiment analyzed pedestrian walking characteristics and the effects of gravel spreading on icy roads, finding that this maintenance countermeasure did not increase significantly the friction coefficient, however it did increase the stability of the pedestrian movements and his/her sense of security. The third experiment utilized a criterion called "ratio of double supporting period", which is the ratio of time when both feet are down per walking cycle, concluding that both longitudinal and cross slopes affect pedestrians under icy conditions, particularly those with less physical strength.

With respect to snow clearance priorities and decision making, the literature indicates that one of the critical elements of a snow clearance policy is the level of service description. This description should clarify what customers can expect in snow and ice service and should define the times when operations are supposed to take place, the treatment sequence, the level of effort, and the priority classification of the entire road system. Regular transit and school bus routes typically have high snow clearance priorities (Amsler, 2008). The literature review could not find clear guidance on how to prioritize snow clearance on urban roads from the pedestrian perspective.

2.1.6 Summary of Literature Review

The following is a synthesis of the literature review:

- Residential arterials and collectors serve the largest pedestrian volumes, since they connect important origins and destinations, and sidewalks are highly desirable on both sides or should be placed at least on one side of these roadways.

- Although frontage roads (all types) are considered local streets based on their low vehicular volumes and low vehicular speeds, nothing in the literature indicates that they can be designed or operated as pedestrian facilities, or used to substitute sidewalks in general.

- Pedestrian facilities should be provided in all urbanized areas unless: (a) pedestrians are not expected in the area; (b) pedestrians are explicitly prohibited; or (c) implementation costs are excessively disproportionate.

- There are different examples of frontage roads designed with a sidewalk along the development side, but there is no clear discussion that evaluates the possibility of locating the sidewalk along the outer separation (sometimes called boulevard).

- The elderly, children and people with mobility impairments particularly benefit from the presence of exclusive, well-maintained sidewalks, due to their pedestrian walking path characteristics.

- For people with disabilities, inaccessible bus stops often present the weak link in the transit system, which can hamper bus ridership by them, limiting their mobility and potentially leading to increased paratransit costs.

- Transit users who are running late may take more risks than they typically would under normal conditions. For this reason, the understanding of pedestrian walking path characteristics of transit users is imperative when promoting pedestrian safety near transit.

- Individuals choose their walking paths based on two main factors: (1) maximization of personal walking utility (e.g. minimum travel time and minimum energy usage); and (2) the pedestrian environment (i.e., sidewalk provisions, sidewalk obstructions and street dimensions).

- All jurisdictions should include the priority classification of their road system as part of their snow control plans; however, there is no clear guidance on how to prioritize these roads from the pedestrian perspective.

2.2 JURISDICTIONAL REVIEW

This section presents findings from a jurisdictional review regarding the accommodation of pedestrians on residential frontage roads, with a particular focus on transit users. The review first presents the findings from the City of Winnipeg, and then presents the findings from selected jurisdictions in Canada and the United states.

2.2.1 The City of Winnipeg

The findings from six interviews performed with transportation professionals from the City of Winnipeg are included in this subsection. The findings are organized by subject as follows: (1) universal design; (2) transportation facilities planning; (3) transit planning; (4) snow removal; and (5) utilities and waste collection. The following are findings from the interviews that contain points of view and relevant documents provided by the given professional.

Universal Design

- The current design does not give good wayfinding clues for the visually impaired (this is particularly true when accessing bus stops along outer separations with no curb cuts, no ramps, and no landing pads). At the same time, low snow clearance priorities are a concern; they increase the chances of the pedestrian right of way becoming slippery, which may prevent people with impairments from walking during winter.

- Paratransit services in Winnipeg are expensive and are up to capacity. Two issues that may prevent the disabled community from using regular services are the lack of accessible bus stops and a discontinuous sidewalk network. Any effort made in this regard would be valuable because some paratransit users would be willing to become regular transit users, due to the enhanced freedom and flexibility offered by regular transit services.

- In 2006, the City of Winnipeg Accessibility Design Standards were adopted. This document addresses accessibility requirements for the design, construction or retrofit of facilities owned by the City. When reviewing these standards, the following inconsistencies with current practices were found: bus stops located on accessible routes should be clear of obstacles to provide access to all members of the community (not true when bus stops along residential frontage roads have no ramps); the standards recommend a maximum cross slope of 2.0% on pedestrian facilities (current crown cross slope along residential frontage roads is 2.5%), and standards mention that accessible routes shall not require people to pass behind parked vehicles, while parking is allowed along residential frontage roads (City of Winnipeg, 2006a and 2006b).

Transportation Facilities Planning

- When planning and designing pedestrian facilities, the City of Winnipeg follows the Geometric Design Guide for Canadian Roads (TAC, 1999). The installation of sidewalks along residential frontage roads adjacent to collectors or arterials is not required since a residential frontage road is considered a local street, due to its low vehicular volumes.

- A concern is that there is no connection from the bus stop to the residential frontage road. During summer months pedestrians may walk across the grass, but during the winter they may have to walk out onto the main road if their walker or wheelchair cannot reach the bus stop. In the City of Winnipeg, there is currently an argument about whether or not by adding a sidewalk the city would create a redundant pedestrian facility that would also limit the available snow storage area, reduce green space, increase run-off, and increase maintenance costs.

Transit Planning

- The City typically requires the installation of sidewalks on residential streets based on their functional classification, not pedestrian volumes, vehicular-pedestrian conflicts or transit ridership. Sidewalks along residential frontage roads are not required since these roads are considered local streets, despite the fact that residential frontage roads are located along collectors or arterials with transit service. Winnipeg Transit has experienced problems when locating bus stops on residential frontage roads. Since the bus cannot operate along the residential frontage road, the only place to locate the bus stop is the outer separation with no sidewalk, and no ramp.

- Winnipeg Transit follows its own guidelines with respect to planning and designing transit facilities - Designing for Sustainable Transportation and Transit in Winnipeg (Winnipeg Transit, 2006) - in consultation with other guidelines like the TCRP Guidelines for the Location and Design of Bus Stops (TCRP, 1996). The following are recommendations from these guidelines that are currently not applied along residential frontage roads with transit service: (1) sidewalks on both sides of collectors are recommended; (2) unobstructed paths should be part of the design of accessible bus stops; (3) the sidewalk must be connected to the bus stop platforms (with a minimum of 2.1m x 8.5m concrete surface to allow for the lowering of the wheelchair ramp).

Snow Removal

- For the purpose of snow clearing, the street network has been classified into three categories, PI, PII and PIII, where PI typically includes all regional streets and streets around the Health Sciences Centre, PII typically includes bus routes and collector streets, and PIII are typically low volume residential or industrial local roads (most residential frontage roads (57%) have been assigned under this category). These same priorities are used for sidewalks, where the sidewalk priority typically matches the street priority. In most cases these priorities are designated based on traffic volumes, using traffic counts provided by the City. Exceptions are those areas with a significant number of seniors, where the sidewalk along a PIII street might change priority to allow access to the nearest bus stop or street designated as PI or PII.

- It is more difficult for the maintenance crews to plow a sidewalk along the development side than along the outer separation. This is because of the different slopes that the plowing machines need to negotiate when crossing private approaches.

Utilities and Waste Collection

- The typical utilities located along residential collectors or arterials are fire hydrants, lighting standards, communications corridors (telephone, cable, internet, etc.), electricity corridors, and water mains. These utilities are typically located along planting strips or grassed boulevards to ease access for the maintenance crews, and because these crews should not work on private property.

- It is inconvenient for waste collection to have a concrete sidewalk along the outer separation, since the machines need to negotiate the different slopes across the private approaches. If sidewalks were installed along the outer separation, it is necessary to leave a planting strip of at least 4.0m to allow proper access to utilities.

This 4.0m criterion is taken from a document prepared by the Underground Structures Committee. This document provides standard locations for utility structures and shows examples of cross sections of arterials and collectors, where 1.5m sidewalks are provided next to a planting strip between 4.0m to 4.5m, where all utilities are located (City of Winnipeg, 1984).

2.2.2 Selected Jurisdictions from Canada and the United States

A total of 54 institutions, including transit agencies, transportation planning or transport operation departments from 27 jurisdictions were contacted both by phone and by e-mail (13 jurisdictions in the U.S. and 14 in Canada). The jurisdictions were selected to cover all major cities in the provinces and states along the Canada - U.S. border, since it was important to have jurisdictions with significant amounts of snowfall and long winters. In total, 20 people from 15 jurisdictions answered the survey, eight jurisdictions in Canada and seven in the U.S. (this represents 55% of the target jurisdictions, and 37% of the professionals that were originally contacted).

Because of the nature of the subject, two types of professionals (one public transportation planner/engineer and one general transportation planning/engineer) were contacted per jurisdiction. Some questions were left as “not available” (N/A), which meant that the professional interviewed was not familiar with the subject, or the question did not apply to the context of the given jurisdiction. The survey format is provided in Appendix A, and the results are presented in the following two subsections.

2.2.2.1 Guidelines and Warrants

When planning and designing pedestrian facilities and bus stops, five surveyed jurisdictions in Canada follow their own guidelines and two complement them with the Geometric Design Guide for Canadian Roads (TAC, 1999). In the United States, five surveyed jurisdictions use the Americans with Disabilities Act Accessibility Guidelines ADAAG (U.S. Access Board, 2004), and complement them with their local policies.

The research found that 'pedestrian-volume warrants' for the installation accessible stops and sidewalks have not been established. It was not clear for eight of the respondents when their jurisdiction required the installation of curb cuts, ramps and landing pads to create accessible bus stops. Of the seven jurisdictions who responded to this question, four reported that their jurisdiction is promoting accessible bus stops by implementing them in every retrofit project. The rest of the jurisdictions had very open criteria (i.e. accessible bus stops are installed where high volumes justify them, but the jurisdiction does not have a specific threshold). Regarding 'sidewalk warrants' along residential streets, four respondents mentioned that sidewalks are warranted depending on the functional classification, four jurisdictions reported that sidewalks are warranted on all residential streets, and one jurisdiction reported to warrant sidewalks giving preference to the elderly, the disabled and low income people. The remaining jurisdictions did not have specific 'sidewalk warrants'. Guidelines and warrants used across jurisdictions are summarized in Table 2-2.

Table 2-2: Guidelines and Warrants across Jurisdictions

Country	Province/ State	City	Guidelines used for Pedestrian Facilities	Guidelines used for Bus Stop Design and Location	When are accessible bus stops required	Sidewalk Warrants on Residential Streets	Residential Frontage Roads Exist?	Important Remarks
Canada	Alberta	Calgary	N/A	Local Guidelines	N/A	All residential streets	Yes, few	Sidewalks are installed along residential frontage roads
		Edmonton	N/A	Local Guidelines	N/A	Depends on functional classification	Yes, few	Residential frontage Roads are not permitted in new areas
	Manitoba	Winnipeg	TAC + ADAAG + Local Guidelines	TCRP + ESPA + FHWA + Local Guidelines	Currently promoting guidelines to improve pedestrian accessibility on all stops.	Depends on functional classification	Yes	Pedestrian access to stops is an important concern
	New Brunswick	St. John	No clear guidelines, follow previous design	N/A	Not clear, not many streets out of downtown have sidewalks	Not specific warrants have been created	No	Not many streets have sidewalks out of downtown
	Ontario	Toronto	Local Guidelines	Local Guidelines	N/A	All residential streets	No	Sidewalks required on all residential streets
	Quebec	Montreal	Local Guidelines	Local Guidelines	N/A	All residential streets	No	Sidewalks required on all residential streets
	Saskatchewan	Regina	Local Guidelines	Canadian Transit Handbook from CUTA	Every intersection with sidewalks must have ramps	Depends on functional classification	No	Every intersection with sidewalks must have ramps
		Saskatoon	TAC + Local Guidelines	Based on local experience, no specific guidelines are followed	Where high volumes justify them, where seniors are expected, in retrofit projects, and in all new developments	Depends on functional classification	Yes	Abandoned this type of design
U.S.	Idaho	Boise - Meridian	N/A	ADAAG in consultation with TCRP	N/A	Preference is given to areas with disable, elderly or low income users	Yes, few	They give preference to areas with disable, elderly and low income users
	Minnesota	Minneapolis - St. Paul	N/A	Local Guidelines	N/A	N/A	Yes, few	Sidewalks on development side and outer separation
	North Dakota	Fargo	AASHTO	N/A	Required in retrofit projects, and required in all new developments	N/A	Yes	Sidewalks required along residential frontage roads
	Ohio	Cleveland	ADAAG	ADAAG + Local guidelines	Required in retrofit projects, and in all new developments	N/A	Yes, few	Sidewalks are requested in residential frontage roads on new developments
	Vermont	Burlington	ADAAG + Local guidelines	ADAAG + Local guidelines	Ramps are requested by transit authority mostly on shelters	N/A	No	Ramps are requested by transit authority mostly on shelters
	Washington	Seattle	ADAAG + Local guidelines	Local Guidelines	N/A	N/A	No	None
	Wisconsin	Milwaukee	N/A	TCRP + ADAAG + ESPA + Local Guidelines	N/A	All residential streets	Yes	Sidewalks required along residential frontage roads

*Acronyms: TAC – Transportation Association of Canada, ADAAG – Americans with Disabilities Act Accessibility Guidelines, TCRP –Transit Cooperative Research Program, ESPA – Easter Seals Project Action, FHWA – Federal Highway Administration, CUTA – Canadian Urban Transit Association. **Source: Prepared by Núñez from various sources, 2010

2.2.2.2 Residential Frontage Road Practices

The research found that 12 of the 15 surveyed jurisdictions do not have a significant amount of residential frontage roads or have abandoned this access management technique. In the U.S. only two jurisdictions reported residential frontage roads being an important element of their road network. In Canada the only jurisdiction that reported having a significant amount of residential frontage roads and is using them extensively is Winnipeg. Of the 15 jurisdictions interviewed, nine confirmed having at least one example of a residential frontage road. These jurisdictions were further investigated to synthesize design practices as they pertain to sidewalk presence, bus stop locations and snow clearance priorities. Photos of residential frontage roads from selected jurisdictions are included in Appendix B.

Regarding sidewalk installation along residential frontage roads, the research found that Winnipeg is the only jurisdiction surveyed with no sidewalks. Five of the eight jurisdictions with sidewalks along residential frontage roads install these pedestrian facilities along the development side, while three of them install sidewalks both along the development side and the outer separation. Figure 2-4 illustrates an example of a residential frontage road with sidewalk on the development side found in Fargo, North Dakota. Figure 2-5 depicts an accessible bus stop located along a residential frontage road in Edmonton, with sidewalks on both sides of the residential frontage road.

Figure 2-4: Residential Frontage Road with Sidewalk on the Development Side
Place: 1st St & 17th Ave W, West Fargo, North Dakota, U.S. Source: ©2010 Google

Figure 2-5: Example of Accessible Bus Stop in Edmonton, Canada
Place: Towne Centre blvd and 23rd Ave in Edmonton, Canada. Source: ©2010 Google

Four of the professionals interviewed had a good understanding of snow clearance priorities in residential neighbourhoods. Two of them reported that their residential frontage roads have the same priority as the rest of the residential streets, while the other two reported that residential frontage roads have a lower priority.

The six jurisdictions with transit service along residential frontage roads were asked about concerns related to pedestrian access to bus stops. Two jurisdictions reported having problems regarding pedestrian accessibility on these roads, one of them being Winnipeg. The second one is Milwaukee, Wisconsin, where sidewalks and bus stops are located along the outer separation and are not completely accessible since they have no ramps and are too narrow to properly install an accessible landing pad. Figure 2-6 illustrates an example of a bus stop in Milwaukee.

Figure 2-6: Example of Residential Bus Stop in Milwaukee, U.S.
Place: Oklahoma Ave & S 68th St, Milwaukee, Wisconsin, U.S. Source: ©2010 Google

The residential frontage road practices previously described are presented by jurisdiction in Table 2-3.

Table 2-3: Residential Frontage Road Practices Across Jurisdictions

Country	Province/ State	City	Example of Residential Frontage Road	Type of Residential Frontage Road	Sidewalks on Residential Frontage Roads?	Location of Sidewalk	Location of Bus Stops	Snow Clearance Priority	Issues Related to Bus Stops on Residential Frontage Roads
Canada	**Alberta**	**Calgary**	1686 6 Ave NW, Calgary, AB, Canada	One-way Continuous	Yes	Development side	Outer Separation	N/A	Not an important concern
		Edmonton	Towne Centre Blvd and 23rd Ave	One-way Continuous	Yes	Development side and outer separation	Outer Separation	N/A	Not an important concern
	Manitoba	**Winnipeg**	Bairdmore Blvd	One-way between intersections	No	N/A	Outer Separation	Lower than adjacent roads	Yes, pedestrian access is a concern
	Saskatchewan	**Saskatoon**	Briarwood Rd and Brookmore Cr	One-way between intersections	Yes	Development side	Located in the vicinity but not on outer separation	Lower than adjacent roads	Not an important concern
U.S.	**Idaho**	**Boise - Meridian**	State Street and 26th Street	One-way between intersections	Yes	Development side	N/A	N/A	N/A
	Minnesota	**Minneapolis - St. Paul**	Olson Memorial Hwy and Humboldt Ave N	Two-way continuous	Yes	Development side and outer separation	Outer Separation	N/A	Not an important concern
	North Dakota	**Fargo**	Sheyenne St & 17th Ave W	One-way between intersections	Yes	Development side	N/A	Same Priority	N/A
	Ohio	**Cleveland**	Chester Ave and 84th Street	One-way Continuous	Yes	Development side and outer separation	N/A	Same Priority	N/A
	Wisconsin	**Milwaukee**	Oklahoma Ave & S 68th St	One-way Continuous	Yes	Development side	Outer Separation	N/A	Yes, pedestrian access is a concern

N/A: Information not available, or not known by the respondent.
Source: Prepared by Núñez from various sources, 2010

This jurisdictional survey found that among the 15 surveyed jurisdictions, only Winnipeg has a combination of a large number of frontage roads (more than one hundred), with no sidewalks, low snow clearance priorities, and transit service on the main road.

2.2.3 Summary of Jurisdictional Review

Six interviews with transportation professionals of the City of Winnipeg found:

- There is an argument regarding whether or not by requiring sidewalks along frontage roads the City would create a redundant pedestrian facility that would also limit the available snow storage area, reduce green space, increase run-off, and increase maintenance costs.

- The installation of sidewalks along residential frontage roads is not required since a residential frontage road is considered a local street, due to its low vehicular volumes.

- Vehicular volumes are the main criteria to select snow clearance priorities along residential frontage roads.

- Current design practices follow the TAC design guidelines which do not have specific recommendations regarding accommodation of pedestrians along residential frontage roads. At the same time, current design and maintenance practices do not adhere to the principles of the City of Winnipeg Accessibility Design

Standards (City of Winnipeg, 2006a), nor the Winnipeg Transit “Designing for Sustainable Transportation and Transit in Winnipeg” guidelines (Winnipeg Transit, 2006).

Twenty four interviews with transportation professionals from 15 jurisdictions from Canada and the United States found:

- Almost all of the interviewed jurisdictions follow their local guidelines with respect to the design and maintenance of sidewalks and accessible bus stops.

- Regarding ‘sidewalk warrants’ along residential streets, four respondents mentioned that sidewalks are warranted depending on the functional classification, four jurisdictions reported that sidewalks are warranted on all residential streets, and one jurisdiction reported to warrant sidewalks giving preference to the elderly, the disabled and low income people.

- Of all the surveyed jurisdictions, only Winnipeg has a combination of a large number of frontage roads (more than one hundred), with no sidewalks, low snow clearance priorities, and transit service on the main road.

3. CHARACTERIZATION OF FRONTAGE ROADS IN WINNIPEG

This chapter describes the characterization of all types of frontage roads in Winnipeg, and their relationship with transit accessibility. To illustrate the transportation modes of interest (pedestrians and transit), the street footprint from the City of Winnipeg was obtained and complemented with transit data from Winnipeg Transit, as well as site visit observations.

The street footprint contained the street and sidewalk networks, and the transit data contained bus stop locations, transit analysis zones, and transit routes. Both of these resources were launched and queried on a Geographic Information System (GIS) platform. The street and sidewalk footprint was used to acquire the typical dimensions of frontage roads in Winnipeg.

After the relevant frontage roads and bus stops were identified, site visits were performed during summer 2009 and winter 2010 to understand current design and maintenance practices and to perform ‘reality checks’ regarding the existing footprint. The ‘reality checks’ were site observations made to confirm that the frontage roads analyzed existed, and that their geometry matched the GIS and AutoCAD® files. If problems were found, the issues were addressed, and the data was re-processed. The final goal was to utilize readily-available data to create meaningful information to be used by decision makers. Figure 3-1 summarizes the methodology followed to characterize frontage roads.

