# FACTORS CONTRIBUTING TO WINTER CYCLING:

# CASE STUDY OF A DOWNTOWN UNIVERSITY CAMPUS IN TORONTO, CANADA


by

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**Abstract**

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Master of Planning (Urban Development)

Ryerson University

Cycling rates in many North American cities decline significantly in winter months, which is a major challenge for practitioners and advocates in advancing active transportation-related policy, planning, and programs. This research investigates Ryerson University as a major commute destination. By combining a student and employee transportation survey, this research examines characteristics associated with winter cycling. Our results indicate that women (OR=0.38) and transit pass holders (OR=.12) were less likely while students rather than staff (OR=1.69) were more likely to cycle during the winter. The density of dedicated bicycle facilities within 500m of the shortest route was positively associated with all-season cycling (OR = 1.57). Also, a cyclist living in a more stable neighbourhood was more likely to bicycle through winter (OR=4.33), when compared to cycling only in warmer seasons. These findings will be useful to city planners considering how to encourage winter cycling to urban university campuses and/or major downtown employment centres.

Key words: winter cycling, active transportation, modal shift, student transportation, employee transportation

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# Chapter 1 Introduction

Cycling rates in many North American cities decline in winter months (Amiri & Sadeghpour, 2013; Sears, Flynn, Aultmann-Hall, & Dana, 2012; Flynn, Dana, Sears, & Aultman-Hall, 2012), which is a major challenge for practitioners and advocates in advancing active transportation-related policy, planning, and programs. Research on winter cycling in North America is sparse; even more so in Canada. Beyond weather and climate, a traveller's socio-demographic characteristics, travel and residential location preferences, and access to cycling infrastructure may also influence whether they continue to cycle in the winter months. This study statistically examines the above-mentioned factors in relation to all-season cycling (versus cycling only in warmer months) among staff and students of Ryerson University in Toronto, Canada.

## 1.1 Perception of Reduced Rates of Cycling

There is a dominant, but difficult to document perception that no one cycles in the winter. The Cycling Embassy of Great Britain (2016) lists adverse weather conditions as one of their "cycling fallacies" – i.e., psychologically constructed barriers that individuals argue prohibits cycling. However, research has found that daily weather patterns, not climate, has a stronger influence on cycling rates across the world (Nankervis, 1999), particularly in countries with more northern climates (Amiri & Sadeghpour, 2013; Sears et al, 2012; Flynn et al, 2012; Pucher & Buehler, 2006; Bergström & Magnusson, 2003).

A major hurdle that bicycle planners face is the perception that cycling only occurs in fair weather. For instance, when the City of Toronto Council reviewed the ten-year cycling plan in June 2016, Deputy Mayor and Councillor Denzil Minnan-Wong requested that City of Toronto staff investigate the option of installing seasonal bicycle lanes (City of

Toronto, 2016a). Minnan-Wong perceives cyclists to be a fair season mode of transportation. Yet, other infrastructure that enables active transportation, such as sidewalks, are not proposed to be installed on a temporary/seasonal basis.

Often, winter cyclists are ‘othered’, and when critics accuse cycling infrastructure of remaining empty in winter months, they explain winter cyclists as divergent, spurious, or outliers. For example, in Strobel’s (2014) opinion piece in a local Toronto newspaper, he argues that bicycle lanes are “a waste of space”, consume “precious road space” (para. 9), and that anyone who *does* cycle in the winter months are “zealots”, members of the “fringe” (para. 16), and belong to a “bicycult” (para. 17). Rather, winter cyclists continue to commute by bicycle *despite* inadequate infrastructure and despite a hostile political climate.

Despite claims that ‘no one cycles in the winter’, some advances in the City of Toronto have been made, enabling cycling even in snowy conditions. In 2014, the City of Toronto adopted a motion to establish a level of service for the winter maintenance of priority bicycle routes, recognizing the importance of winter cycling in advancing active transportation in this city.

### 1.2 Emerging Literature Studying University Commutes

There exists a large body of literature that examines transportation mode choice behavior, and the demographic, social and environmental influences on travel outcome in urban areas (Ewing and Cervero, 2010). Within this broad field of investigation, an emerging research has explored travel by university students and employees. It is important to study universities because they are distinct commuter destinations and can be the source of significant demand. Additionally, they can also generate trips throughout the day, from the 9-to-5 full-time employees' schedule to evening classes for continuing education students.

Researchers have studied commute mode choice among students in large cities, (Páez & Whalen, 2010; Whalen, Páez, & Carrasco, 2013; Zhou, 2012; Zhou, 2014), college towns[1] (Delmelle & Delmelle, 2012), and rural campuses (Limanond, Butsingkorn, & Chermkhunthod, 2011). There is some research that focuses specifically on cycling among students in college towns (Hu & Schneider, 2015; Akar & Clifton, 2009), medium-sized cities (Whannell, Whannell, & White, 2012; Gatersblen & Appleton, 2006; Agarwal & North, 2012), and one study on a large city (Nankervis, 1999). There are also studies on student and employee cycling rates, such as those in medium-sized cities[2] (Gatersblen & Appleton, 2006) and college towns (Thigpen, Driller, & Handy, 2015), although research focusing on cycling among students *and* employees seems to be less plentiful. In comparison, this study examines cycling among students and employees in a large Canadian city, which is rather unique in this field. This study focuses more narrowly on winter cycling among students and employees attending an urban university in a large metropolis, so it is unlike other studies that exist.

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[1] College towns are a colloquial term and I have tried to define it here. I consider a 'college town' to be medium-sized city (a population between 100,000 and 499,999) where the main employer and/or commute destination is the university or college; has a large student population; and may be one large university or many small ones.

[2] I define cities in the following metrics, based somewhat on Statistics Canada's definition of population centres (2015):

- Large city: > 500,000
- Medium city: 100,000 < x < 499,999
- Small city: 20,000 < x < 99,000
- Small town: < 20,000

### 1.3 Paper Direction

In this Masters Research Paper (MRP), I will combine two surveys conducted among students and employees of Ryerson University, which is an urban university located in downtown Toronto, Ontario, to investigate the potential modal shift of cyclists in winter months. In this paper, I am studying cyclists to identify factors that are correlated with all-season cycling compared to cycling only in the spring/ fall.

Factors explored include: demographics, such as age and gender; access to alternative travel options, such as whether respondents own a transit pass or a car; the distance from home to campus; travel experiences and preferences, such as whether cyclists have difficulty finding parking, where they park, and the reasons behind why they commute by bicycle; cycling infrastructure and routes, including the amount of cycling infrastructure along the shortest path from home to campus; and the built environment near their home, such as land use mix and neighbourhood maturity.

By focusing on an urban university, this MRP will focus specifically on cycling in winter months from the city's inner urban neighbourhoods. Cycling rates in downtown wards in the City of Toronto are higher than the cycling rate for the entire agglomerated City. Ryerson University is located in ward 27, which is one of the wards with a higher bicycle modal share, and more cyclists may be interested in cycling in winter months. Moreover, cycling infrastructure and winter cycling route maintenance (City of Toronto, n.d.-a) is also currently concentrated in the urban parts of the city. Thus, the inner urban neighbourhoods of Toronto, which constitutes the expected 'bicycle shed' for Ryerson campus, is likely to have favourable environment for cycling throughout the year compared to other parts of the city.

This paper begins with a Literature Review in Chapter 2 of the impact of climate and seasons, weather, demographics, travel distance, infrastructure, and neighbourhood characteristics on cycling. Where research exists, I will also discuss the impact on winter cycling specifically. Last, I will discuss how current literature is examining cycling rates among post-secondary students as a unique demographic. Next, the Methods section (Chapter 3) will discuss the study area – Toronto, Ontario and Ryerson University, specifically – before moving on to a discussion of the data and the specific variables explored in this study.

In the Results section (Chapter 4), I will discuss the difference between seasonal cyclists and all-season cyclists regarding their socio-demographic, travel route and residential environment-related characteristics. Following that, results from multi-variate logistic regression model will be presented to outline the correlates of seasonal variation in cycling in Chapter 5.