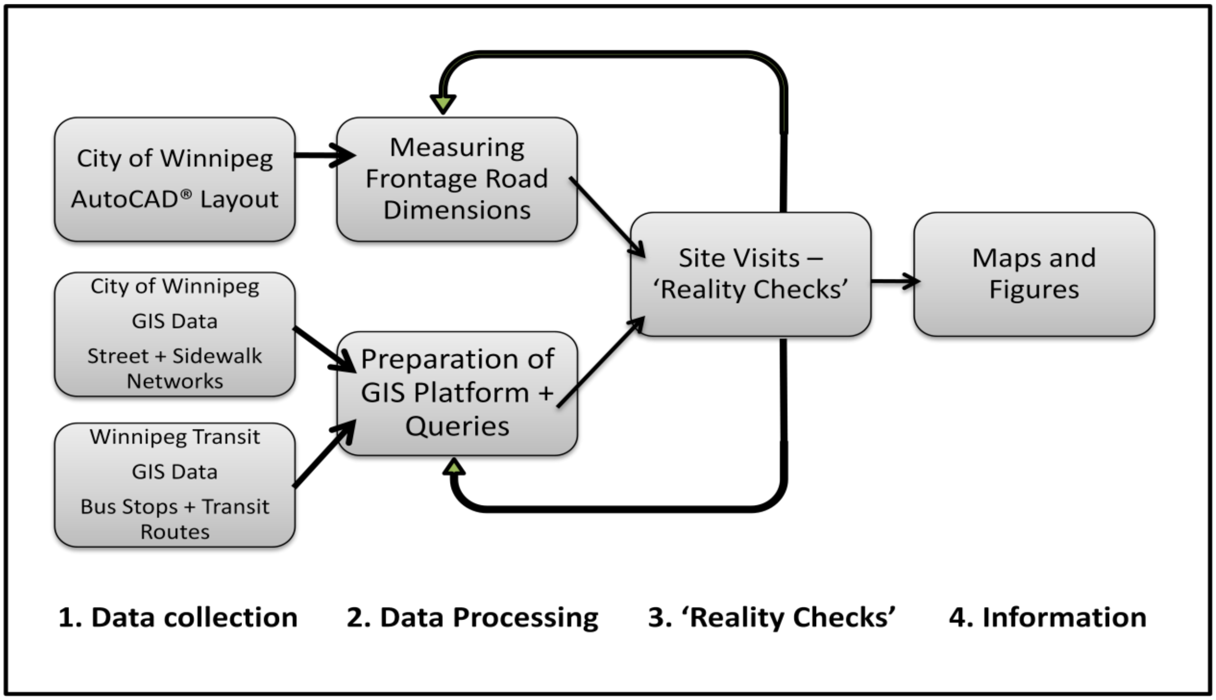


Figure 3-1: Methodology for the Characterization of Frontage Roads
Source: Developed by Núñez, 2009

3.1 FRONTAGE ROADS IN WINNIPEG

Most frontage roads in Winnipeg are one-way and are not continuous, beginning and ending between intersections. There are 134 frontage roads located along transit service routes in residential neighbourhoods. Only eight of these residential frontage roads have sidewalks, and the remaining 126 function as pedestrian facilities, without sidewalks. There are a total of 190 bus stops located in the vicinity of these residential frontage roads (within 50m from the centre line of the frontage road).

Regarding snow clearance priority for the 126 residential frontage roads with transit service and no sidewalks, 57% of them have the lowest snow clearance priority in the city (PIII). The remaining 43% have a medium snow clearance priority (PII). Figure 3-2 summarizes this issue, which is explained in detail in the following subsections.

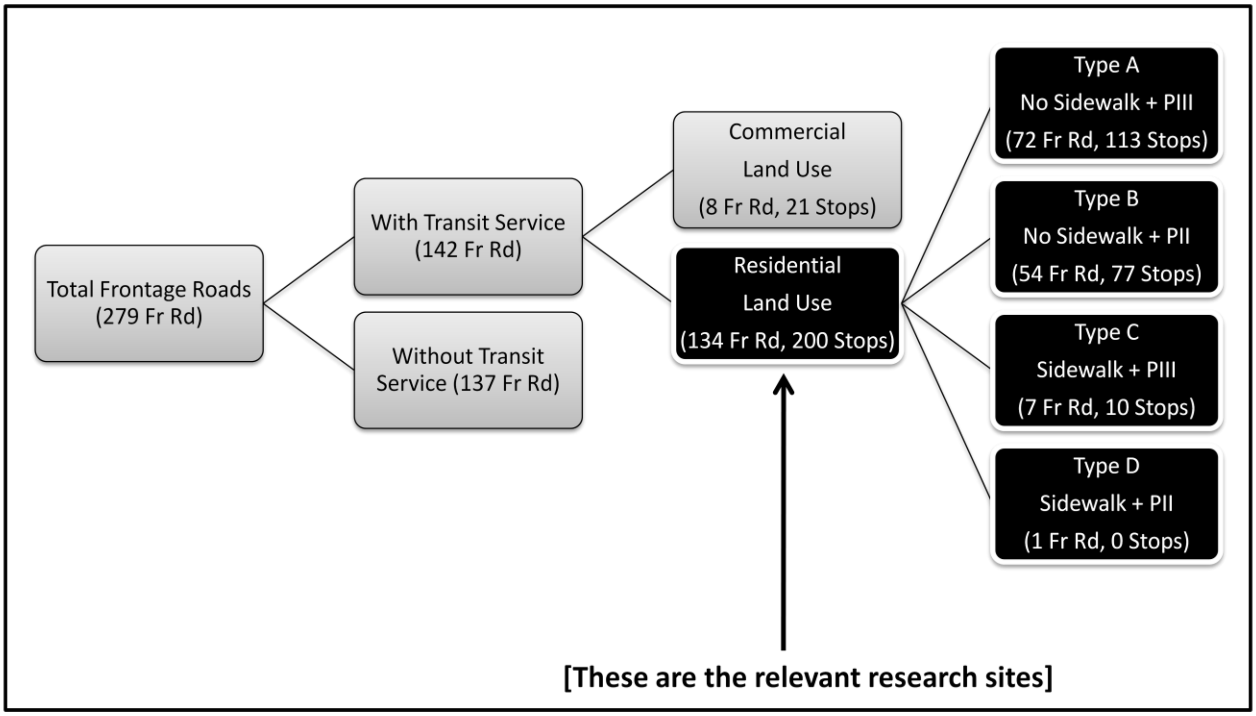


Figure 3-2: Findings from GIS Analysis

Source: Prepared by Núñez from various sources, 2009
Note: The number of stops in this chart consists of all the bus stops contained in a radius of 50m from the centerline of the frontage road.

3.1.1 Context of Frontage Roads

In Winnipeg there are a total of 279 frontage roads (all types), with 142 of these frontage roads located along arterials or collectors that serve transit routes. The majority of the frontage roads' population was found in the south of the city. Figure 3-3 illustrates the frontage road population, differentiating between frontage roads with transit service and frontage roads without service.

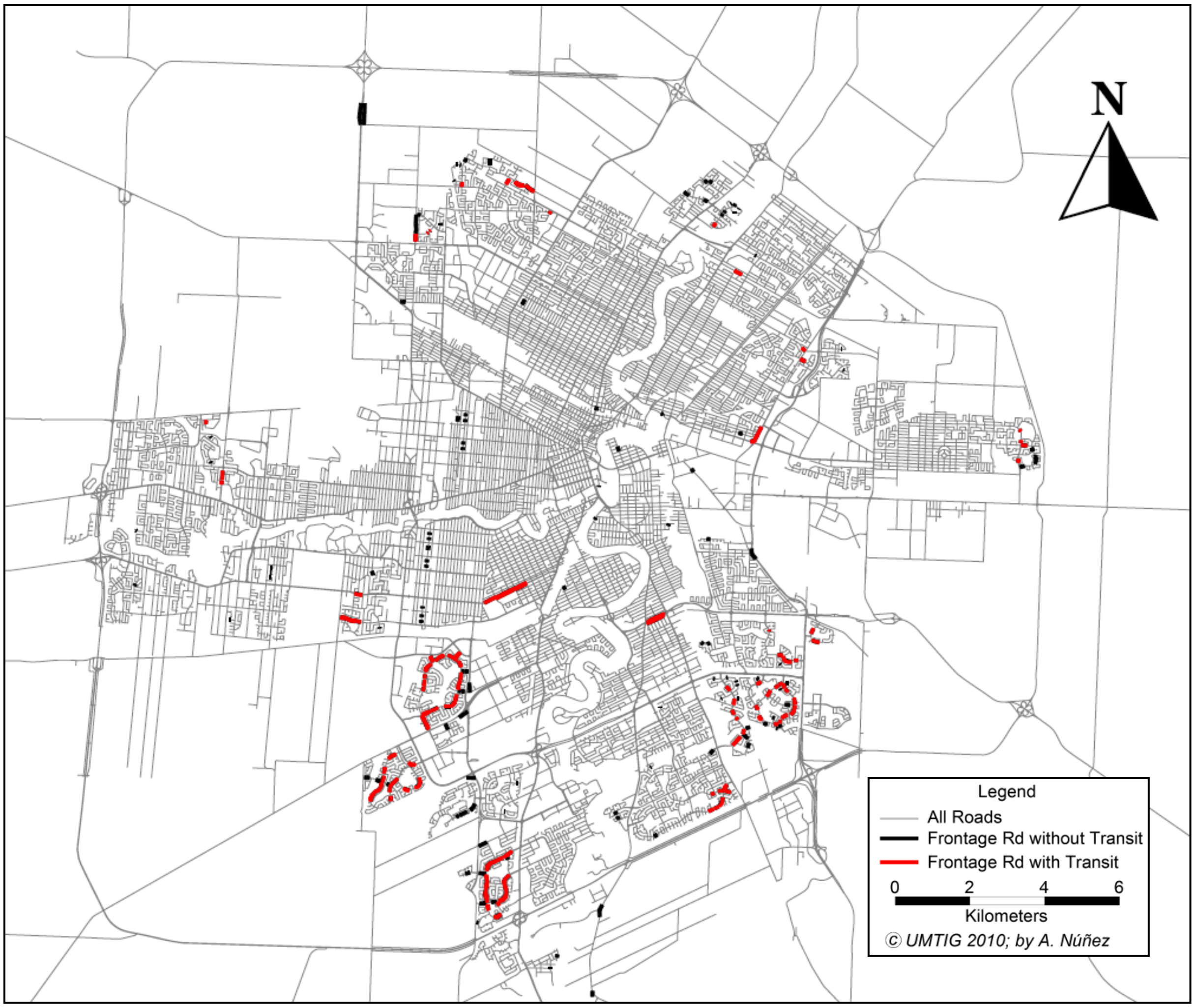


Figure 3-3: Frontage Roads in Winnipeg by Transit Service

Source: Prepared by Núñez from various sources, 2010

Residential land uses account for 134 of the 142 frontage roads with transit service (this does not include Grant Avenue and Panet Road since they serve commercial areas). These 134 residential frontage roads constitute the relevant study sites of this research and serve 200 bus stops located in their vicinity. A radius of 50m was chosen as the vicinity of a residential frontage road because it gives a good representation of the area that a pedestrian might cover within a one-minute walk.

Many of the 134 residential frontage roads are clustered in the south of the city, in recently developed neighbourhoods. Most of the older parts of the city do not have residential frontage roads but have sidewalks on both sides of the street. Figure 3-4 identifies the neighbourhoods with the highest amount of frontage roads and illustrates bus stops, differentiating between commercial and residential land use areas.

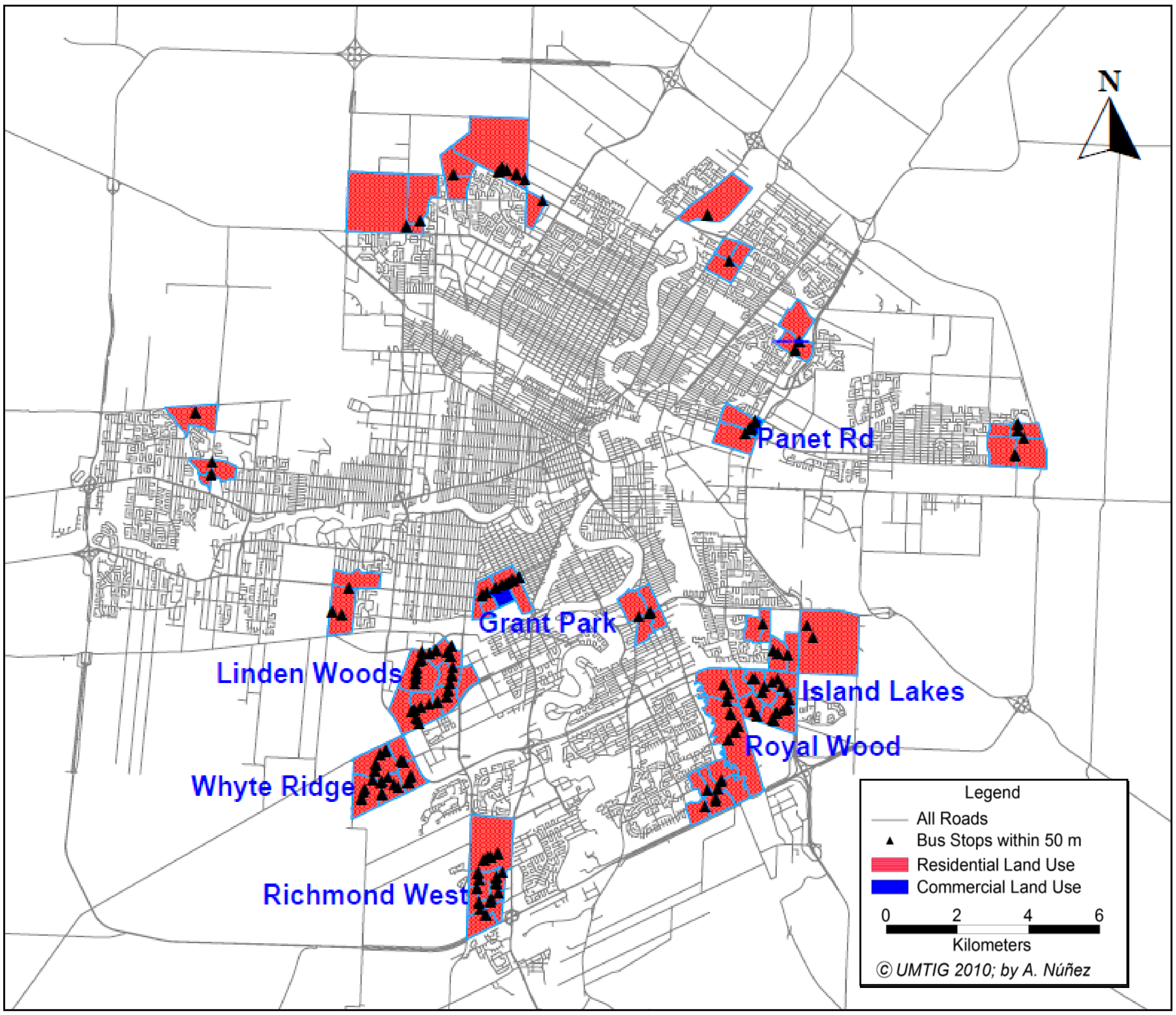


Figure 3-4 Frontage Roads with Transit Service by Land Use
Source: Prepared by Núñez from various sources, 2010

3.1.2 Sidewalk Presence

Current design practices in Winnipeg do not require the installation of sidewalks along residential frontage roads adjacent to collectors or arterials, and therefore residential frontage roads are used as a substitute for sidewalks. Figure 3-5 shows residential frontage roads with and without sidewalks. Of the 134 residential frontage roads of interest to this research, only eight have sidewalks.

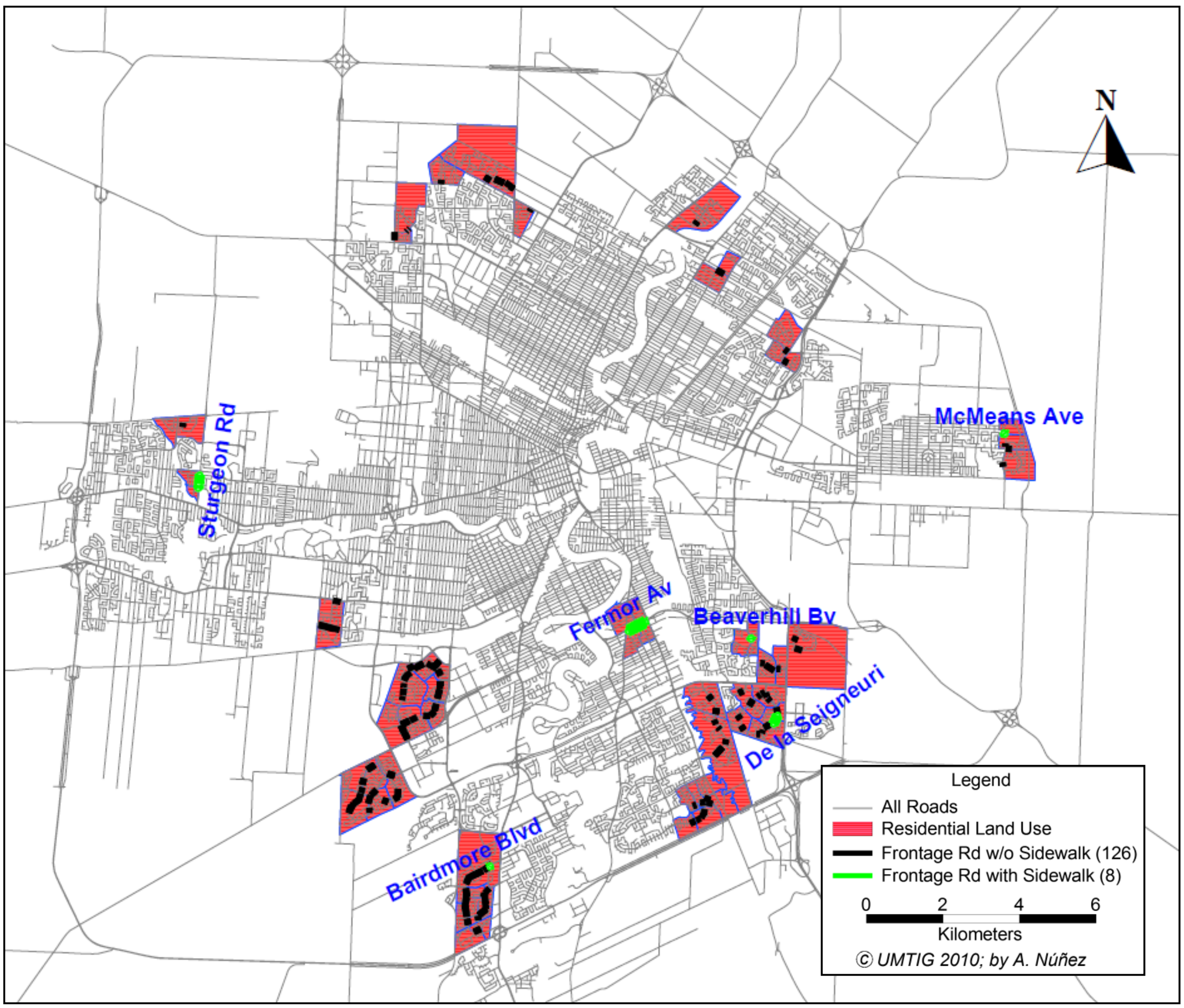


Figure 3-5: Frontage Roads by Sidewalk Presence

Source: Prepared by Núñez from various sources, 2010

3.1.3 Snow Clearance

The Public Works Department of the City of Winnipeg has defined three snow clearance priorities (PI, PII and PIII) to classify the street network, where PI is the most critical, and PIII is the least critical. The research found that none of the residential frontage roads with transit service have the highest snow clearance priority. Seventy nine of the 134 residential frontage roads have a low priority (PIII), and 55 have a medium priority (PII). Figure 3-6 illustrates residential frontage roads organized by snow clearance priority.

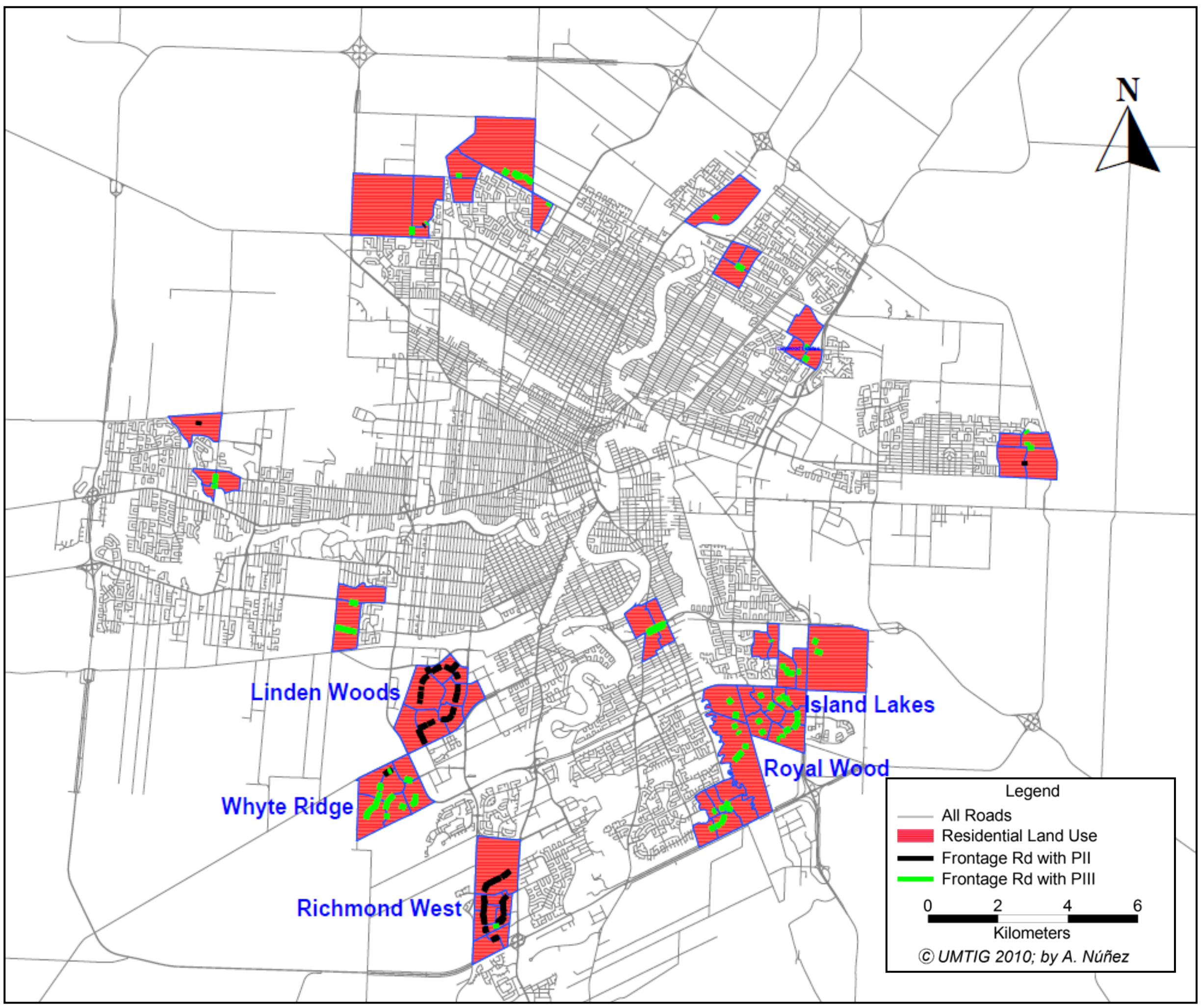


Figure 3-6: Residential Frontage Roads by Snow Clearance Priority

Source: Prepared by Núñez from various sources, 2010

3.1.4 Typical Dimensions of Residential Frontage Roads

Typical dimensions of residential frontage roads are presented for two reasons: (1) to understand the magnitude of the distances traveled by the pedestrian along these facilities, and (2) to explore different possibilities regarding sidewalk and utilities installation (access to utilities like fire hydrants and communication corridors is discussed in the jurisdictional review). All the residential frontage roads located in five neighbourhoods with the highest amount of residential frontage roads were measured using an AutoCAD® footprint. Three specific dimensions were collected: (D1) frontage road length, (D2) frontage road width, and (D3) outer separation width. Table 3-1 summarizes residential frontage road dimensions by neighbourhood and Figure 3-7 illustrates a typical residential frontage road layout.

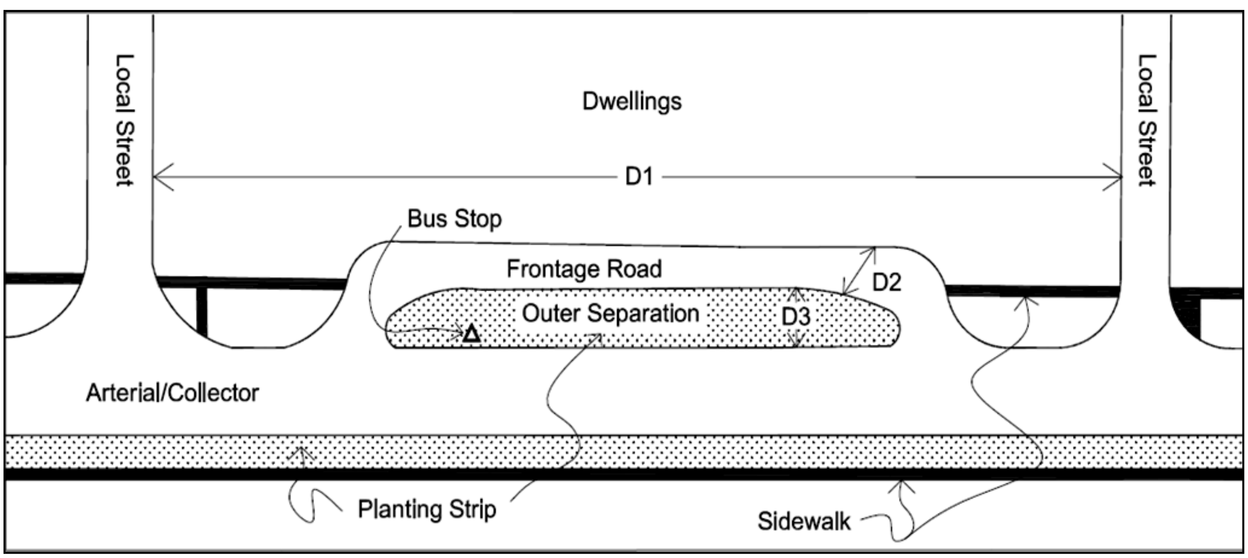


Figure 3-7: Typical Residential Frontage Road Layout in Winnipeg
Drawing is not to scale
Source: Prepared by Núñez from various sources, 2010

	Dimension					
	D1 (metres)		D2 (metres)		D3 (metres)	
Neighbourhood	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Linden Woods	59.8	305.3	4.9	6.3	4.6	8.9
Whyte Ridge	63.4	336.1	4.7	7.3	5.9	8.6
Richmond West	53.2	369.5	4.4	6.5	4.6	10.7
Island Lakes	78.5	282.1	5.4	7.0	2.6	6.1
Royal Wood	73.7	296.9	5.4	7.4	3.8	9.9
Average	157.9		5.6		6.5	
Standard Deviation	66.5		0.6		1.8	

**All dimensions are in metres*

Table 3-1: Frontage Road Dimensions by Neighbourhood

Source: Prepared by Núñez from various sources, 2009

The table shows that there is variability between residential frontage road lengths (D1). This observation is relevant because it means that a given pedestrian might walk anywhere from 60 to 300 meters along a residential frontage road with no sidewalk. Outer separations also have different widths (D3). There may be enough room for utilities and a 1.5m sidewalk along the 10m wide outer separations located in Richmond West, while it would be difficult to have access to utilities in places like Island Lakes, with outer separation widths of 2.6m. Furthermore, residential frontage road width (D2) is the most consistent dimension, since most residential frontage roads have an average width of 5.6m. This distance allows enough space for parking plus a small drive lane, which is the shared right of way for vehicles and pedestrians.

3.1.5 Design and Maintenance Practices of Residential Frontage Roads

Tables 3-2, 3-3 and 3-4 synthesize observations regarding the design and maintenance practices recorded during the site visits performed between 2009 and 2010.

Observation no.1 (residential frontage road in Island Lakes): There are ramps that connect the beginning and end of the frontage road with the contiguous sidewalks, directing the pedestrian to walk along the frontage road.

Observation no.2 (residential frontage road in Richmond West): Bus stops, with street furniture and amenities are typically located on the outer separation. Concrete pads are provided instead of a concrete landing platform or sidewalk.

Observation no.3 (bus stop on outer separation in Richmond West): There are no ramps to connect the contiguous sidewalk or the frontage road with the bus stop, creating a barrier for the user with mobility impairments.

Observation no.4 (residential frontage road with wide curb in Royal Wood): A few frontage roads have splash strips around the outer separation, which is sometimes used as a sidewalk by pedestrians.

Table 3-2: Design and Maintenance Practices Observed during Site Visits (1 to 4)
Pictures by: Núñez, 2009

	**Observation no.5 (residential frontage road in Whyte Ridge):** Some locations have curb cuts but no ramps along the outer separation. Despite the absence of ramps and sidewalks, these curb cuts are still used by the captive sidewalk users (e.g., parents with strollers or people with impairments).
	**Observation no.6 (residential frontage roads in Whyte Ridge:** In some cases, two frontage roads face each other, creating a corridor where sidewalks are eliminated on both sides of the residential arterial or collector. These corridors can be as long as 300m, as defined in the frontage road dimensions summary.
	**Observation no.7 (residential frontage road in Linden Woods):** Parking is allowed along every frontage road; therefore the pedestrian is expected to walk between parked vehicles.
	**Observation no.8 (residential frontage road in Richmond West):** Transit buses never operate along the frontage road, therefore the bus stops are never located along the development side but on the outer separation. These bus stops are used not only by Winnipeg Transit but also by school bus users.

Table 3-3: Design and Maintenance Practices Observed during Site Visits (5 to 8)

Pictures by: Núñez, 2009

	**Observation no.9 (residential frontage road in Whyte Ridge):** Snow clearance priority is given to the main road which is typically cleared to bare pavement, while the frontage road, where the pedestrians are expected to walk, has a layer of compacted snow, which under freezing and thawing conditions becomes slippery.
	**Observation no.10 (front yard drain in a residential frontage road in Royal Wood):** The front yards of adjacent dwellings drain towards the frontage roads, increasing the potential of the road becoming slippery under freezing and thawing conditions.
	**Observation no.11 (bus stop in a residential frontage road in Richmond West):** The outer separation is typically used for snow storage purposes. The high piles of snow around bus stops leave little room for pedestrians. This practice may compromise the access to bus stops, and obstructs the sightlines of the smaller pedestrians, and those in wheelchairs or scooters.
	**Observation no.12 (frontage road in Whyte Ridge):** Footprints indicate that pedestrians and transit users create their own informal paths when traversing these facilities during the winter. These paths are found along the outer separation or along the main road.

Table 3-4: Design and Maintenance Practices Observed during Site Visits (9 to 12)

Pictures by: Núñez, 2009 and 2010

3.2 SUMMARY OF CHARACTERIZATION OF FRONTAGE ROADS IN WINNIPEG

The following is a synthesis from the characterization of frontage roads in Winnipeg:

- Most frontage roads in Winnipeg are one-way frontage roads, and most of the frontage roads located along residential collectors or arterials are one-way frontage roads between intersections.

- In Winnipeg, there are 134 residential frontage roads with transit service. One hundred and twenty six of them do not have sidewalks and function as pedestrian facilities for transit users who want to access 190 bus stops located within a radius of 50 m from the centre of the residential frontage road.

- Regarding snow clearance priority for the 126 residential frontage roads with transit service and no sidewalks, 72 of them have the lowest snow clearance priority in the city (PIII). The remaining 54 residential frontage roads have a medium snow clearance priority (PII).

- There is variability between residential frontage road lengths. This observation is relevant since it means that a given pedestrian might walk anywhere from 60 to 300 meters along a residential frontage road with no sidewalk.

- Outer separation widths vary between neighbourhoods. There is enough room for utilities and a 1.5m sidewalk in neighbourhoods with 6.0m or wider outer separations, but it would be difficult to have appropriate access to utilities in areas where outer separation widths are 2.6m (the current minimum planting-strip width to access utilities is 4.0m).

- There are differences in residential frontage road design, but there are common practices regarding the way in which they are utilized: (1) bus stops are located in outer separations, in areas where there are no sidewalks; (2) bus stops do not have provisions for captive sidewalk users (i.e. ramps); and (3) bus stops are used not only by Winnipeg Transit but also by school bus users.

- Snow clearance priority is given to the main road, which is typically cleared to bare pavement, while the residential frontage road has a layer of compacted snow. Under freezing and thawing conditions this layer of snow reduces its friction (becomes slippery). This is also true for those properties whose front yard drains towards the residential frontage road.

- The outer separation is typically used for snow storage purposes. The high piles of snow around bus stops leave little room for pedestrians reaching bus stops. This practice may compromise access to bus stops, and may obstruct the sightlines of smaller pedestrians, and those in wheelchairs or scooters.

- Footprints and informal paths located along outer separations and the main street indicate that pedestrians and transit users sometimes avoid residential frontage roads and create their own paths when traversing these facilities during the winter.

4. RESEARCH METHODOLOGY

This chapter discusses the methodology used in this research for the collection of data on pedestrian paths along residential frontage roads. The chapter first defines the characteristics of pedestrian study groups and study sites. It then describes the data collection process used to capture the variables required to analyze differences in seasonality, gender, age, and ambulatory capabilities. Pedestrian walking paths are grouped into three main trajectories: (a) pedestrians walking on the frontage road; (b) pedestrians walking on the outer separation; and (c) pedestrians walking on the main road. Pedestrian paths were collected for bus stop users and non bus stop users walking along residential frontage roads with transit service.

4.1 CHARACTERISTICS OF THE STUDY GROUPS AND THEIR WALKING PATHS

Before collecting the pedestrian walking paths (trajectories), users were classified depending on bus stop usage, into one of the following two groups: (1) people on their walking journey along a residential frontage road before boarding, or after alighting the transit or school bus (bus stop users), or (2) pedestrians traversing a residential frontage road and not using the transit stop (non bus stop users).

During the data collection process, the following situations and/or types of pedestrians were excluded to improve the accuracy of the analysis:

- People cycling, or walking with bicycles

- People using skate boards or roller skates
- People playing sports along residential frontage roads
- People whose gender or age could not be easily determined
- People whose trajectories were errant (i.e. people walking a few steps along the outer separation, a few steps on the road, and then crossing the street).
- People not walking a significant distance along the residential frontage road (i.e. people living in dwellings along the residential frontage road and just crossing the street).

An important criterion to accept or reject pedestrians and transit users for this study was whether or not the person was walking a significant distance along the given residential frontage road. Based on site observations, pedestrians walking at least 15 meters along the residential frontage road had to face three path choices: (a) to walk on the frontage road; (b) to walk on the outer separation; or (c) to walk on the main road.

Figure 4-1 and Figure 4-2 give examples of different paths of bus stop users and non bus stop users that are considered valid for this research. Figure 4-3 and Figure 4-4 illustrate examples of invalid walking paths that are rejected because they are considered errant or because their trajectories cannot be classified in any of the three path choices mentioned above.

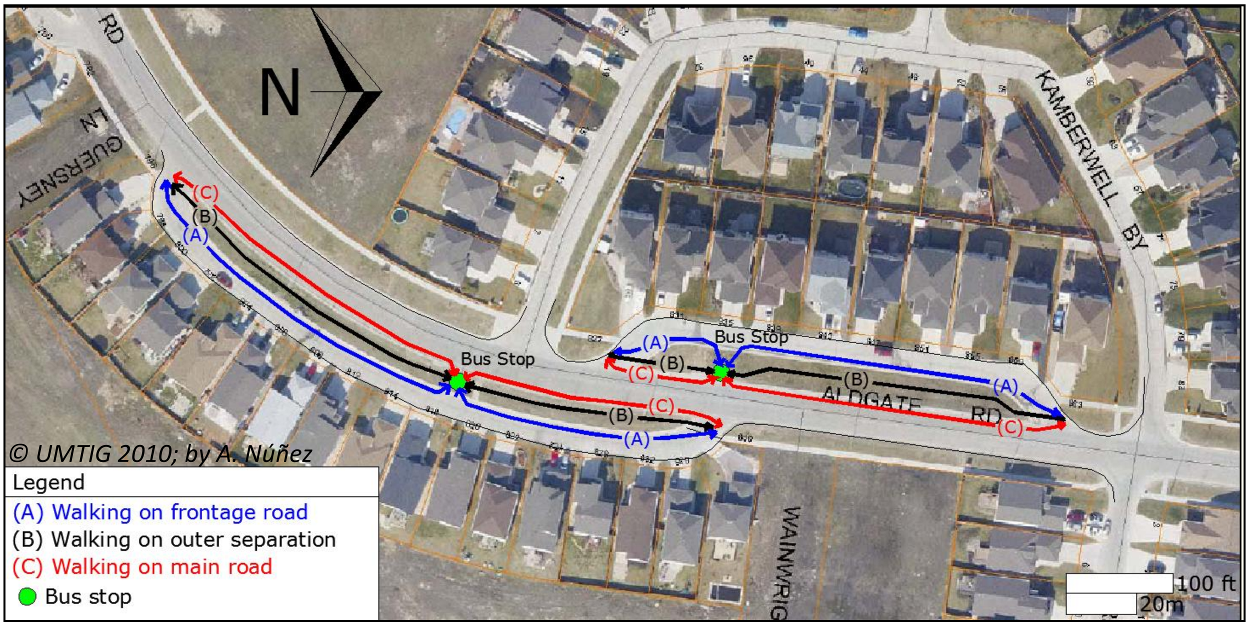


Figure 4-1: Valid Walking Paths of Bus Stop Users

Source: Aerial photo provided by City of Winnipeg, paths developed by Núñez, 2010

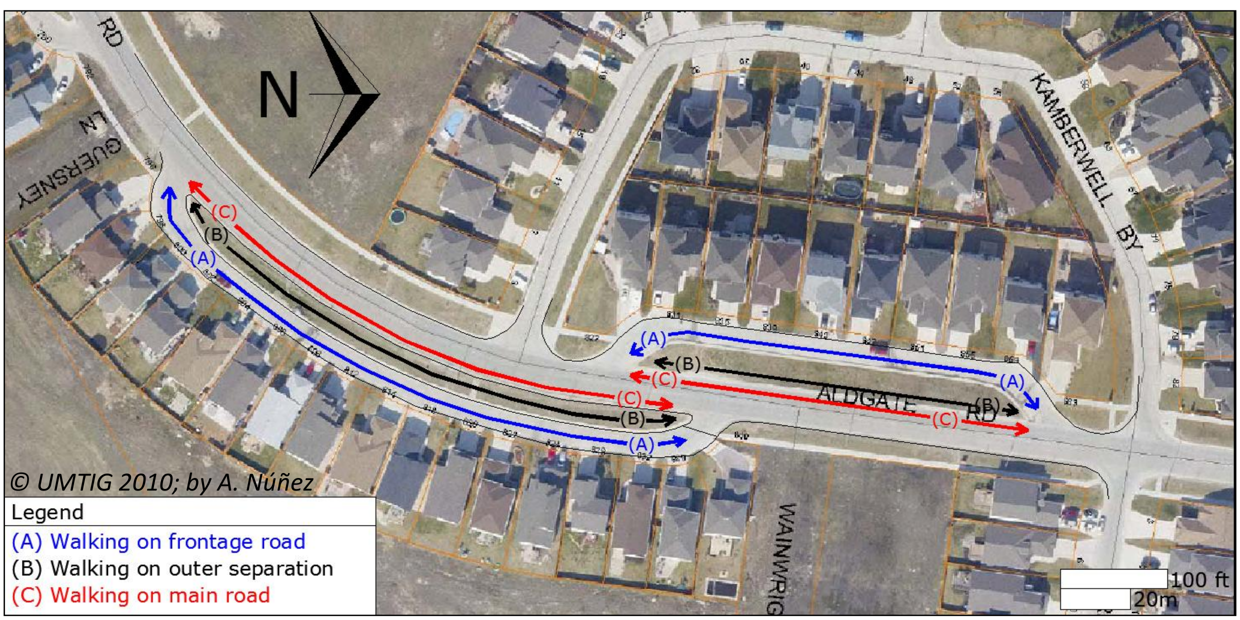


Figure 4-2: Valid Walking Paths of Non Bus Stop Users

Source: Aerial photo provided by City of Winnipeg, paths developed by Núñez, 2010