In the Conclusion (Chapter 6), I will discuss the implications of the findings from the model in advancing knowledge and policy.

Ultimately, the goal of this paper is to give transportation planners and university staff the tools with which to understand how to encourage winter cycling among both students and employees. While a city may be responsible for infrastructure throughout a city, university campuses are unique and have discretion to plan their campus environment uniquely and often distinctly from the rest of the city. For urban, integrated campuses, this research provides direction on how to partner with municipalities and improve cycling winter rates through upgrades to and the expansion of city-maintained cycling infrastructure. Universities can see themselves as partners in the urban fabric and therefore have a great deal to contribute to enabling and encouraging winter cycling.

# Chapter 2 Literature Review

Researchers have studied the relationship between cycling and other factors, such as socio-demographics, including cycling among students specifically; infrastructure; and neighbourhood characteristics, land use mix, and built environment. Literature on the relationship between cycling and climatic conditions emerging, with limited evidence suggesting that climate and weather conditions may be inter-related with the other above-mentioned factors in influencing cycling (Agarwal & North, 2012). A limited research has also reported similar relationship between walking, weather, and climatic variations (Mitra & Faulkner, 2012).

## 2.1 Defining Climate, Seasons, and Weather

In this literature review, two related terms are examined when discussing the topic of 'winter cycling': climate and weather. The difference between weather and climate is temporal: weather describes the characteristics of the atmosphere over a short time range, whereas the climate is a demonstration of how the atmosphere behaves over a long time range (Government of Canada, 2016).

This research paper examines seasonal changes in cycling behaviour, such as by comparing winter or all-season cyclists to individuals who only cycle during warmer seasons, e.g., in the summer and the warmer parts of the fall months. In this regard, we can understand seasons to be more closely related to climate. Therefore, climate and seasons are considered synonymous in this study and can be contrasted with the impact of weather on cycling rates. In comparison, weather is understood to be the day-to-day conditions.

## 2.2 Impact of Seasonal Climate on Cycling

Research that studies the relationship between climate and cycling often takes one of the following forms: first, researchers will study stated preferences versus recorded behaviour. Also, the way a question is framed can impact responses. Researchers may ask respondents to estimate their most common form of transportation (Bergström & Magnusson, 2003), estimate the number of times they cycle per week (Winters, Friesen, Koehoorn, & Teschke, 2007) or month, maintain a travel diary (Sears et al, 2012), measure cycling rates, such as by using an intercept study (Amiri & Sadeghpour, 2014), or use census data, such as for nation-wide or cross-country comparisons (Pucher & Buehler, 2006).

When considering the impact of climate on cycling, there are three conflicting paths of consideration. First, in the USA, cycling during the summer is more common compared to other seasons (Guo et al, 2007; Sears et al, 2012). Yet, some surveys of cyclists suggest that many continue cycling throughout the winter (Amiri & Sadeghpour, 2014). Finally, when comparing countries and regions with differing climates, some research has found that there are areas with high cycling rates compared to other regions despite colder climates (Pucher & Buehler, 2006; Flynn et al, 2012).

There is an apparent decrease in cycling rates during winter months. Yet, some regions have overcome some of the factors that make winter cycling less enjoyable: for instance, improved snow clearance and quality cycling infrastructure are two ways to encourage cyclists to commute throughout the year (Pucher & Buehler, 2006; Bergström and Magnussen, 2003). Additionally, research seems to suggest that day-to-day weather patterns (Nankervis, 1999) and road conditions (Amiri & Sadeghpour, 2014) have a greater influence on whether a cyclist will choose to commute by bicycle or not.

Therefore, while climate does seem to impact cycling rates, climate in and of itself may not be the only factor affecting cycling rates in a country or region. Instead, perception of bad weather in certain seasons may have a more profound influence on cycling behavior.