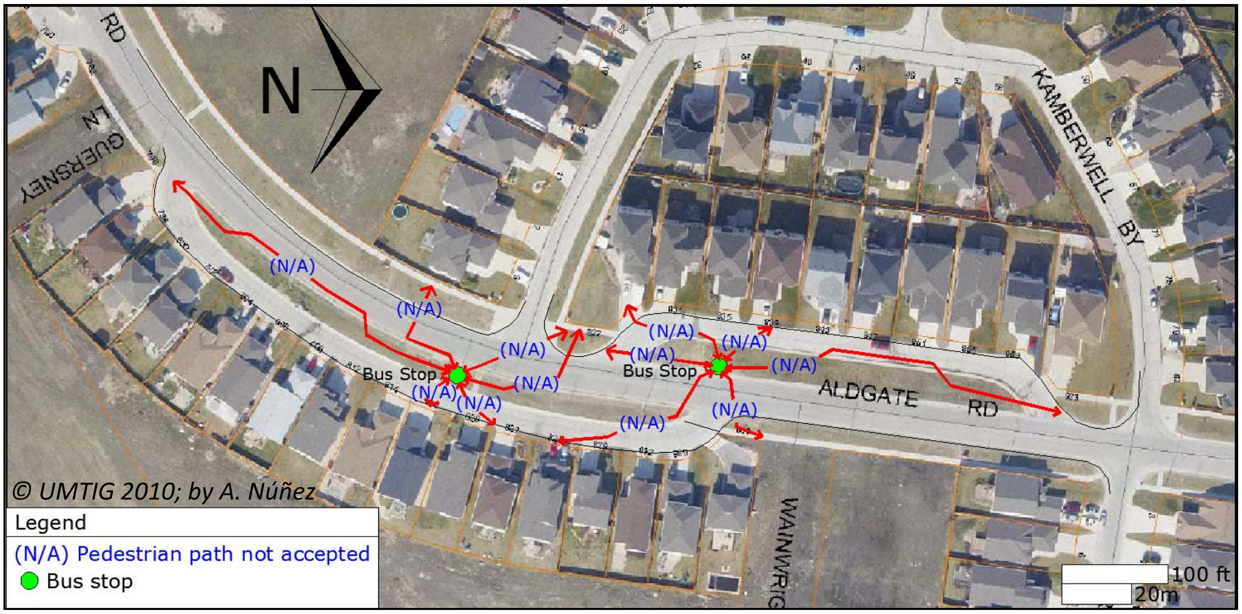


Figure 4-3: Invalid Paths of Bus Stop Users
Source: Aerial photo provided by City of Winnipeg, paths developed by Núñez, 2010

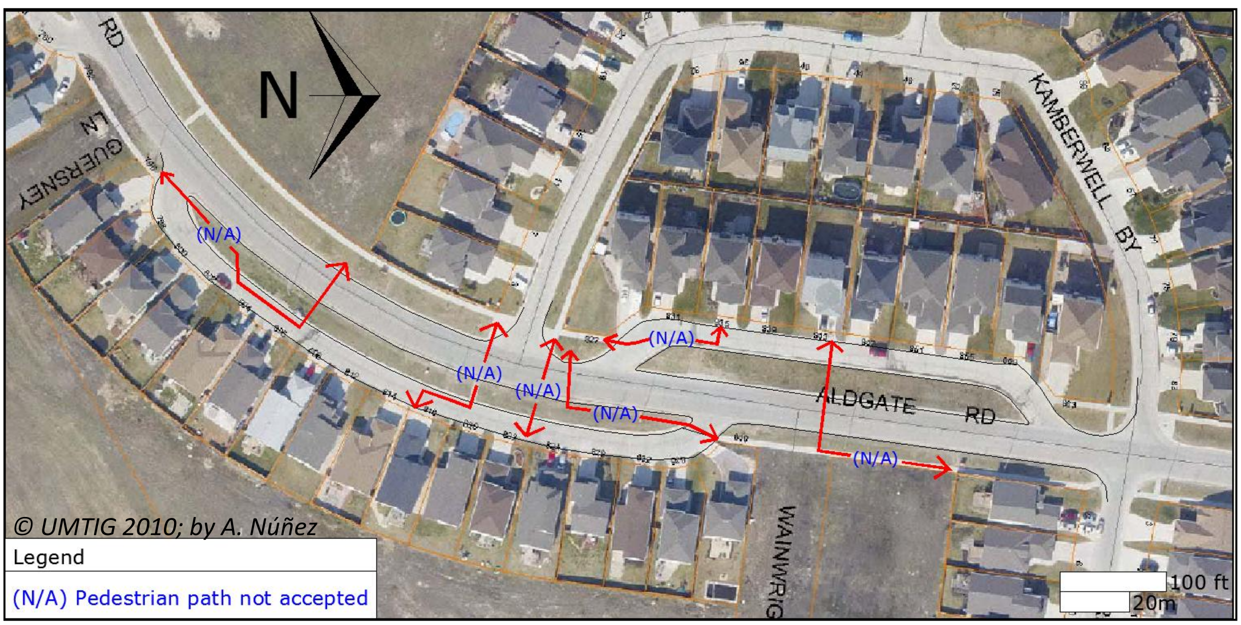


Figure 4-4: Invalid Paths of Non Bus Stop Users
Source: Aerial photo provided by City of Winnipeg, paths developed by Núñez, 2010

4.2 DEFINING AGE AND SPECIAL AMBULATORY CHARACTERISTICS

With the purpose of identifying age-related differences, pedestrians' ages were grouped into two categories: below and above 65 years old (judged by observation). With regards to special ambulatory situations, pedestrians were also classified into seven categories: (1) pedestrian using a wheelchair; (2) pedestrian walking with a cane; (3) pedestrian using a walker; (4) pedestrian walking with a stroller; (5) people using scooters; (6) pedestrian walking with young children (this category includes all situations where adults decide the walking paths of young children); and (7) other special situations (e.g., walking with crutches). These seven categories were combined to create the 'captive sidewalk users' group, as defined in the terminology of Chapter 1.

4.3 SAMPLE SIZE

In statistics theory, tests have higher levels of statistical power when: (1) studies can detect small differences; (2) their expected effects are large; and (3) their criteria for statistical significance are relaxed. However in practice, sample size (number of observations) is the most trusted determinant of power (Murphy et al., 2009).

To calculate the minimum sample size of this research, the following parameters were established:

$$\alpha = 0.05\ (typical\ alpha\ value)$$

$$P = (1 - \ \beta) = 0.8\ (typical\ power\ value)$$

$$d = 0.35\ (standaraized\ mean\ difference\ used\ to\ find\ medium\ to\ small\ diferences)$$

$$Groups = 8\ \ (number\ of\ groups\ from\ four\ comparisons)$$

$$df_{hyp} = 8\ groups - 1 = 7\ (degrees\ of\ freedom)$$

Utilizing these parameters the minimum number of observations calculated was 479, which was rounded to 480. The methodology, equations and tables used for this calculation are recommended by Murphy et al. (2009).

The minimum sample size of 480 observations was applied only to the most relevant study group, the “bus stop users group”. It is important to note that data on “non bus stop users” was collected to have additional evidence regarding the walking paths of pedestrians. As a result, “non bus stop user” walking paths were recorded only while collecting the 480 bus stop user path observations.

These 480 observations are evenly distributed amongst the two seasons and the different study sites. Since the final site selection includes four sites, each site has 120 observations, 60 under ‘no-snow’ and 60 under ‘snow on the ground’ conditions. There are no specific splits (minimum amount of observations) regarding age, gender or ambulatory capabilities.

4.4 SITE SELECTION

The site selection process utilizes the same data, tools and software platforms described in Chapter 3. This site selection process is designed to optimize the data collection by targeting those sites with a high number of transit users and pedestrians walking along residential frontage roads with no sidewalks.

The site selection process is subdivided into three screening steps: the first step classifies all the potential study sites by looking at relevant design features; the second step looks at the transit user volumes to identify the busiest locations; and the third step involves site visits to identify those locations with the ideal context to survey pedestrian paths in an efficient manner.

4.4.1 Site Design Screening

As discussed in Chapter 3, there are 134 residential frontage roads in Winnipeg. These residential frontage roads are further grouped into two categories: (1) sites with bus stops within a radius of 10m; and (2) sites without bus stops within 10m. This 10m radius increases the potential of finding pedestrians walking on a residential frontage road when accessing the transit stop, as opposed to the 50m radius utilized in Chapter 3, which represented a one-minute walk.

The 10m radius was measured from the centre line of the residential frontage road right of way and was also selected to ensure that all the bus stops in this category were located along the same side of the residential frontage road, not across the given arterial or collector street. By using this new criterion, 71 sites with bus stops were selected for further investigation.

It was found that the majority of these sites are located in the south of the city, particularly in five neighbourhoods: Linden Woods, Whyte Ridge, Richmond West, Royalwood, and Island Lakes.

The literature states that sidewalk provisions affect walking experience and pedestrian walking paths. For this reason, the potential study sites were classified taking into consideration the absence or existence of sidewalks along residential frontage roads and across their corresponding arterial or collector streets. Using these considerations, the 71 selected residential frontage roads were classified into the following site types:

- Type 1: sidewalk along + sidewalk across (only 1 residential frontage road)
- Type 2: sidewalk along + no sidewalk across (only 1 residential frontage road)
- Type 3: no sidewalk along + sidewalk across (46 residential frontage roads)
- Type 4: no sidewalk along + no sidewalk across (23 residential frontage roads)

Sites Type 1 and Type 2 could only be found on one residential frontage road each. They were rejected because they are not representative of current design practices, leaving 69 potential sites. Figure 4-5 summarizes the findings from the site classification screening.

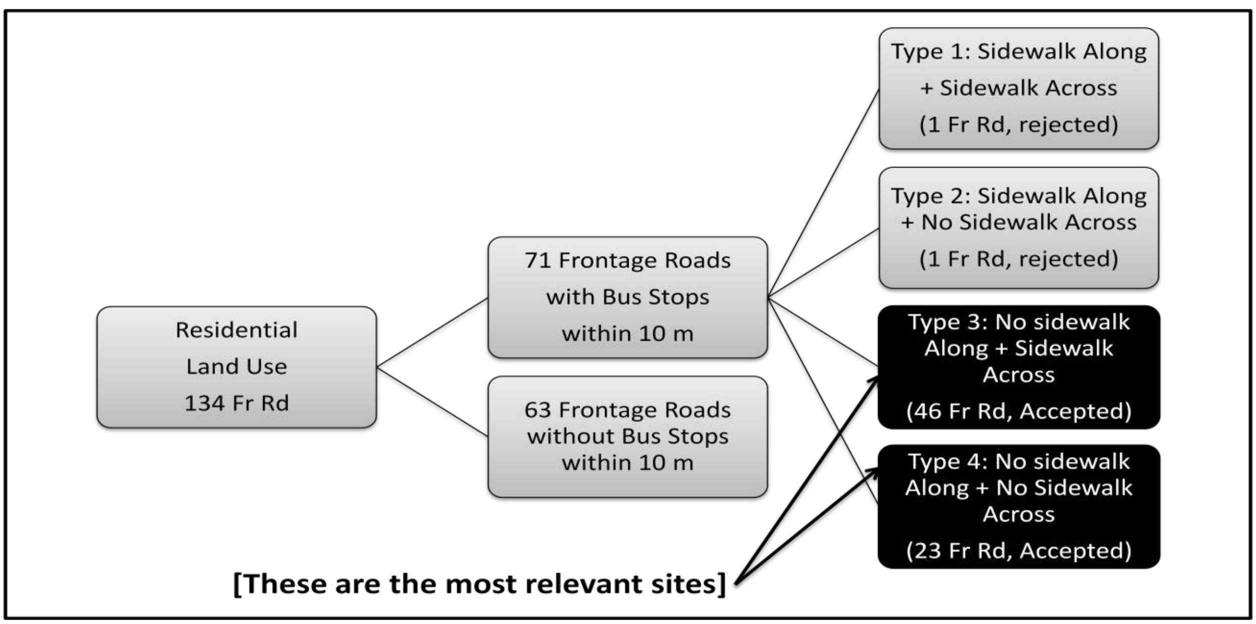


Figure 4-5: Findings from Study Site Classification

Source: Developed by Núñez, 2009

4.4.2 Site Volume Screening

Step 1 of the site selection process resulted in 69 residential frontage roads (with one bus stop each) of further interest to this research. These residential frontage roads were selected by analyzing their context and their design elements. In this second screening step, these sites are filtered by analyzing transit user volumes. The purpose of this task is to specifically target those sites with the highest number of transit users boarding or alighting the transit bus, becoming pedestrians who are likely to walk along the residential frontage road.

Automated Passenger Counting Systems (APC) and Automated Vehicle Location (AVL) data was obtained from Winnipeg Transit. This data is collected automatically on everyday operations by using a Global Positioning System (GPS) that locates the exact position of the bus every second, plus a series of on-board infrared cameras that count pedestrians boarding and alighting the transit bus. All this information is logged into a hard disk installed inside the bus. This hard disk is also connected to a wireless modem that transfers the data to a main computer once the bus is back at the transit garage.

The APC-AVL dataset was obtained from Winnipeg Transit in 2009; this data corresponds to the fall period of 2008 (September through November). This period was chosen since it is the most representative of the yearly transit ridership average (spring and summer riderships are low, and winter ridership is higher than the average).

This dataset was queried and summarized to obtain daily bus stop user averages per bus stop. These averages were classified by bus stop type and are shown in Appendix C. When analyzing this data, it was found that 35 of the 69 sites serve 80% of the people boarding or alighting the transit bus. These 35 sites are comprised by 23 bus stops Type 3 (no sidewalk along + no sidewalk across) and 12 stops Type 4 (no sidewalk along + no sidewalk across).

Figure 4-6 shows the cumulative distributions of bus stop users organized by type of site. Based on these results, the 10 bus stops with the highest amount of users (per type of site) were selected for further screening.

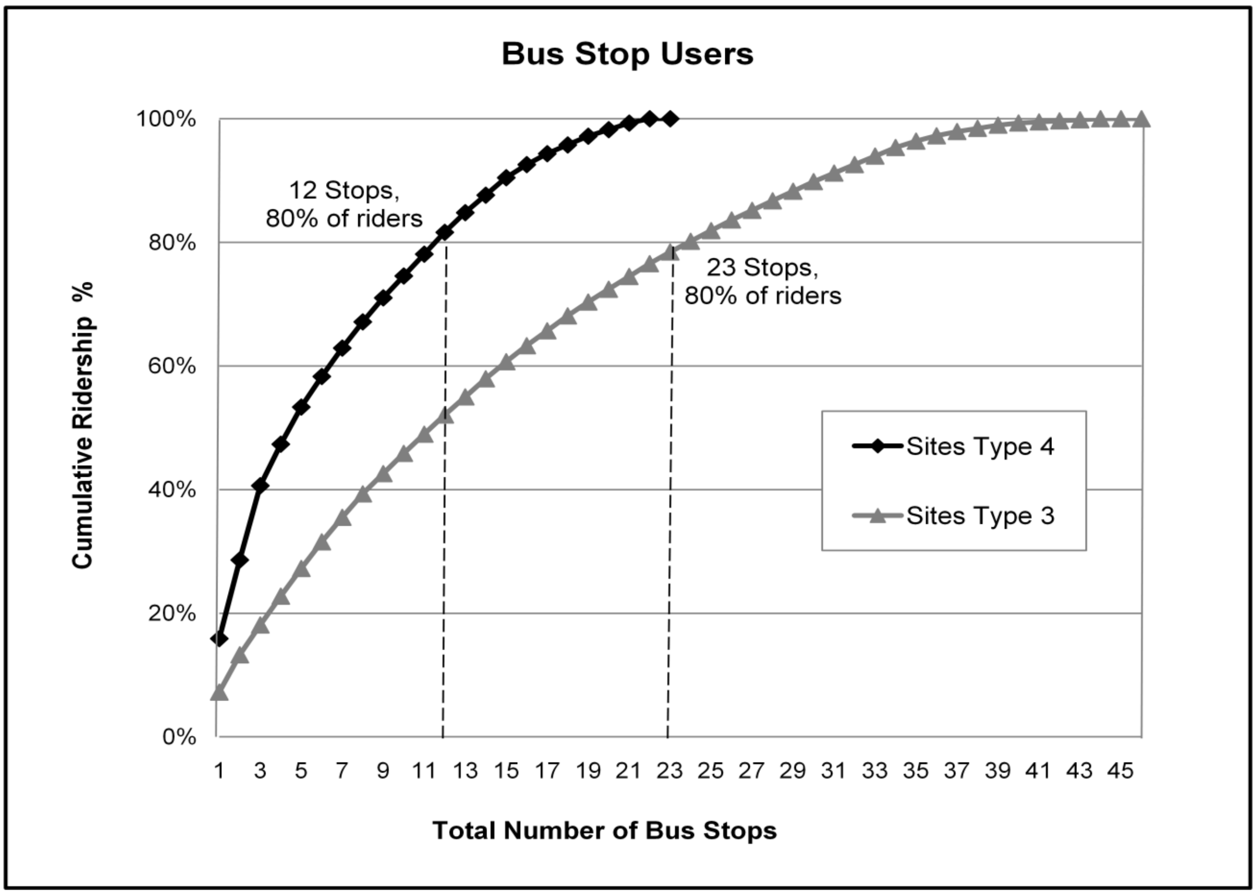


Figure 4-6: Cumulative Distribution of Bus Stop Users by Type of Site

Source: Developed by Núñez in 2009, based on Winnipeg Transit ridership data

4.4.3 Site Visit Screening

Site visits were performed as part of the third screening step with two purposes: (1) to verify the results from the site selection and volume analyses; and (2) to perform data collection tests. A total of 20 site visits and 20 data collection tests were performed at the 10 sites with the highest amount of bus stop users (10 bus stops Type 3, and 10 bus stops Type 4).

When verifying the site selection analysis it was found that most of the information was accurate. The residential frontage road geometry and number of bus stop users was similar to the one in the analysis. However, while performing the data collection tests, the research found that sites Type 3 (sidewalk along + sidewalk across) were not suitable to objectively collect pedestrian paths of transit users. The reason for this is that when approaching or leaving the bus stops, the bus stop users walked along the sidewalk across the street. Also, when the bus stop was located at one of the ends of the outer separation, the user walked the shortest path. It was not clear if the pedestrian made any real path choice under this context.

As an example, two data collection tests of 2.5 hours each were performed at the bus stop located along John Forsyth Rd. and Winterhaven Dr. During this time only four transit users walked along the residential frontage road in the “valid” direction, and 30 users were rejected. Figure 4-7 illustrates the valid and invalid paths on this particular site.

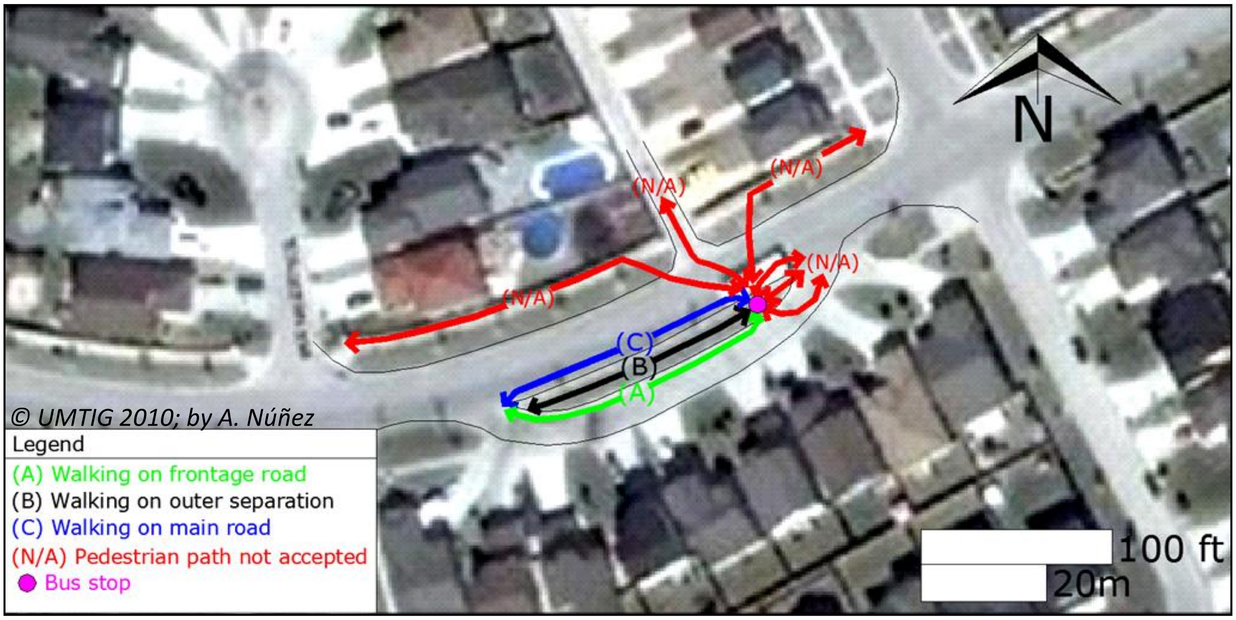


Figure 4-7: Accepted & Rejected Paths on J. Forsyth Rd. and Winterhaven Dr.
Source: Aerial photo provided by City of Winnipeg, paths developed by Núñez, 2010

When performing data collection tests at Type 4 sites, it was observed that these sites facilitated the classification of pedestrian paths, particularly those of transit users. Bus stops Type 4 are located along residential arterials or collectors with no sidewalks on either side. This design context is created when residential frontage roads are located on both sides of the main road. This situation provides a context where the pedestrian does not have the choice of walking along a sidewalk across the street, and where multiple Type 4 bus stops can be surveyed at the same time. These advantages allowed the data collection tests on Type 4 sites to be successful. An example is found on the site located at Waterbury Dr. and Lindenwood Dr. Two data collection tests of 2.5 hours each were performed at this site, during this time 20 transit users walked along the residential frontage road in the desired direction, and 11 were rejected. Figure 4-8 illustrates examples of valid and invalid paths at this particular site.

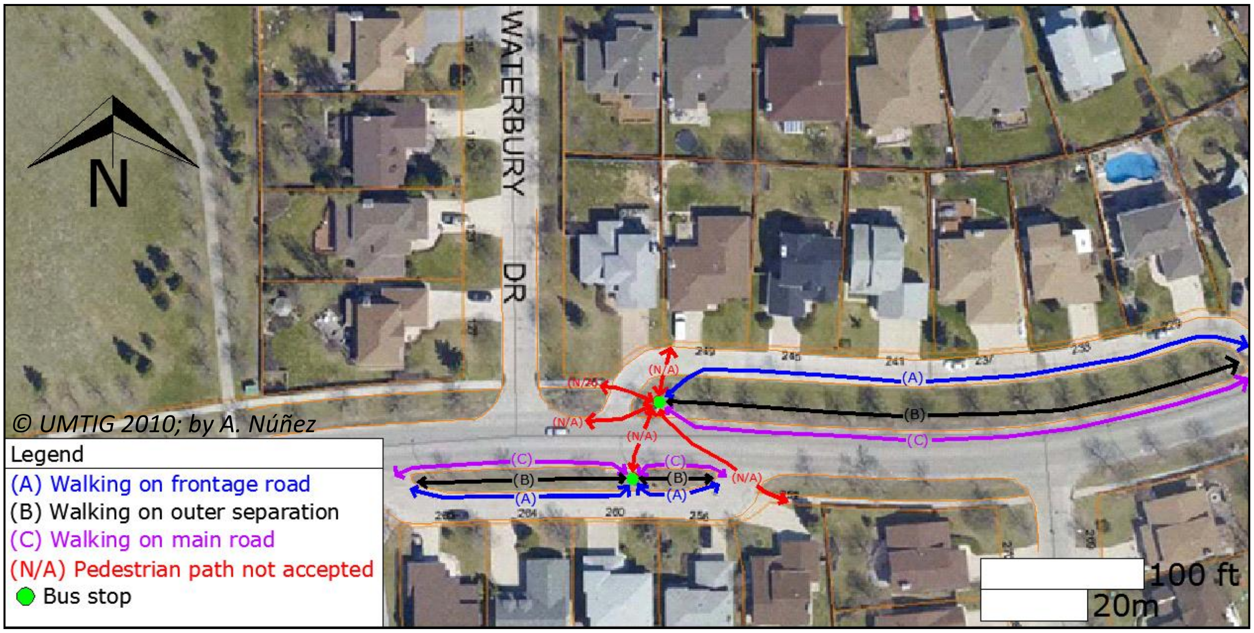


Figure 4-8: Accepted & Rejected Paths at Waterbury Dr. and Lindenwood Dr.
Source: Aerial photo provided by City of Winnipeg, paths developed by Núñez, 2010

4.4.4 Final Site Selection

The screening process determined that only Type 4 sites (no sidewalk along + no sidewalk across the main road) were going to be further investigated. A total of 12 stops serve 80% of the transit riders in this context, and by using expert advice and the results from the data collection tests, eight bus stops located in four sites were selected. Figure 4-9 shows a map the final site selection, contrasting the 71 bus stops within 10m of a residential frontage road versus the four sites selected for the study (two bus stops per site). Figure 4-9 also shows how these sites are distributed over the neighbourhoods with the highest amount of residential frontage roads in the city. Figures 4-10 and 4-11 present aerial pictures of these sites.

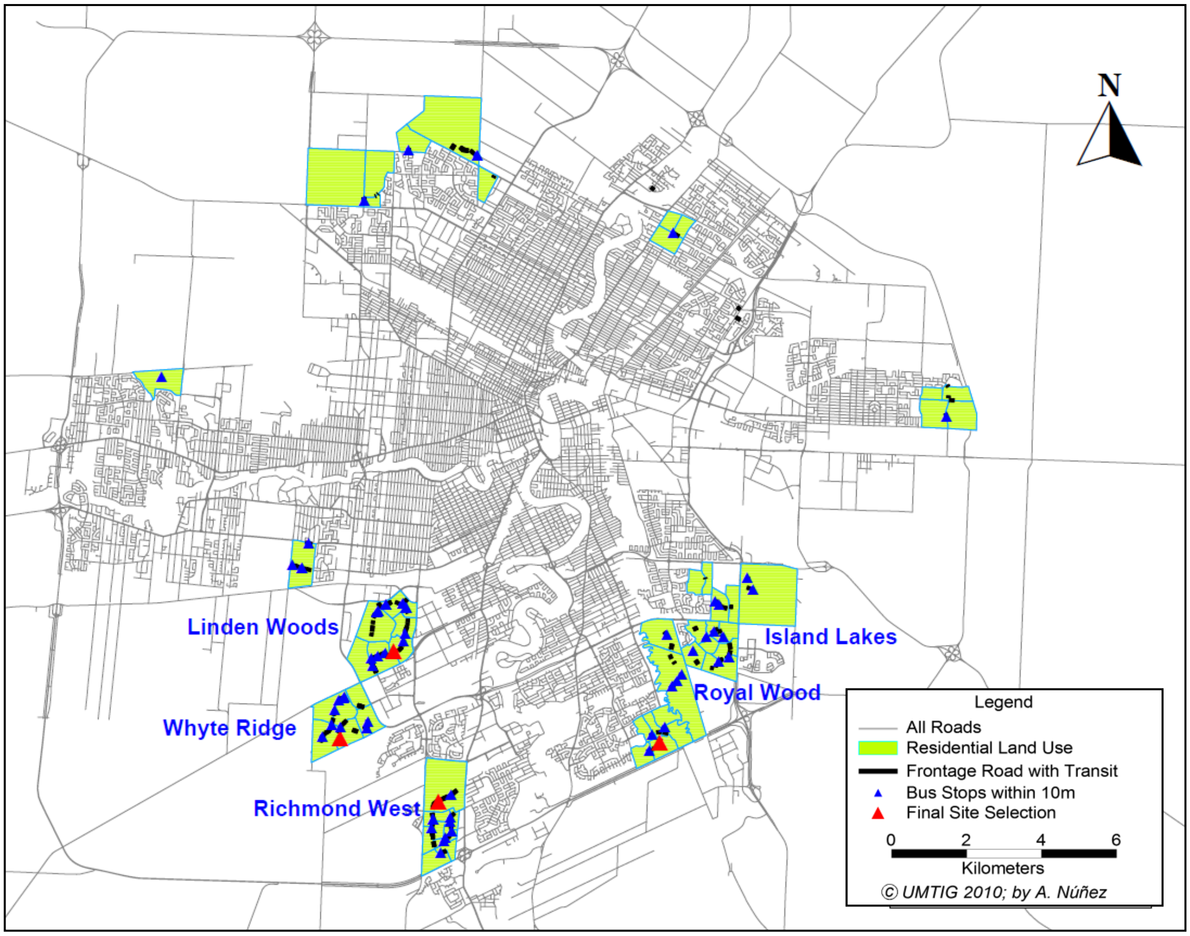
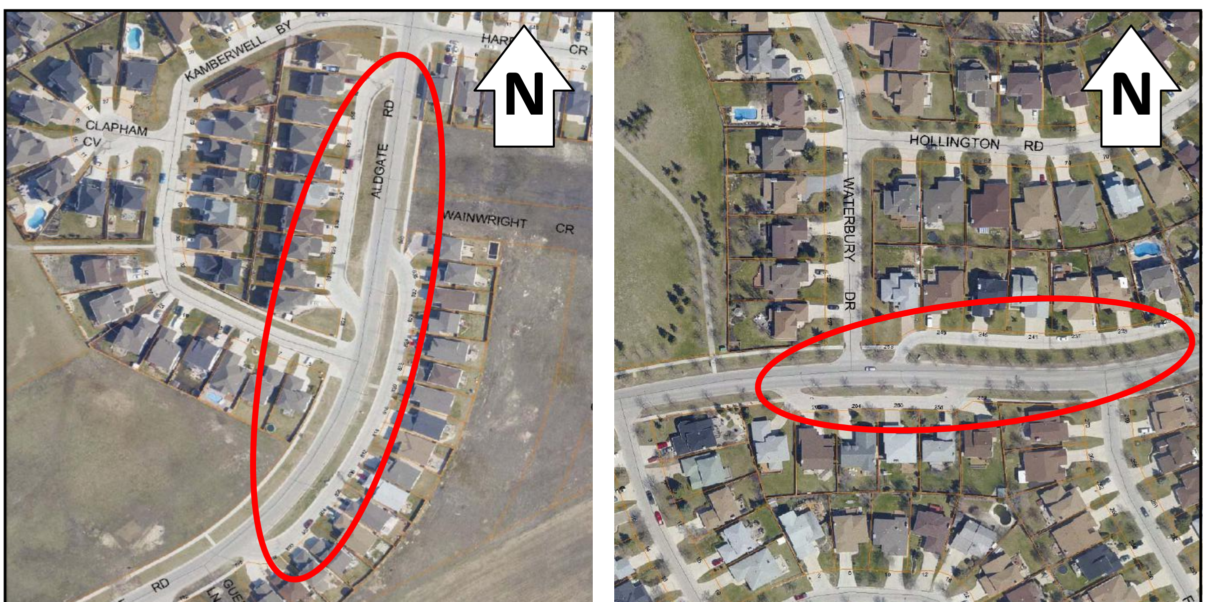
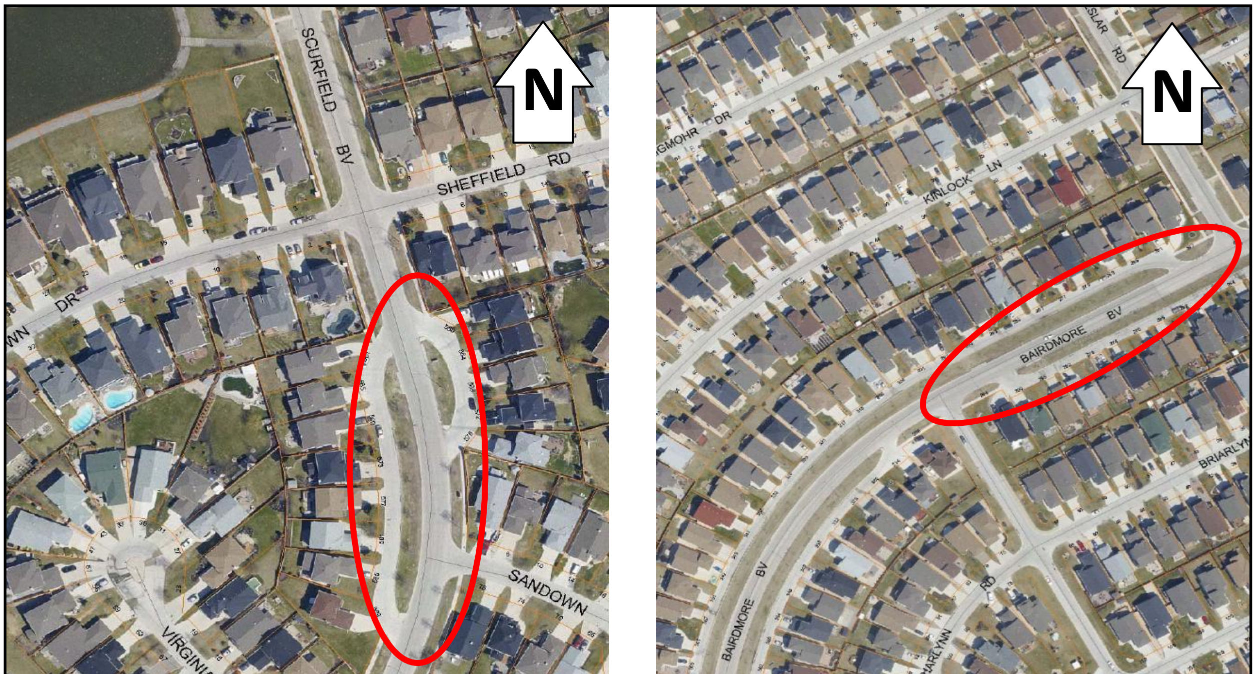


Figure 4-9: Map of Final Site Selection
Source: Developed by Núñez, 2009



Aldgate Rd. and Kamberwell Bay
Waterbury Dr. and Lindenwood Dr.

Figure 4-10: Aerial Pictures of Final Site Selection (Sites 1 and 2)
Source: Aerial photos provided by City of Winnipeg, 2010



Sheffield Rd. and Scurfield Blvd. *Bairdmore Blvd. and Calderwood Bay*

Figure 4-11: Aerial Pictures of Final Site Selection (Sites 3 and 4)

Source: Aerial photos provided by City of Winnipeg, 2010

4.5 DATA COLLECTION PROCESS

Each count consisted of one trained person (also called "counter") observing the pedestrian paths during a period of 2.5 hours, each day data was collected. All the data was recorded by hand using the formats shown in Appendix D.

At the beginning of the count, the counter was required to record the date, time, location of the count, and condition of the site in terms of snow presence (snow vs. no-snow on the ground).

Once the time and site conditions were entered, the criteria explained in this chapter were used to determine valid vs. invalid paths. The valid paths of unaware pedestrians were further classified into one of three categories: (1) pedestrian walking on frontage road; (2) pedestrian walking on outer separation; or (3) pedestrian walking on main road (residential arterial or collector).

At the same time, the counter identified the particular characteristics of each pedestrian. Those characteristics were: (1) gender; (2) if the pedestrian was a transit or school bus user; and (3) if the pedestrian was a senior or not (all pedestrians whose estimated age was 65 years or older were considered seniors).

The last field recorded for these counts classified special ambulatory situations. Under this field seven options were predetermined: (1) wheelchair user; (2) pedestrian walking with cane; (3) pedestrian using walker; (4) pedestrian walking with young children; (5) pedestrian walking with stroller; (6) pedestrian using scooter; or (7) other ambulatory challenges (e.g., walking with crutches). If the pedestrian was classified into any of these categories, this person was considered a captive sidewalk user.

This data was collected during the morning and afternoon peak periods (from 6:30 to 9:30 am and from 3:00 to 6:00 pm), during weekdays, excluding statutory holidays. The counts were performed at the four selected locations until the sample of 480 walking path observations of bus stop users was obtained. Each site required 60 observations during no-snow conditions and 60 during snow conditions. The sample was collected over a period of eight months.

5. ANALYSIS OF PEDESTRIAN WALKING PATHS

This chapter discusses the data analysis of pedestrian travel paths along residential frontage roads. The analysis is divided into two subsections: (1) bus stop users; and (2) non bus stop users. A total of 1,301 pedestrian path observations of both types of users (pedestrians) were collected from August 2009 to March 2010.

5.1 BUS STOP USERS

A total of 480 observations of unaware bus stop users are included in this part of the analysis. The observations are distributed proportionally amongst four sites and two seasons. All these observations of pedestrian paths were classified into three categories: (A) pedestrian walking on frontage road; (B) pedestrian walking on outer separation; and (C) pedestrian walking on the main street. For more details on what is a bus stop user, and what is a valid pedestrian path, refer to Chapter 4.

Statistical tests of association were performed to find potential relationships between pedestrian path selections and two types of variables: (1) pedestrian-related variables (age, gender and ambulatory capabilities); and (2) variables related to the pedestrian's context (season and site characteristics). Table 5-1 illustrates the pedestrian path choices organized by variable.

Pedestrian-Related Variables	Gender		Senior ≥ 65 years old?		Captive Sidewalk User?	
Category*	F	M	No	Yes	Yes	No
A	157	132	280	9	16	273
B	71	77	146	2	5	143
C	26	17	43	0	0	43
Sum	254	226	469	11	21	459
Total	480		480		480	

Context-Related Variables	Season		Site Number			
Category*	No-Snow	Snow	1	2	3	4
A	125	164	35	82	87	85
B	113	35	76	27	24	21
C	2	41	9	11	9	14
Sum	240	240	120	120	120	120
Total	480		480			

*Categories: (A) pedestrian walking on frontage road; (B) pedestrian walking on outer separation; and (C) pedestrian walking on the main street.

Table 5-1: Walking Path Observations of Bus Stop Users Organized by Variable

Source: Developed by Núñez, 2010

The statistical tests of association account for the size of the different variables. In every case the null hypothesis was tested; this hypothesis assumes that the pedestrian walking path choice and the given variable are not associated.

The Bonferoni correction for multiple comparisons was also utilized; this method was employed as illustrated in the Encyclopaedia of Measurement and Statistics (Salkind, 2007). To explain this method in more detail, typical significance levels are set at an alpha value of 0.05. This means that the probability of accepting a null hypothesis when it is actually true is 1 - 0.05 = 0.95 or (95%), this is the test's confidence level. This alpha value is valid for one test, but since this analysis has 10 tests, the alpha value is adjusted to 0.05/10 = 0.005. This criterion is stricter and would not easily reject the null hypothesis (which assumes no association between variables). This criterion implies that tests would not find small associations between variables; this outcome is positive because these small associations could be outliers. All the tests of association procedures are presented in Appendix E.

5.1.1 Pedestrian-Related Variables

Three tests of association were performed to find potential relationships between pedestrian walking paths and gender, age or ambulatory capabilities (one test each). None of these tests could reject the null hypothesis, which assumed no association between variables. In other words, there was not enough evidence to affirm that gender, age or ambulatory capabilities were associated with pedestrian travel paths. The results of the tests of association on pedestrian related variables are shown in Table 5-2.

Variable	Degrees of Freedom	X^2 (Chi - Squared)	Critical X^2 **	Reject the Null Hypothesis?
Gender	2	2.67	10.60	No
Age	2	2.47	10.60	No
Mobility	2	3.25	10.60	No
***Note: This critical chi-squared value corresponds to a P=0.005, if a given chi-squared is bigger than the critical value, then the corresponding null hypothesis is rejected.*				

Table 5-2: Results of Tests of Association on Pedestrian-Related Variables
Source: Developed by Núñez, 2010

Regarding age and ambulatory capabilities, despite statistical tests of association being designed to account for the size of the groups, it was unlikely for the tests to draw any relationship with a small number of observations. Only 11 seniors and 21 captive sidewalk users were collected because there was not a minimum sample requirement for these types of pedestrians. The low presence of seniors found on the sample matched the information presented by Statistics Canada (2006). This document showed how the percentage of population aged 65 years or older in these neighbourhoods was the lowest in the city. Furthermore, few pedestrians with mobility impairments (who have access to Winnipeg's paratransit services) were found during the eight months of data collection. None of the 21 captive sidewalk users utilized wheelchairs, scooters or walkers; most of them were parents pushing strollers or walking with young children. For these reasons, it would not have been feasible to set a minimum sample of seniors or captive sidewalk users for this research.