**United States of America (USA)**: In the United States, researchers have identified that cycling is more popular in the summer compared to other seasons (Sears et al, 2012; Guo et al, 2007). Yet, in Vermont, Flynn et al (2012) found that, despite the relatively harsh winters of New England - compared to the rest of the country – 20% of surveyed cyclists (n=185) continued to cycle in winter months based on daily log reports. Sears et al (2012) came to similar findings, noting that many respondents cycled throughout the year through a variety of weather conditions.

**Canada**: Canada is regarded as having a harsher winter than the USA. Pucher and Buehler (2006) explored why cycling rates for Canadians is three times higher than Americans despite the colder climate. The study was framed by a discussion of climate, but the paper does not focus on winter cycling specifically. Rather, it is a comparative analysis of cycling rates between the two countries. They conclude that the Canada's higher cycling rate may be influenced by factors beyond climate. For example, they identified higher urban densities; mixed-use development; shorter trip distances; lower GDP per capita;[3] higher costs of owning, driving, and parking a car; safer conditions for

[3] Pucher and Buehler 2003 estimates from the Organisation for Economic Cooperation and Development (OECD), which estimate a GDP per capita of $37,000 USD for the United States compared to a GDP per capita of $30,500 USD for Canada. They suggest that these lower GDP per capita rates may explain lower car ownership levels in Canada compared to the United States. 2015 OECD data indicates that the GDP per capita for the United States is still higher than GDP per capita in Canada at $56,066 USD compared to Canada's $44,201 USD (OECD, 2017).

cycling; more comprehensive cycling networks; and more cycling education and training initiatives may explain why cycling rates are higher in Canada than the US.

Cycling rates in Canada have historically shown growth: from 1996 to 2006, work trips recorded in the Canadian Census show that the percentage bike share of workers increased from 1.1% in 1996 to 1.3% in 2006 (Pucher, Buehler, & Seinen, 2011). At the same time, the daily bike share of commuters increased from 137,000 in 1996 to 196,000 in 2006, a 42% increase (Pucher et al, 2011).

Amiri and Sadeghpour (2014) found that 60% of cyclists they surveyed in Calgary would cycle regardless of weather. This is unsurprising because the survey was conducted in March 2012, during which time the temperature ranged from -14.9°C to +14.2°C. Surveyed cyclists were likely all-season cyclists, which may indicate why they were so comfortable cycling in colder temperatures. Yet, they nonetheless identified self-reported barriers to cycling, of which 20.4% identified road conditions (e.g., broken or cracking road pavement) as a barrier.

Finally, Winters et al (2007) found in a study that utilized the 2003 Canadian Community Health Survey (CCHS), areas with more days of precipitation and days of freezing temperature per year had lower levels of utilitarian cycling.

**Australia**: In Australia, the climate lends to rainy winters.[4] However, Nankervis (1999) indicated in a study that while weather impacts daily cycling patterns, climate does not impact commuting by bicycle. Instead, Nankveris indicates that the daily temperature

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[4] Winter in Australia occurs from June to August and snow is extremely rare in Melbourne (Tourism Australia, 2017).

category (defined as the following four bins: very good (24-30°C), good (17-23°C), poor (<17°C), and very poor (>30°C), p<.000), daily wind category (defined in the following three bins: very good (<5kph), good (5-10kph), and poor (>10kph), p<.011), daily rain category (defined in the following four bins: very good (none), good (possible), poor (showers), and very poor (heavy), p<.052), and daily weather category (the four bin categories of very good, good, poor, and very poor, p<.002) were statistically significant.

#### *2.2.1 Impact of Daylight on Cycling*

Previous research indicates that the presence of daylight can encourage cycling, whereas nighttime may be a deterrent (Gatersleben & Appleton, 2007; Cervero & Duncan, 2003). Additionally, while in Sears et al's (2012), respondents indicated lack of daylight as a barrier to cycling, no statistical association between daylight and cycling could be identified. Their model included parameter estimates and odd ratios for the likelihood of bicycle commuting on a given day.

Gatersleben & Appleton's (2007) study found that, among university staff who had begun cycling to campus for the first time, poor weather or darkness accounted for 24% of self-reported unpleasant experiences. Since the research was conducted from February to April, they suspected that the change seasons explained why these two factors were the most-reported negative experience. Negative experiences related to traffic, bad weather, and a lack of daylight were mentioned less over time.