5.1.2 Context-Related Variables

Seven tests of association were performed to investigate relationships between pedestrian walking paths and context-related variables. The tests rejected the null hypothesis and therefore found a statistically significant relationship between walking path selection and seasonality, and site characteristics.

The tests were performed in a way that accounted for combined effects. This meant that a first test was performed to find association between walking paths and season; once this test demonstrated that there was a relationship between these variables, the site characteristic tests were divided by season. Further tests were performed to find whether or not the sites were different within each other. The tests' sequence is illustrated in Figure 5-1.

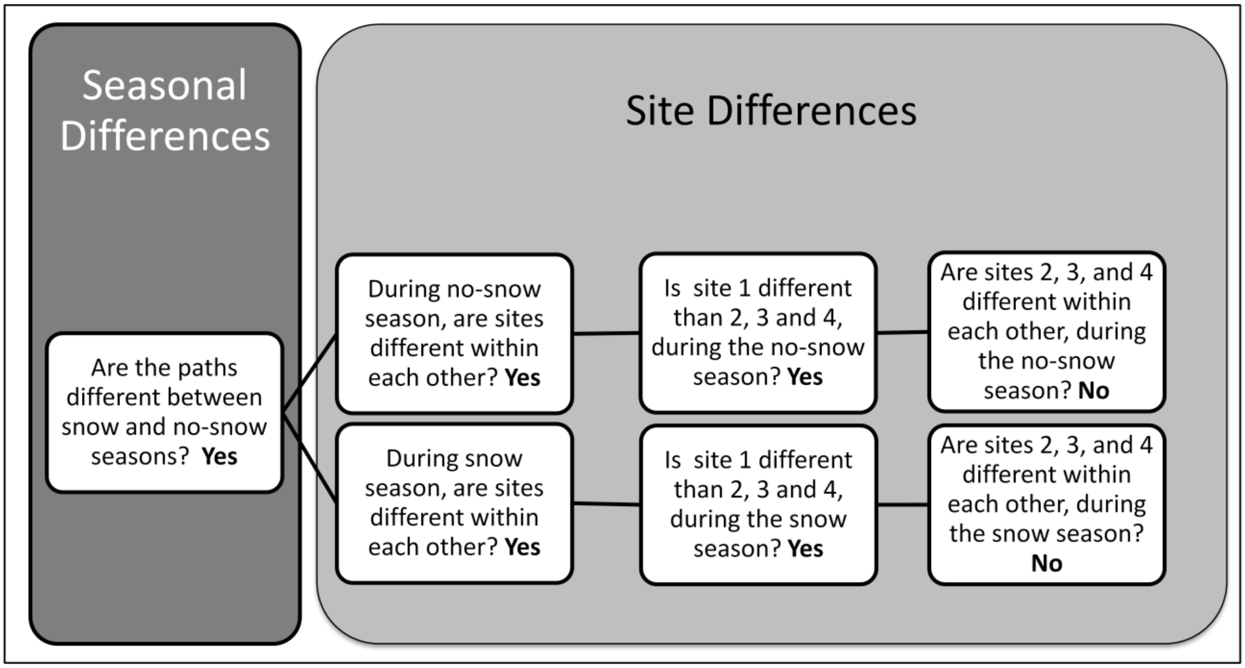


Figure 5-1: Tests of Association Sequence
Source: Developed by Núñez, 2010

As shown in Figure 5-1, Site 1 was specifically compared to Sites 2, 3 and 4. This decision was taken since the contribution to the chi-squared (X^2) from this particular site was 10 times higher than the contribution from any other site (see Appendix E). This means that the pedestrian path selections on Site 1 were different to those on Sites 2, 3 and 4 (as shown on Tables 5-1 and 5-4). The results of the seven tests of association for seasonal and site differences are presented in Table 5-3.

Variables	Degrees of Freedom	X^2 (Chi - squared)	Critical X^2**	Reject Null Hypothesis?
Season	2	81.74	10.60	Yes
All Sites (No-Snow)	6	63.76	18.55	Yes
All Sites (Snow)	6	35.19	18.55	Yes
Site 1 vs. 2, 3 & 4 (No-Snow)	2	59.16	10.60	Yes
Site 1 vs. 2, 3 & 4 (Snow)	2	31.64	10.60	Yes
Sites 2, 3 & 4 only (No-Snow)	4	4.60	14.86	No
Sites 2, 3 & 4 only (Snow)	4	5.89	14.86	No
***Note: This critical chi-squared value corresponds to a P=0.005, if a given chi-squared is bigger than the critical value, then the corresponding null hypothesis is rejected.*				

Table 5-3: Results of Tests of Association on Context-Related Variables
Source: Developed by Núñez, 2010

The tests of association found that there is enough statistical evidence to say that: (1) pedestrian walking path selection is associated with the presence of snow (seasonal effects); (2) path selection and site characteristics are associated; (3) site no.1 is statistically different than the other three sites; and (4) Sites 2, 3 and 4 are similar to each other. The association of seasonality, site characteristics and pedestrian walking paths can be observed in Table 5-4.

	No-Snow Season					Snow Season				
Category*	Site Number				Sum	Site Number				Sum
	1	2	3	4		1	2	3	4	
A	6	34	44	41	125	29	48	43	44	164
B	54	25	16	18	113	22	2	8	3	35
C	0	1	0	1	2	9	10	9	13	41
Sum	60	60	60	60	240	60	60	60	60	240

*Categories: (A) pedestrian walking on frontage road; (B) pedestrian walking on outer separation; and (C) pedestrian walking on the main street.

Table 5-4: Bus Stop User Paths by Season, by Site
Source: Developed by Núñez, 2010

Other important observations can be made in light of the statistical findings. With respect to seasonal effects, Table 5-4 shows how only two bus stop users walked along the main road during the no-snow season, while 41 people were found walking on the main road during the snow season. It is also shown that the proportion of people walking on the outer separation (Category B) decreased considerably during winter, indicating that there is a walking path switch from the outer separation to the frontage road (Category A) and to the main road (Category C), due to the presence of snow. Therefore, there is a significantly higher amount of bus stop users walking on arterials or collectors adjacent to residential frontage roads when snow is on the ground.

With respect to site-related effects, Site 1 had a significantly higher number of bus stop users walking along the outer separation (Category B) when compared to the other three sites (which are very similar to each other). For example, Table 5-4 shows how in Site 1 during the snow season, 22 people were observed walking along the outer separation (Category B), while the other three sites combined had 13 people walking on outer separations during the same period. A significantly higher number of people walking along the outer separation of Site 1 was found during both seasons, and is related to the fact that Site 1 is the only site with a splash strip. A splash strip is a 60cm concrete strip, adjacent to the curb, located around the outer separation. This concrete structure may be used as a sidewalk but cannot substitute a 1.5m sidewalk. Figure 5-2 illustrates a picture of a pedestrian walking along a splash strip in Site 1 and also presents a cross section of a splash strip).

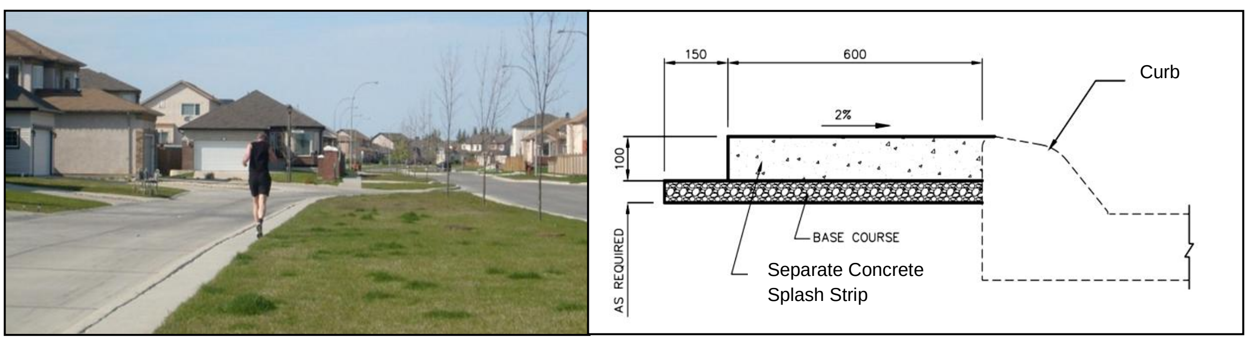


Figure 5-2: Pedestrian Walking on a Splash Strip & Splash Strip Dimensions
Picture by Núñez, 2009, and cross section taken from "Reference Spec. No. CW 3310", City of Winnipeg Website visited on June, 2010.

Regarding combined effects, Table 5-4 also shows that despite the higher proportion of people walking along the outer separation in Site 1, during the snow season there is a higher number of pedestrians walking on the main road despite the presence of the splash strip. This finding indicates that there is a shift of pedestrian paths from the splash strip to the frontage road, and to the main road, when snow is present.

5.2 NON BUS STOP USERS

As explained in the "Research Methodology" (Chapter 4), the purpose of the data collection was to obtain the minimum sample of observations regarding bus stop users. The purpose of this "non bus stop user's analysis" is to complement the previous findings with evidence as it pertains to the pedestrian paths of non bus stop users (for a definition of non bus stop users, refer to Chapter 4).

A sample of 821 non bus stop users was obtained as part of this research. This sample is not considered to be significant from the statistical perspective since it is not evenly distributed between sites and seasons. In particular, Sites 1 and 4 experienced low pedestrian activity during the data collection period, and could not reach the minimum sample of 60 observations. Table 5-5 shows the seasons and sites where it was not possible to reach the minimum sample.

	Non Bus Stop Users	
Site No.	No-Snow Season	Snow Season
1	39*	28*
2	265	154
3	131	119
4	66	19*
Sum	501	320

**These sites do not meet the minimum sample of 60 observations*

Table 5-5: Non Bus Stop User Observations per Season per Site
Source: Developed by Núñez, 2010

The same statistical tests of association from the bus stop user's analysis were performed on this non-significant sample. The tests confirmed the relationships found in the previous analysis. There was not enough evidence to say that there is a relationship between pedestrian-related variables and path selections of non bus stop users; however, the tests found evidence confirming that path selections of non bus stop users are associated with seasonal effects and site characteristics. The path selections of non bus stop users are summarized by season and site in Table 5-6.

No-Snow Season

Category*	Site Number 1		2		3		4		Total
	Users	%	Users	%	Users	%	Users	%	
A	26	67%	251	95%	126	96%	63	95%	
B	13	33%	13	5%	4	3%	3	5%	
C	0	0%	1	0%	1	1%	0	0%	
Sum	39	100%	265	100%	131	100%	66	100%	501

Snow Season

Category*	Site Number 1		2		3		4		Total
	Users	%	Users	%	Users	%	Users	%	
A	22	79%	145	94%	110	92%	17	89%	
B	5	18%	2	1%	2	2%	1	5%	
C	1	4%	7	5%	7	6%	1	5%	
Sum	28	100%	154	100%	119	100%	19	100%	320

*Categories: (A) pedestrian walking on frontage road; (B) pedestrian walking on outer separation; and (C) pedestrian walking on the main street.

Table 5-6: Non Bus Stop User Paths by Season, by Site
Source: Developed by Núñez, 2010

The majority of non bus stop users walked along the residential frontage roads (Category A); however, there are several relevant findings to be noticed in table 5-6:

- With regards to seasonal effects, during the snow season there is a decrease in the proportion of paths along the outer separation (Category B), while there is an increase in the proportion of people walking along the main road.

- When looking at site differences, the percentage of non bus stop users walking along the outer separation (Category B) is always higher at Site 1, compared to the other three sites.

- With regards to combined effects, the percentage of people walking along the main road (Category C) is higher during the snow season in every site, even on Site 1, which has a splash strip.

All the findings from the non bus stop user's analysis matched the bus stop user's analysis. These findings indicate that under the current scenario people are more likely to walk along a residential arterial or collector during winter. The findings also indicate that if clear pedestrian facilities (i.e., properly maintained sidewalks) would be provided along outer separations of residential frontage roads, they may increase the potential of people walking along them. Figure 5-3 presents pictures of pedestrians walking along collectors and arterials adjacent to residential frontage roads.

Figure 5-3: Pedestrians Walking along Residential Arterials and Collectors
Pictures by Núñez, 2010

5.3 IMPLICATIONS FOR TRANSIT PLANNING AND ENGINEERING APPLICATIONS

As a summary from previous chapters, the current practice in Winnipeg does not require the installation of sidewalks along residential frontage roads adjacent to collectors and arterials. Residential frontage roads are considered local streets because of their low vehicular volumes; however they accommodate important volumes of pedestrians, including transit and school bus users.

There are currently 126 residential frontage roads with transit services being used as pedestrian facilities for people who want to access 190 bus stops (in a radius of 50m from the centre of the frontage road). Most of these residential frontage roads have low snow clearance priorities, and bus stops located in outer separations with no accessible connections. Most of these roads are located in relatively new residential developments.

This research found that under the current scenario a significantly higher number of bus stop users walked on arterials and collectors adjacent to residential frontage roads, during the snow season. This finding implies that the presence of snow along frontage roads may have decreased the quality of the pedestrian environment and created a context where a significantly higher amount of pedestrians engaged in risk taking behaviour. If a transportation professional reviewed current snow clearance practices, the professional would find that bus routes and collector streets currently have a medium snow clearance priority (City of Winnipeg, 2008), but most adjacent residential frontage roads have the lowest priority in the city.

The research also found that when a splash strip is provided along outer separations, this 60cm wide concrete element is used as a sidewalk by a significantly higher number of bus stop users, when compared to sites with no splash strip. This finding indicates that if pedestrian facilities were provided along outer separations, they may have an impact on the path chosen by pedestrians when traversing frontage roads.

As stated in the literature, pedestrians try to walk along the shortest path, which in the case of residential frontage roads is located along the outer separation. If sidewalks were installed along outer separations, a planting strip of at least 4.0m would be necessary to allow access to utilities (e.g., telephone, cable, electricity corridors, etc).

With regards to combined effects of seasonality and site characteristics, it was found that there was a shift of pedestrian paths from the splash strip to the frontage road, and to the main road, due to the presence of snow. The splash strip covered by snow was not able to prevent an increase in the number of bus stop users walking along residential arterials or collectors. This finding may indicate that if pedestrian accommodation improvements were provided along residential frontage roads, they should ideally include a combination of improved design and maintenance practices.

All the findings from the bus stop user's analysis were confirmed in the analysis of a non-statistically significant sample of 821 observations of non bus stop users. This evidence indicates that if pedestrian improvements were provided for bus stop users, they would also benefit other pedestrians.

Transportation engineers and planners should not only pay attention to the research findings, they should also understand the implications of those aspects that the research could not find. This research could not find enough evidence to associate gender, age or ambulatory capabilities to pedestrian travel paths. Only 11 seniors out of 480 bus stop users were observed, since neighbourhoods with residential frontage roads have the lowest percentage of seniors in the city. After eight months of data collection, no pedestrians with wheelchairs, walkers or scooters were observed in these neighbourhoods. This situation raises an important question to the transportation professionals: are they not walking on these neighbourhoods because the current practices are not accommodating them properly? This question is not part of the scope of this thesis, but represents an opportunity for future research.

In many cities in North America (including Winnipeg), there are numerous transportation projects that aim to promote transit accessibility, transit oriented developments, active transportation, and road safety. This research gives transportation engineers and planners the opportunity to better understand travel paths of bus stop and non bus stops users in residential frontage roads to collaborate towards the final goal of all these transportation projects: to achieve safer, more accessible and more equitable transportation systems.

6. CONCLUSIONS AND OPPORTUNITIES FOR FUTURE RESEARCH

This chapter discusses research findings, draws conclusions and presents opportunities for future research. The findings are organized using the same chapter structure of this thesis.

6.1 ENVIRONMENTAL SCAN

The environmental scan comprises a review of the literature and a jurisdictional review of selected jurisdictions along Canada and the United States. The following are the relevant findings and conclusions from the environmental scan:

- In Winnipeg, the installation of sidewalks along frontage roads adjacent to residential collectors or arterials is not required since a frontage road is considered a local street, due to its low vehicular volumes.

- Vehicular volumes are the main criteria to select snow clearance priorities along residential frontage roads in Winnipeg.

- Of all the surveyed jurisdictions, only Winnipeg has a combination of a large number of frontage roads (more than one hundred), with no sidewalks, low snow clearance priorities, and transit service on the main road.

- Current design practices in Winnipeg follow the TAC design guidelines which do not have specific recommendations regarding accommodation of pedestrians along residential frontage roads. At the same time these design practices do not adhere to the principles of the City of Winnipeg Accessibility Design Standards (City of Winnipeg, 2006a), nor the Winnipeg Transit "Designing for Sustainable Transportation and Transit in Winnipeg" guidelines (Winnipeg Transit, 2006).

- There are no specific guidelines regarding sidewalk warrants in the literature. However, it is mentioned that pedestrian facilities should be provided in all urbanized areas unless: (a) pedestrians are not expected in the area; (b) pedestrians are explicitly prohibited; or (c) implementation costs are excessively disproportionate. Residential frontage roads do not meet any of the above criteria.

- Although frontage roads are considered local streets based on their low vehicular volumes and low vehicular speeds, the literature does not indicate that they can be designed or operated as pedestrian facilities, nor does it say that they can be used as a substitute for sidewalks.

- The literature indicates that residential arterials and collectors serve the largest pedestrian volumes since they connect important origins and destinations. Policies and guidelines state that sidewalks are highly desirable on both sides or should be placed at least on one side of residential arterials.

- People with ambulatory challenges would benefit from the presence of exclusive, well-maintained pedestrian facilities due to their walking path characteristics. This includes the elderly, children and particularly people with disabilities, for whom inaccessible bus stops often present the weak link in the system. This situation can potentially hamper bus ridership by people with disabilities, limiting their mobility and leading to increased paratransit costs.

- Individuals choose their walking paths based on two main factors: (1) maximization of personal walking utility (i.e. shortest path); and (2) the pedestrian environment (i.e., sidewalk provisions and street dimensions). The shortest path from both ends of the typical frontage road design goes along the outer separation.

- Most interviewed professionals agreed that if sidewalks were installed along frontage roads, it would be preferable to locate them along the outer separation (as opposed to the development side). This sidewalk location would allow proper snow clearance, waste collection and utilities maintenance as long as a minimum of 4.0m planting strip is provided adjacent to the 1.5m sidewalk.

6.2 CHARACTERIZATION OF FRONTAGE ROADS IN WINNIPEG

For the preparation of this section, databases from the City of Winnipeg and Winnipeg Transit were analyzed and complemented with site visits. The following are the relevant findings from this section:

- Most frontage roads in Winnipeg are one-way frontage roads, and most of the frontage roads located along residential collectors or arterials are one-way frontage roads between intersections.

- In Winnipeg, there are 134 residential frontage roads with transit service. One hundred and twenty six of them do not have sidewalks and function as pedestrian facilities for transit users who want to access 190 bus stops located within a radius of 50 m from the centre of the residential frontage road.

- Regarding snow clearance priority for the 126 residential frontage roads with transit service and no sidewalks, 57% of them have the lowest snow clearance priority in the city (PIII). The remaining 43% residential frontage roads have a medium snow clearance priority (PII).

- There are several differences in residential frontage road design, but there are common practices regarding the way in which they are utilized: (1) bus stops are located on outer separations, in areas where there are no sidewalks; (2) bus stops do not have provisions for captive sidewalk users (i.e. ramps); and (3) bus stops are used not only by Winnipeg Transit but also by school bus users.

6.3 ANALYSIS OF PEDESTRIAN WALKING PATHS

A sample of 1,301 pedestrian path observations of both bus stop and non bus stop users was collected from August 2009 to March 2010, and are included in this analysis. The conclusions of this analysis are the following:

- Differences in walking path choices of bus stop users are statistically significant when considering seasonal effects. There is a shift of bus stop user paths from the outer separation to the frontage road, and to the main road (from the no-snow season to the snow season). This indicates that there is a significantly higher amount of people walking on the main road as a result of seasonal effects.

- There is also a statistically significant difference in pedestrian path choices of bus stop users regarding site characteristics. When comparing four different sites, one of them was found to be statistically different (the only one that provides a splash strip). During both seasons, there is a higher amount of bus stop users walking along the outer separation, using the splash strip as a sidewalk.

- With regards to combined effects, it was found that there was a shift of bus stop user paths from the splash strip to frontage road, and to the main road, due to the presence of snow.

- When performing the analysis from the bus stop users sample to a non-statistically significant sample of 821 non bus stop users, the associations mentioned above were confirmed.

- There was not enough evidence to find a statistically significant relationship between pedestrian walking paths of bus stop users and pedestrian-related variables. The pedestrian-related variables are gender, age and ambulatory capabilities. No people with wheelchairs, scooters or walkers were found during the data collection, and demographic data from Statistics Canada indicates that these areas have the lowest percentage of seniors in the city.

6.4 FUTURE RESEARCH

The research has identified the following opportunities for future research:

- Analysis of different design and maintenance scenarios of pedestrian accommodation along frontage roads and other residential streets.

- Impacts of sidewalk presence on pedestrian travel paths along residential streets. Further research may consider installing sidewalks along selected roads to perform a ‘before and after’ study.

- The safety impacts associated with the presence of sidewalks and snow removal practices on urban roads.

- Investigation of the needs of sidewalk warrants on urban streets and the characteristics of those warrants.

BIBLIOGRAPHY

American Association of State Highway and Transportation Officials (AASHTO, 2004a). “A Policy on Geometric Design of Highways and Streets”. Washington, D.C.

American Association of State Highway and Transportation Officials (AASHTO, 2004b). “Guide for the Planning, Design, and Operation of Pedestrian Facilities”. Publication No. GPF-1, July 2004, Washington, D.C.

Amsler D. (2008). “Guidance for Creating and Maintaining Written Snow and Ice Control Plan and Policy Documents”. Presented on the Seventh International Symposium on Snow Removal and Ice Control Technology. Sponsored by the Transportation Research Board. June 2008. Washington, D.C.

Canadian Urban Transit Association (CUTA, 2009). Issue Paper 33 “Transit Vision 2040: Setting the Course for the Future”, Toronto Ontario, June 2009. Available online at: http://www.cutaactu.ca/sites/cutaactu.ca/files/Issue_Paper_33E11_0.pdf

Campanella M., Hoogendoorn S., Daamen, Winnie (2009). “Effects of Heterogeneity on Self-Organized Pedestrian Flows”. Transportation Research Record: Journal of the Transportation Research Board, issue number 2124. Washington, D.C.

Cervero R. (2000). “Factors Influencing Pedestrian Access to Transit”. Journal of Public Transportation, Volume 3, Number 4. Center for Urban Transportation Research. Tampa, Florida.

City of Winnipeg Underground Structures Committee (City of Winnipeg, 1984). “Manual for the Production of Construction Drawings”, Winnipeg, Manitoba. Available online at: http://www.winnipeg.ca/waterandwaste/pdfs/dept/constructionManual.pdf

City of Winnipeg, Planning, Property and Development (City of Winnipeg, 2006a). “2006 City of Winnipeg Accessibility Design Standards”. Available online at: http://winnipeg.ca/ppd/pdf_files/Access_Design_Standards.pdf

City of Winnipeg, Planning, Property and Development (City of Winnipeg, 2006b). “Universal Design Guiding Principles”. Available online at: http://winnipeg.ca/ppd/planning/pdf_folder/UDesignGuidingPrinciples.pdf

City of Winnipeg, Street Maintenance Division (City of Winnipeg, 2008). “Snow and Ice Control Operations Manual”. Public Works Department, Winnipeg, Manitoba.

Easter Seals Project Action (ESPA, 2006). “Toolkit for the Assessment of Bus Stop Accessibility and Safety”. Washington, D.C. Available online at: http://projectaction.easterseals.com

Federal Highway Administration (FHWA, 2000). “Design Guidance Accommodating Bicycle and Pedestrian Travel: A Recommended Approach, A US DOT Policy Statement Integrating Bicycling and Walking into Transportation Infrastructure”. Washington, D.C. Available online at: http://www.fhwa.dot.gov/environment/bikeped/design.htm

Federal Highway Administration (FHWA, 2005). “Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users”. Public Law 109-59, 109th Congress of the United States of America. August 2005, Washington, D.C.

Federal Highway Administration (FHWA, 2008), U.S. Department of Transportation. “Pedestrian Safety Guide for Transit Agencies”. Publication No. FHWA-SA-07-017. February 2008.

Florida Department of Transportation (Florida DOT, 2009). “2009 Quality/Level of Service Handbook”. Tallahassee, Florida. Also available at: www.dot.state.fl.us

Guo, Z. (2009). “Does the pedestrian environment affect the utility of walking? A case of path choice in downtown Boston”. Transportation Research Part D: Transport and Environment. Published by Elsevier on July, 2009.

Hart R., J. Mewes, Benjamin Hershey, L. Osborne, and D. Huft (2008). “An Overview of Implementation and Deployment of the Pooled Fund Study Maintenance Decision Support System”. Presented on the Seventh International Symposium on Snow Removal and Ice Control Technology. Sponsored by the Transportation Research Board. June 2008. Washington, D.C.

Institute of Transportation Engineers (ITE, 2008). “Urban Street Geometric Design Handbook”. Washington, D.C.

Murphy K., Myors B., and Wolach A. (2009). “Statistical Power Analysis: A Simple and General Model for Traditional and Modern Hypothesis Tests”, third edition. Editorial Routledge, New York.

Muraleetharan T., Hagiwara T. (2007). “Overall Level of Service of Urban Walking Environment and Its Influence on Pedestrian Route Choice Behavior: Analysis of Pedestrian Travel in Sapporo, Japan”. Transportation Research Record: Journal of the Transportation Research Board, issue number 2002, Washington, D.C.

National Cooperative Highway Research Program (NCHRP, 1999). “Impacts of Access Management Techniques”. Transportation Research Board, Washington, D.C.

Salkind N., K. Rasmussen (2007). “Encyclopaedia of Measurement and Statistics”, Sage Publications. Thousand Oaks, California.

Shintani Y., H. Fumihiro, A. Fukumoto, and T. Akiyama (2003). “Empirical Study on Walking Behaviour in Icy Conditions and the Effect of Measures to Improve the Winter Pedestrian Environment”. Transport Research Board 2003 Annual Meeting CD-ROM. Washington, D.C.

Shintani Y., H. Fumihiro, K. Hori, and M. Yuri (2002). “Walking Experiment under Icy Conditions”. Transport Research Board 2002 Annual Meeting CD-ROM. Washington, D.C.

Sisiopiku, V., J. Byrd and A. Chittoor (2007). “Application of Level of Service Methods for Evaluation of Operations at Pedestrian Facilities”. In Transportation Research Record No. 2002, Washington, D.C., pp. 117-124.

Smith, A. (2009) “Contribution of Perceptions in Analysis of Walking Behavior”. Transportation Research Record: Journal of the Transportation Research Board, Issue number 2140. Washington, D.C.

Smithson L., Iowa Department of Transportation (2004). “Proactive Snow and Ice Control Toolbox”. Presented on the Sixth International Symposium on Snow Removal and Ice Control Technology. Sponsored by the Transportation Research Board. June 2004. Washington, D.C.

Statistics Canada (Statistics Canada, 2006) “2006 Community Profiles”, Ottawa, Ontario. Available online at: http://www12.statcan.gc.ca/census-recensement/2006/dp-pd/prof/92-591/index.cfm?Lang=E

Takahashi N., R. Tokunaga, and A. Motoki (2007). “Strategic PDCA for Pedestrian-Friendly Northern Communities”. Presented on the Eleventh International Conference on Mobility and Transport for Elderly and Disabled Persons, hosted by Transport Canada. Montreal, Canada.

Tokunaga R., N. Takahashi, and A. Motoki (2007). “More and Better Practice to Evaluate Winter Pedestrian Mobility”. Presented on the Eleventh International Conference on Mobility and Transport for Elderly and Disabled Persons, hosted by Transport Canada. Montreal, Canada.

Transit Cooperative Research Program (TCRP, 1996). “TCRP Report 19: Guidelines for the Location and Design of Bus Stops”. Sponsored by the Federal Transit Administration. Transportation Research Board, Washington, D.C.

Transit Cooperative Research Program (TCRP, 2003). “TCRP Report 100: Transit Capacity and Quality of Service Manual 2nd Edition”. Sponsored by the Federal Transit Administration. Transportation Research Board, Washington, D.C.

Transportation Association of Canada (TAC, 1999). “Geometric Design Guide for Canadian Roads”. September 1999 with 2007 Updates, Ottawa, Canada.

Transportation Research Board (TRB, 2000). “Highway Capacity Manual”. National Research Council. Washington, D.C.

United States Access Board (U.S. Access Board, 2004). “Americans with Disabilities Act, Accessibility Guidelines”. Washington, D.C. Available online at: http://www.access-board.gov/ada-aba/index.htm

Winnipeg Transit (Winnipeg Transit, 2006). “Designing for Sustainable Transportation and Transit in Winnipeg”, Winnipeg, Manitoba. Available online at: http://myride.winnipegtransit.com/en/inside-transit/transitreports/

APPENDIX A:

JURISDICTIONAL SURVEY FORMATS

Survey Template for Transit Planner

1. Are you aware of previous research addressing pedestrian paths to bus stops, taking into account ambulatory capabilities, age, gender or seasonal differences?

   (a) No
   *(b) Yes, please specify:*____

2. When designing and locating bus stops, which guidelines do you follow? (you may choose more than one)

   (a) TCRP 19 Guidelines for the Location and Design of Bus Stops
   (b) TCRP 100 Transit Capacity and Quality of Service Manual (TCQSM)
   (c) ADA Accessibility Guidelines for Buildings and Facilities (ADAAG)
   (d) Easter Seals (ESPA) - Toolkit for the Assessment of Bus Stop Accessibility and Safety
   (e) FHWA Pedestrian Safety Guide for Transit Agencies
   (f) NCHRP Bus Transit Accessibility for the Handicapped in Urban Areas
   (g) Other, please specify ____

3. When do you require the installation of a sidewalk on a residential street? (you may choose more than one)

   (a) Depending on the functional classification (i.e. all residential arterials should have a sidewalk)
   (b) Depending on the expected volumes of pedestrians
   (c) Depending on traffic volumes
   (d) Depending on the expected number of seniors
   (e) Other, please specify ____

4. Are there frontage roads adjacent to residential collectors or arterials in your jurisdiction? (If "yes" please provide an example, if the answer is "no", do not address the rest of the questionnaire, we greatly appreciate your time).

   (a) No
   *(b) Yes, for example:*____

5. Which is your common practice regarding implementation of sidewalks along frontage roads adjacent to residential collectors or arterials? (you may choose more than one)

   (a) They are required in every frontage road adjacent to residential collectors or arterials
   (b) They are required where high pedestrian volumes justify the installation
   (c) They are required in areas where high volumes of seniors are expected
   (d) They are required in all new residential developments
   (e) They are not required since a frontage road is considered a local street, and sidewalks are not required on local streets
   (f) Other, please specify ____

6. Which of the following statements is true in your jurisdiction? (you may choose more than one)

   (a) There are bus stops located along outer separations (sometimes called boulevards) of residential frontage roads
   (b) There are bus stops located in the vicinity of residential frontage roads
   (c) There are typically no bus stops located along or in the vicinity of residential frontage roads

7. Regarding bus stops located along or in the vicinity of frontage roads, which of the following statements is true in your jurisdiction?

   (a) I have not experienced issues when designing or locating bus stops along frontage roads
   (b) I have experienced issues when designing or locating bus stops on these locations, please give an example: ____

Survey Template for Operations Engineer

1. Are you aware of previous research addressing pedestrian walking paths, taking into account ambulatory capabilities, age, gender or seasonal differences?

   (a) No
   *(b) Yes, please specify:*____

2. What guidelines do you use when planning, designing or maintaining the implementation of sidewalks on your jurisdiction? (you may choose more than one)

   (a) Guide for the Planning, Design, and Operation of Pedestrian Facilities (AASHTO, 2004)
   (b) Geometric Design Guide for Canadian Roads (TAC, 1999)
   (c) ADA Accessibility Guidelines for Buildings and Facilities (ADAAG)
   (d) Other guide (please specify) ____

3. Which is your common practice regarding the installation of curb cuts, ramps and landing pads leading to bus stops on residential neighbourhoods? (you may choose more than one)

   (a) They are required in every residential bus stop
   (b) They are required where high pedestrian volumes justify the installation
   (c) They are required in areas where high volumes of seniors are expected
   (d) They are required in all new residential developments
   (e) They are required in all the sidewalk upgrade projects
   (f) Other, please specify: ____

4. Are there frontage roads adjacent to residential collectors or arterials in your jurisdiction? (If "yes" please provide an example, if the answer is "no", please let us know and do not address the rest of the questionnaire, we greatly appreciate your time).

   (a) No
   *(b) Yes, for example:*____

5. When do you require the installation of sidewalks along frontage roads adjacent to residential collectors or arterials? (you may choose more than one)

   (a) They are not required since a frontage road is considered a low volume local street
   (b) They are required in every frontage road adjacent to residential collectors or arterials
   (c) They are required where high pedestrian volumes justify the installation
   (d) They are required where high vehicular volumes justify the installation
   (e) They are required in areas where high volumes of seniors are expected
   (f) They are required in all new residential developments
   (g) Other, please specify ____

6. Which is your common practice, regarding the location of sidewalks along frontage roads adjacent to residential collectors or arterials?

   (a) Sidewalks are not required since a frontage road is considered a local street
   (b) Sidewalks are typically installed on the side of the development
   (c) Sidewalks are typically installed along the outer separation (sometimes called boulevard)
   (d) Other, please specify ____

7. Which is your common practice regarding snow clearance priorities along frontage roads adjacent to residential collectors or arterials?

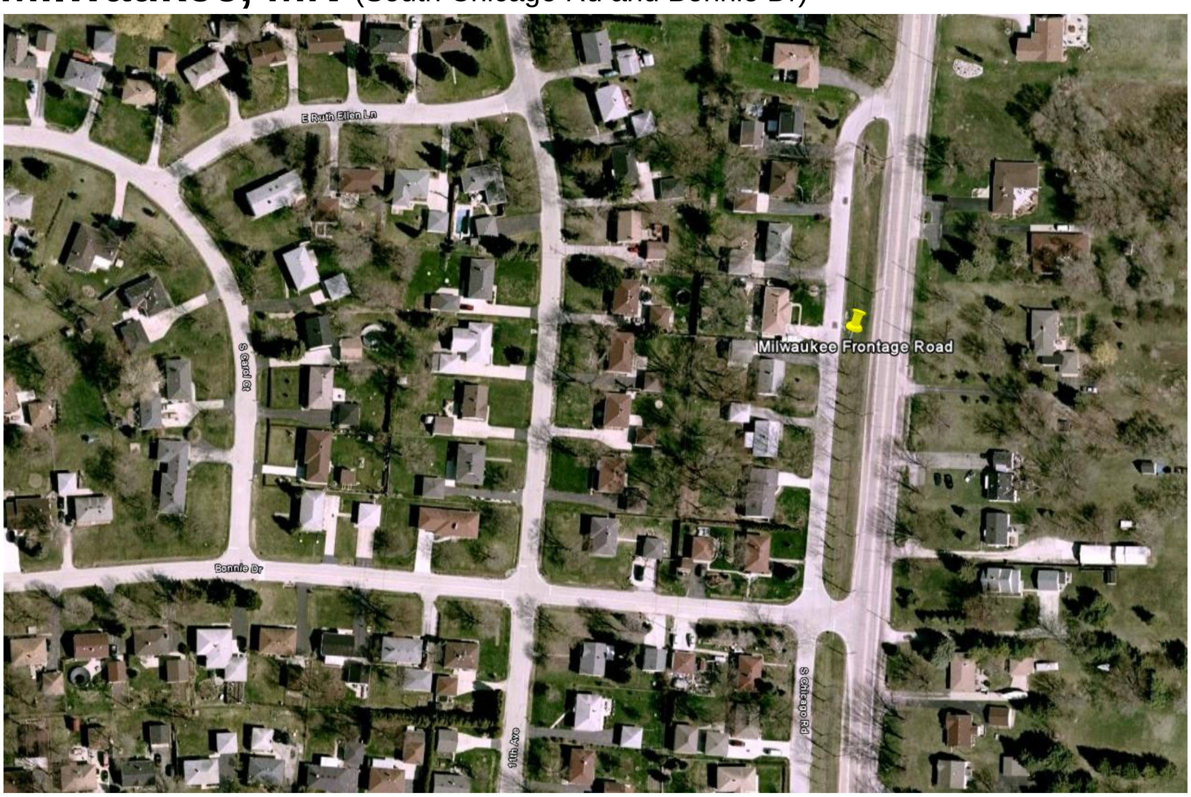
   (a) Those frontage roads have typically the same priority of the adjacent street
   (b) Those frontage roads have typically a lower priority than the adjacent street
   (c) Those frontage roads have typically a higher priority than the adjacent street
   (d) Other, please specify ____

APPENDIX B:

PHOTOS OF FRONTAGE ROADS FROM SELECTED JURISDICTIONS

Saskatoon SK (Briarwood Rd and Brookmore Cr)*

Milwaukee, MN (South Chicago Rd and Bonnie Dr)*



*Pictures taken from ©2010 Google

Fargo, ND (17th Avenue and 1st St)*

Edmonton, AB (Towne center blvd and 23rd Ave)*

*Pictures taken from ©2010 Google

Boise, ID (State Street and 26th Street)*

Minneapolis, MN (Olson Memorial Hwy / Humboldt Ave N)*

*Pictures taken from ©2010 Google

Calgary, AB (Bow Trail and 26th)*

Calgary, AB (1686, 6th Ave NW)*

*Pictures taken from ©2010 Google

Cleveland, OH (Chester Ave and 84th Street)*

Milwaukee, WI (Oklahoma Ave & S 68th St)*

*Pictures taken from ©2010 Google

APPENDIX C:

AVERAGE NUMBER OF BUS STOP USERS
BY TYPE OF SITE

Schedule Type	Site Type	Winnipeg Transit Stop ID	Location	Daily Avg Ons+Offs	%	Cummulative %
1	3	50937	EB John Forsyth – Winterhaven	42	7.2%	7.2%
1	3	40750	EB Springfield – Graduate	35	6.0%	13.3%
1	3	60814	EB Lindenwood – Princemere	28	4.8%	18.1%
1	3	60952	NB Scurfield - Fleetwood West	27	4.7%	22.8%
1	3	50795	SB De La Seigneurie – Pynoo	26	4.5%	27.2%
1	3	61125	SB Scurfield – Moncrief	25	4.3%	31.6%
1	3	61011	SB Bairdmore - Calderwood East	23	4.0%	35.5%
1	3	60888	NB Lindenwood – Farmingdale	22	3.8%	39.3%
1	3	60813	SB Avon - Lindenwood West	19	3.3%	42.6%
1	3	61018	NB Bairdmore - Bernfield North	19	3.3%	45.9%
1	3	61014	SB Bairdmore – Hawstead	18	3.1%	49.0%
1	3	60935	EB Scurfield – Sheffield	18	3.1%	52.1%
1	3	60905	NB Lindenwood – Wethersfield	17	2.9%	55.0%
1	3	60743	EB Kirkbridge - Hawstead	17	2.9%	57.9%
1	3	60859	SB Columbia - Saxon	16	2.8%	60.7%
1	3	60867	NB Lindenwood - Waterbury South	15	2.6%	63.3%
1	3	60879	SB Lindenwood - Waterbury North	14	2.4%	65.7%
1	3	50793	NB Desjardins - Surfside	14	2.4%	68.1%
1	3	30857	SB Ritchie - Jefferson	13	2.2%	70.3%
1	3	40840	NB Ravenhurst - Lopuck	12	2.1%	72.4%
1	3	50918	NB De La Seigneurie - Pauline Boutal North	12	2.1%	74.5%
1	3	50926	NB Island Shore - Island Lakes	12	2.1%	76.6%
1	3	50916	NB De La Seigneurie - Pauline Boutal South	11	1.9%	**78.4%***
1	3	50822	WB Royal Mint - Morning Glory	10	1.7%	80.2%
1	3	60517	EB Grant - Kelvin	10	1.7%	81.9%
1	3	50792	NB Desjardins - Myles Robinson	10	1.7%	83.6%
1	3	60817	SB Lindenwood - Thorncliff	9	1.6%	85.2%
1	3	60937	EB Scurfield - Fleetwood East	9	1.6%	86.7%
1	3	60874	NB Avon - Lindenwood West	9	1.6%	88.3%
1	3	60683	WB Kirkbridge - Allendale	9	1.6%	89.8%
1	3	50609	EB Aldgate - Keelegate	8	1.4%	91.2%
1	3	60511	NB Lindenwood - Tweedsmuir	8	1.4%	92.6%
1	3	60855	EB Columbia - Prospect	8	1.4%	94.0%
1	3	50887	SB Shorehill - Beaudry	8	1.4%	95.3%
1	3	60446	NB Scurfield - Invermere	6	1.0%	96.4%
1	3	61002	NB Lindenwood - Wellesley	5	0.9%	97.2%
1	3	61040	SB Bairdmore - Marrington	4	0.7%	97.9%
1	3	61126	SB Scurfield - Breckenridge	3	0.5%	98.4%
1	3	50333	EB Shamrock - Cliffwood	3	0.5%	99.0%
1	3	50955	EB Aldgate - Kamberwell West	2	0.3%	99.3%
1	3	50951	SB Shorehill - Westwater East	1	0.2%	99.5%
1	3	50947	EB Aldgate - Abbotsfield	1	0.2%	99.7%
1	3	50949	SB Shorehill - Westwater West	1	0.2%	99.8%
1	3	50868	NB Royal Mint - Blue Mountain South	1	0.2%	100.0%
1	3	50905	NB Shorehill - Demetrioff	0	0.0%	100.0%
1	3	60744	EB Kirkbridge - Ainsworth	0	0.0%	100.0%
			Total	**580**	**100%**	

*This percentage is highlighted to show the 23 stops that account for 80% of the bus stop users at Type 3 sites.