### 2.3 Impact of Weather on Cycling

Some authors have investigated stated preferences of cycling during adverse weather conditions (Flynn et al, 2012; Nankervis, 1999; Abasahl & Bakhsh Kelaresraghi, 2017; Gatersleben & Appleton, 2006) while others have tracked actual cycling rates (Nankervis, 1999; Flynn et al, 2012). Nankervis (1999), for instance, compared both stated preferences and actual cycling rates across four university campuses.

Precipitation may affect commute mode types differently. Böcker, Dijst, and Prillwitz's (2013) literature scan found that precipitation, wind, and temperature impacted different commute modes in different ways. Also, the effect of weather conditions may be different based on reason for travel – e.g., traveling for personal versus work reasons.

**Precipitation**: Existing literature has indicated that precipitation on the day of travel (Sears et al, 2012; Flynn et al, 2012), the monthly average of precipitation (Pucher & Buehler, 2006) can impact cycling rates. Yet, some other research has found that rainfall, measured as the number of inches of rain on the day of the trip, may have a negligible effect on cycling rates (Cervero & Duncan, 2003). Heinen, van Wee, and Maat (2010) speculate that divergences in the reported significance of rainfall on cycling rates may be due to the different ways in which precipitation is measured.

A longitudinal survey of working adults in four cities in Vermont, USA, found that temperature, wind speed, and precipitation (no vs yes), including snow conditions, were significant in explaining whether a respondent would commute by bicycle (Flynn et al, 2012). Researchers used convenience sampling with email lists from local organizations to study commute habits of adults on 28 specified days over a 10-month period. Precipitation and temperature had the strongest influence on whether a respondent chose to cycle: the odds of commuting by bicycle were nearly double when there was no precipitation recorded during morning commute hours. Wind speed had modestly diminished the odds of whether a participant cycled and snow depth also reduced cycling rates among those who commuted by bicycle in the winter.

Sears et al (2012) identify seasonal variations on winter cycling as including: temperature, type of precipitation (e.g., snow, rain, hail, etc), amount of precipitation, and hours of daylight. They also point out that the seasonal variation can particularly impact the north and central northeast regions of the United States and that these factors can differ, to a great degree, across the annual seasonal cycle.

Gatersleben and Appleton (2007) characterize weather as one of the barriers to cycling that are out of one's control. Other barriers include a lack of cycling infrastructure and hills. However, they further note that respondents in their two surveys who were prepared to cycle in the winter perceived fewer structural barriers, such as a lack of dedicated infrastructure, but identified more personal barriers, including work and commitments to family.

**Temperature**: A study by Sears et al (2012) in Vermont found that the likelihood of commuting by bicycle increased 3% with every 1°F in morning temperature and decreased by 5% with every 1 mph increase in wind speed. Nankervis (1999) could not find a clear relationship between daily temperature and *reported* cycling rates, and concluded that while temperature may affect cycling rates, the impact is likely moderate. Yet, observations of the number of bicycles parked at the study sites, indicated that the daily temperature was somewhat related to the daily number of riders, and that the daily temperature particularly affected cyclists.

**Wind**: Previous research has identified that high wind speeds can be a deterrent to cycling (Sears et al, 2012; Heinen et al., 2010). As Heinen et al. (2010) point out, while the consequences of other weather patterns, such as precipitation, as well as temperature and the amount of daylight are well-researched, the impact of wind is less known. One study by Sears et al (2012) found that the likelihood of a cyclist commuting decreased by

5% for every 1 mph (1.6 km/h) increase in wind speed. Variables, such as wind speed were linked to the reported baseline data based on date and location. The wind speed would therefore most likely be more of a daily average because it was not self-reported.

In Melbourne, Nankervis (1999) found that daily wind conditions were statistically significant when observing the number of bicycles parked on university campuses.

### 2.4 Demographics of Winter Cycling

Age and gender are two commonly-discussed demographics in winter cycling literature, but for the purpose of this study, students as a focus in winter cycling is also discussed.