Source: Prepared by Núñez, 2009

Schedule Type	Site Type	Winnipeg Transit Stop ID	Location	Daily Avg Ons+Offs	%	Cummulative%
1	4	60881	SB Lindenwood - Waterbury South	45	15.9%	15.9%
1	4	60711	SB Lindenwood - Lindenwood West	36	12.7%	28.6%
1	4	61021	NB Bairdmore - Calderwood West	34	12.0%	40.6%
1	4	60803	NB Bairdmore - Point West	19	6.7%	47.3%
1	4	60946	WB Scurfield - Sheffield	17	6.0%	53.4%
1	4	61019	NB Bairdmore - Hawstead	14	4.9%	58.3%
1	4	60951	NB Scurfield - Izzatt School	13	4.6%	62.9%
1	4	60893	WB Kirkbridge - Brentlawn South	12	4.2%	67.1%
1	4	60908	SB Lindenwood - Fairhaven	11	3.9%	71.0%
1	4	20444	EB Quail Ridge - Apple West	10	3.5%	74.6%
1	4	50956	WB Aldgate - Kamberwell West	10	3.5%	78.1%
1	4	60873	WB Lindenwood - Wallingford	10	3.5%	**81.6%***
1	4	60851	SB Brentlawn - Allendale	9	3.2%	84.8%
1	4	30784	NB King Edward - Garton	8	2.8%	87.6%
1	4	60136	SB Lindenwood - Tweedsmuir	8	2.8%	90.5%
1	4	30899	EB Ambergate - Pipeline	6	2.1%	92.6%
1	4	61129	NB Scurfield - Moncrief	5	1.8%	94.3%
1	4	61001	SB Lindenwood - Wellesley	4	1.4%	95.8%
1	4	61031	EB West Taylor - Holland	4	1.4%	97.2%
1	4	61028	WB West Taylor - Holland	3	1.1%	98.2%
1	4	61029	WB West Taylor - Shaftesbury	3	1.1%	99.3%
1	4	30898	WB Ambergate - Pipeline	2	0.7%	100.0%
1	4	50335	SB Newcroft - Shamrock	0	0.0%	100.0%
			Total	**283**	**100%**	

*This percentage is highlighted to show the 12 stops that account for 80% of the bus stop users at Type 4 sites.
Source: Prepared by Núñez, 2009

APPENDIX D:

DATA COLLECTION FORMATS FOR
PEDESTRIAN WALKING PATHS

Name:

Date	Time Period
Location	
Study Site Type	Bus Stop ID
Season	Temperature / Wind

Sidewalk and Bus Stop Conditions:

Pedestrian No#	Transit User?	School Bus User?	Gender (F/M)	Senior >65 (Yes/No)	Path # (A,B or C)	Special Ambulatory Situation	Comments
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							

Path Choices	
A	Walking on frontage road
B	Walking on boulevard (outer separation)
C	Walking on the main road

Special Ambulatory Situation	
i	Wheelchair
ii	Cane
iii	Walker
iv	Walking with young children
v	Walking with stroller
vi	scooters
vii	Other (specify)

APPENDIX E:

STATISTICAL TESTS OF ASSOCIATION

Bus Stop User Paths (Gender)

Path Type		Gender		Sum
		F	M	
A	Actual	157	132	**289**
	Expected	152.9	136.1	**289**
B	Actual	71	77	**148**
	Expected	78.3	69.7	**148**
C	Actual	26	17	**43**
	Expected	22.8	20.2	**43**
	Sum	**254**	**226**	**480**

D.F. = (3-1)*(2-1) 2
Yates Correction: No

Path Type	Gender	
	F	M
A	0.1	0.1
B	0.7	0.8
C	0.5	0.5

Chi squared? 2.67
Critical Value? 4.61 for a P=.100 (small relationship)
10.6 for a P=.005* (medium relationship)
Result: No relationship

Conclusion: There is not an important difference regarding gender

*p=(0.05/10) =0.005

Bus Stop User Paths (Ambulatory Capabilities)

Path Type		Captive Sidewalk User?		Sum
		Yes	No	
A	Actual	16	273	**289**
	Expected	12.6	276.4	**289**
B	Actual	5	143	**148**
	Expected	6.5	141.5	**148**
C	Actual	0	43	**43**
	Expected	1.9	41.1	**43**
	Sum	**21**	**459**	**480**

D.F. = (3-1)*(2-1) 2
Yates Correction: No

Path Type	Captive Sidewalk User?	
	Yes	No
A	0.9	0.0
B	0.3	0.0
C	1.9	0.1

Chi squared? 3.25
Critical Value? 4.61 for a P=.100 (small relationship)
10.6 for a P=.005* (medium relationship)
Result: No relationship

Conclusion: Not important difference regarding mobility situations

*p=(0.05/10) =0.005

Bus Stop User Paths (Age)

Path Type		Senior > 65 years old?		Sum
		No	Yes	
A	Actual	280	9	**289**
	Expected	282.4	6.6	**289**
B	Actual	146	2	**148**
	Expected	144.6	3.4	**148**
C	Actual	43	0	**43**
	Expected	42.0	1.0	**43**
	Sum	**469**	**11**	**480**

D.F. = (3-1)*(2-1) 2
Yates Correction: No

Path Type	Senior > 65 years old?	
	No	Yes
A	0.0	0.9
B	0.0	0.6
C	0.0	1.0

Chi squared? 2.47
Critical Value? 4.61 for a P=.100 (small relationship)
10.6 for a P=.005* (medium relationship)
Result: No relationship

Conclusion: There is not an important difference regarding age

*p=(0.05/10) =0.005

Bus Stop User Paths

Path Type		Season		Sum
		No-Snow	Snow	
A	Actual	125	164	**289**
	Expected	144.5	144.5	**289**
B	Actual	113	35	**148**
	Expected	74.0	74.0	**148**
C	Actual	2	41	**43**
	Expected	21.5	21.5	**43**
	Sum	**240**	**240**	**480**

D.F. = (3-1)*(2-1) 2
Yates Correction: No

Path Type	Season	
	No-Snow	Snow
A	2.6	2.6
B	20.6	20.6
C	17.7	17.7

Chi squared? 81.74
Critical Value? 10.6 for a P=.005* (strong relationship)
13.82 for a P=.001 (very strong relationship)
Result: Very Strong Relationsip

Conclusion: Very strong relationship between season and path selection

*p=(0.05/10) =0.005

Bus Stop User Paths (No - Snow)

Path Type		Site Number 1	2	3	4	Sum
A	Actual	6	34	44	41	**125**
	Expected	31.25	31.25	31.25	31.25	**125**
B	Actual	54	25	16	18	**113**
	Expected	28.25	28.25	28.25	28.25	**113**
C	Actual	0	1	0	1	**2**
	Expected	0.5	0.5	0.5	0.5	**2**
	Sum	**60**	**60**	**60**	**60**	**240**

D.F. = (3-1)*(4-1) 6
Yates Correction? No

Path Type	Site Number 1	2	3	4
A	20.4	0.2	5.2	3.0
B	23.5	0.4	5.3	3.7
C	0.5	0.5	0.5	0.5

Chi squared? 63.76
Critical ritical Value? 18.55 for a P=.005*
Result: Very strong relationship

Bus Stop User Paths - No snow - Wide curb vs No Wide Curb

Path Type		Station Type: Wide Curb (1)	No Wide Curb (2, 3 & 4)	Sum
A	Actual	6	119	**125**
	Expected	31.3	93.8	**125**
B	Actual	54.0	59.0	**113**
	Expected	28.3	84.8	**113**
C	Actual	0.0	2.0	**2**
	Expected	0.5	1.5	**2**
	Sum	**60**	**180**	**240**

D.F. = (3-1)*(2-1) 2
Yates Correction? No

Path Type	Station Type: Wide Curb (1)	No Wide Curb (2, 3 & 4)
A	20.40	6.80
B	23.47	7.82
C	0.50	0.17

Chi squared? 59.16
Critical Value? 10.6 for a P=.005*
Result: Very strong relationship

Bus Stop User Paths - No snow - Within No Wide Curb Sites

Path Type		Site Number 2	3	4	Sum
A	Actual	34	44	41	**119**
	Expected	39.7	39.7	39.7	**119**
B	Actual	25	16	18	**59**
	Expected	19.7	19.7	19.7	**59**
C	Actual	1	0	1	**2**
	Expected	0.7	0.7	0.7	**2**
	Sum	**60**	**60**	**60**	**180**

D.F. = (3-1)*(3-1) 4
Yates Correction? No

Path Type	Site Number 2	3	4
A	0.8	0.5	0.0
B	1.4	0.7	0.1
C	0.2	0.7	0.2

Chi squared? 4.60
Critical Value? 14.86 for a P=.005*
7.78 for a P=.100
Result: No relationship, not even small

Conclusion: One of the sites is different than the other three

*p=(0.05/10) =0.005

Bus Stop User Paths (Snow)						
Path Type		Site Number				Sum
		1	2	3	4	
A	Actual	29	48	43	44	**164**
	Expected	41	41	41	41	**164**
B	Actual	22	2	8	3	**35**
	Expected	8.75	8.75	8.75	8.75	**35**
C	Actual	9	10	9	13	**41**
	Expected	10.25	10.25	10.25	10.25	**41**
	Sum	**60**	**60**	**60**	**60**	**240**

D.F. = (3-1)*(4-1) 6
Yates Correction? No

Path Type	Site Number			
	1	2	3	4
A	3.5	1.2	0.1	0.2
B	20.1	5.2	0.1	3.8
C	0.2	0.0	0.2	0.7

Chi squared? 35.19
Critical Chical Value? 18.55 for a P=.005*
Result: Very strong relationship

Bus Stop User Paths - Snow - Wide curb vs No Wide Curb				
Path Type		Station Type		Sum
		Wide Curb (1)	No Wide Curb (2, 3 & 4)	
A	Actual	29	135	**164**
	Expected	41.0	123.0	**164**
B	Actual	22.0	13.0	**35**
	Expected	8.8	26.3	**35**
C	Actual	9.0	32.0	**41**
	Expected	10.3	30.8	**41**
	Sum	**60**	**180**	**240**

D.F. = (3-1)*(2-1) 2
Yates Correction? No

Path Type	Station Type	
	Wide Curb (1)	No Wide Curb (2, 3 & 4)
A	3.51	1.17
B	20.06	6.69
C	0.15	0.05

Chi squared? 31.64
Critical Value? 10.6 for a P=.005*
Result: Very strong relationship

Bus Stop User Paths - Snow - Within No Wide Curb Sites					
Path Type		Site Number			Sum
		2	3	4	
A	Actual	48	43	44	**135**
	Expected	45.0	45.0	45.0	**135**
B	Actual	2	8	3	**13**
	Expected	4.3	4.3	4.3	**13**
C	Actual	10	9	13	**32**
	Expected	10.7	10.7	10.7	**32**
	Sum	**60**	**60**	**60**	**180**

D.F. = (3-1)*(3-1) 4
Yates Correction? No

Path Type	Site Number		
	2	3	4
A	0.2	0.1	0.0
B	1.3	3.1	0.4
C	0.0	0.3	0.5

Chi squared? 5.89
Critical Value? 14.86 for a P=.005*
7.78 for a P=.100
Result: No relationship, not even small

Conclusion: One of the sites is different than the other three

*p=(0.05/10) =0.005

Non Bus Stop User Walking Paths

Path Type		Gender F	Gender M	Sum
A	Actual	437	323	**760**
	Expected	439.7	320.3	**760**
B	Actual	29	14	**43**
	Expected	24.9	18.1	**43**
C	Actual	9	9	**18**
	Expected	10.4	7.6	**18**
	Sum	**475**	**346**	**821**

D.F. = (3-1)*(2-1) 2
Yates Correction: No

Path Type	Gender F	Gender M
A	0.0	0.0
B	0.7	0.9
C	0.2	0.3

Chi squared? 2.12
Critical Value? 4.61 for a P=.100 (small relationship)
10.6 for a P=.005* (medium relationship)
Result: No relationship

Conclusion: There is not an important difference regarding gender

*p=(0.05/10) =0.005

Non Bus Stop User Walking Paths

Path Type		Captive Sidewalk User? No	Captive Sidewalk User? Yes	Sum
A	Actual	635	125	**760**
	Expected	639.7	120.3	**760**
B	Actual	39	4	**43**
	Expected	36.2	6.8	**43**
C	Actual	17	1	**18**
	Expected	15.1	2.9	**18**
	Sum	**691**	**130**	**821**

D.F. = (3-1)*(2-1) 2
Yates Correction: No

Path Type	Captive Sidewalk User? No	Captive Sidewalk User? Yes
A	0.0	0.2
B	0.2	1.2
C	0.2	1.2

Chi squared? 3.02
Critical Value? 4.61 for a P=.100 (small relationship)
10.6 for a P=.005* (medium relationship)
Result: No relationship

Conclusion: Not important difference regarding mobility situations

*p=(0.05/10) =0.005

Non Bus Stop User Walking Paths

Path Type		Senior > 65 years old? No	Senior > 65 years old? Yes	Sum
A	Actual	662	98	**760**
	Expected	664.7	95.3	**760**
B	Actual	39	4	**43**
	Expected	37.6	5.4	**43**
C	Actual	17	1	**18**
	Expected	15.7	2.3	**18**
	Sum	**718**	**103**	**821**

D.F. = (3-1)*(2-1) 2
Yates Correction: No

Path Type	Senior > 65 years old? No	Senior > 65 years old? Yes
A	0.0	0.1
B	0.1	0.4
C	0.1	0.7

Chi squared? 1.30
Critical Value? 4.61 for a P=.100 (small relationship)
10.6 for a P=.005* (medium relationship)
Result: No relationship

Conclusion: There is not an important difference regarding age

*p=(0.05/10) =0.005

Non Bus Stop User Walking Paths

Path Type		Season No-Snow	Season Snow	Sum
A	Actual	466	294	**760**
	Expected	463.8	296.2	**760**
B	Actual	33	10	**43**
	Expected	26.2	16.8	**43**
C	Actual	2	16	**18**
	Expected	11.0	7.0	**18**
	Sum	**501**	**320**	**821**

D.F. = (3-1)*(2-1) 2
Yates Correction: No

Path Type	Season No-Snow	Season Snow
A	0.0	0.0
B	1.7	2.7
C	7.3	11.5

Chi squared? 23.35
Critical Value? 4.61 for a P=.100 (small relationship)
10.6 for a P=.005* (medium relationship)
Result: Very Strong Relationsip

Conclusion: Very strong relationship between season and path selection

*p=(0.05/10) =0.005

Non Bus Stop User Paths (No - Snow)

Path Type		Site Number 1	2	3	4	Sum
A	Actual	26	251	126	63	**466**
	Expected	36.3	246.5	121.8	61.4	**466**
B	Actual	13	13	4	3	**33**
	Expected	2.6	17.5	8.6	4.3	**33**
C	Actual	0	1	1	0	**2**
	Expected	0.2	1.1	0.5	0.3	**2**
	Sum	**39**	**265**	**131**	**66**	**501**

D.F. = (3-1)*(4-1) 6

Yates Correction? No

Path Type	Site Number 1	2	3	4
A	2.9	0.1	0.1	0.0
B	42.4	1.1	2.5	0.4
C	0.2	0.0	0.4	0.3

Chi squared? 50.43

Critical Value? 18.55 for a P=.005*

Result: Very strong relationship

Non Bus Stop User Paths - No Snow - Wide curb vs No Wide Curb

Path Type		Station Type: Wide Curb (1)	No Wide Curb (2, 3 & 4)	Sum
A	Actual	26	440	**466**
	Expected	36.3	429.7	**466**
B	Actual	13.0	20.0	**33**
	Expected	2.6	30.4	**33**
C	Actual	0.0	2.0	**2**
	Expected	0.2	1.8	**2**
	Sum	**39**	**462**	**501**

D.F. = (3-1)*(2-1) 2

Yates Correction? No

Path Type	Station Type: Wide Curb (1)	No Wide Curb (2, 3 & 4)
A	2.91	0.25
B	42.36	3.58
C	0.16	0.01

Chi squared? 49.26

Critical Value? 10.6 for a P=.005*

Result: Very strong relationship

Non Bus Stop User Paths - No Snow - Within No Wide Curb Sites

Path Type		Site Number 2	3	4	Sum
A	Actual	251	126	63	**440**
	Expected	252.4	124.8	62.9	**440**
B	Actual	13	4	3	**20**
	Expected	11.5	5.7	2.9	**20**
C	Actual	1	1	0	**2**
	Expected	1.1	0.6	0.3	**2**
	Sum	**265**	**131**	**66**	**462**

D.F. = (3-1)*(3-1) 4

Yates Correction? No

Path Type	Site Number 2	3	4
A	0.0	0.0	0.0
B	0.2	0.5	0.0
C	0.0	0.3	0.3

Chi squared? 1.36

Critical Value? 14.86 for a P=.005*

7.78 for a P=.100

Result: No relationship, not even small

Conclusion: One of the sites is different than the other three

*p=(0.05/10) =0.005

Non Bus Stop User Paths (Snow)

Path Type		Site Number 1	2	3	4	Sum
A	Actual	22	145	110	17	**294**
	Expected	25.7	141.5	109.3	17.5	**294**
B	Actual	5	2	2	1	**10**
	Expected	0.9	4.8	3.7	0.6	**10**
C	Actual	1	7	7	1	**16**
	Expected	1.4	7.7	6.0	1.0	**16**
	Sum	**28**	**154**	**119**	**19**	**320**

D.F. = (3-1)*(4-1) 6
Yates Correction? No

Path Type	Site Number 1	2	3	4
A	0.5	0.1	0.0	0.0
B	19.4	1.6	0.8	0.3
C	0.1	0.1	0.2	0.0

Chi squared? 23.17
Critical Value? 18.55 for a P=.005*
Result: Strong relationship

Non Bus Stop User Paths - Snow - Wide curb vs No Wide Curb

Path Type		Station Type: Wide Curb (1)	No Wide Curb (2, 3 & 4)	Sum
A	Actual	22	272	**294**
	Expected	25.7	268.3	**294**
B	Actual	5.0	5.0	**10**
	Expected	0.9	9.1	**10**
C	Actual	1.0	15.0	**16**
	Expected	1.4	14.6	**16**
	Sum	**28**	**292**	**320**

D.F. = (3-1)*(2-1) 2
Yates Correction? No

Path Type	Station Type: Wide Curb (1)	No Wide Curb (2, 3 & 4)
A	0.54	0.05
B	19.45	1.86
C	0.11	0.01

Chi squared? 22.03
Critical Value? 10.6 for a P=.005*
Result: Strong relationship

Non Bus Stop User Paths - Snow - Within No Wide Curb Sites

Path Type		Site Number 2	3	4	Sum
A	Actual	145	110	17	**272**
	Expected	143.5	110.8	17.7	**272**
B	Actual	2	2	1	**5**
	Expected	2.6	2.0	0.3	**5**
C	Actual	7	7	1	**15**
	Expected	7.9	6.1	1.0	**15**
	Sum	**154**	**119**	**19**	**292**

D.F. = (3-1)*(3-1) 4
Yates Correction? No

Path Type	Site Number 2	3	4
A	0.0	0.0	0.0
B	0.2	0.0	1.4
C	0.1	0.1	0.0

Chi squared? 1.84
Critical Value? 14.86 for a P=.005*
7.78 for a P=.100
Result: No relationship, not even small

Conclusion: One of the sites is different than the other three

*p=(0.05/10) =0.005