**Age**: Winter cycling is more typically seen among younger, rather than older, populations (Begström & Magnusson, 2003; Flynn et al, 2012; Hebich, Böcker, & Dijst, 2014; Winters et al, 2007; Amiri & Sadeghpour, 2015). Cycling in two Swedish cities found that winter cycling was more common among younger age groups (Begström & Magnusson, 2003). The cycling rate during the winter was higher among a younger age group (20-34 years) compared to older ages (50-64 years).

**Gender**: Some studies (Amiri & Sadeghpour, 2013; Begström & Magnusson, 2003; Flynn et al, 2012; Hebich, Böcker, & Dijst, 2014; Winters et al, 2007;) have found that gender is related to winter cycling in that men are more likely to cycle in the winter than women. However, other authors have noted that due to higher response rates from men, results may be skewed, which may incorrectly overvalue the statistical relevant of men's winter cycling preferences (Sears et al, 2012; Flynn et al, 2012).

**Student cycling**: Agarwal & North (2012) conducted a study on student cycling in Kingston, ON. The authors examined preferences among non-cyclists, seasonal cyclists, and winter cyclists as well differences and similarities among men and women. Winter cyclists were more likely (91.7%) than other cyclists (non-bicyclist: 79.4%; seasonal cyclist: 84.8%) to agree that when cycling on the road shoulder, snow ploughed into the shoulder makes the route less safe.

### 2.5 Travel Distance and Cycling

Studies have investigated the relationship between travel distance and cycling (Sears et al, 2012; Braun et al, 2016; Cervero & Duncan, 2003; Parkin et al, 2007; Timperio et al, 2006; Stinson & Bhat, 2005; Dickinson et al, 2003; Mitra, Smith Lea, Cantello, & Hanson, 2016) and some studies have investigated the correlation particularly as it pertains to winter cycling (Agarwal & North, 2012; Begström & Magnusson, 2003; Flynn et al, 2012).

Bergström and Magnusson (2003) showed a correlation between trip distance from home to work and mode choice in both their 1998 and 2000 surveys. Increasing distance from work was correlated with a decrease in cycling and walking trips and an increase in car trips. Over 20 km, almost no one cycled to work and over 10 km, cycling to work diminished significantly in the winter.

Sears et al found (2012) that the rate of cycling decreased as the distance increased at a rate of an 8% decrease for every additional mile of commute distance.

### 2.6 Infrastructure and Cycling

Previous studies have established a link between the quality of cycling infrastructure provided and willingness to cycle. For instance, inexperienced cyclists are more interested in a separate path or bicycle lane compared to experienced cyclists (Stinson & Bhat, 2005; Dill & Gliebe, 2008) and women often report a preference for dedicated cycling infrastructure compared to men (Dill & Gliebe, 2008), although actual use of dedicated cycling infrastructure may be similar among men and women (Dill & Gliebe, 2008). Overall, studies have found that cyclists generally prefer routes with dedicated cycling infrastructure (Monsere, Buehler & Dill, 2016; Krizek, El-Geneidy, & Thompson, 2007; McNeil, & Dill; 2012; Menghini, Carrasco, Schüssler, & Axhausen, 2010; Tilahun, Levinson, & Krizek, 2007; Agarwal & North, 2012; Dill, 2009; Stinson & Bhat, 2005).

According to results from two Swedish surveys conducted in 1998 and 2000, 57% of the respondents in 1998 (n=866) and 62% of respondents in 2000 (estimated n=597)[5] thought that there should be improvements made to snow clearance (Begström & Magnusson, 2003). Respondents in the 2000 survey suggested that winter maintenance could be improved with more frequent snow clearance, de-icing, and conducting snow clearance earlier in the morning. In the 1998 survey, 38% of respondents stated that they would cycle more if winter maintenance improved. In the 2000 survey, 43% of respondents indicated the same. This may suggest that over time, people have become more sensitive to the issue of snow clearance; however, the authors do not pursue this point any further.

Improved winter maintenance would not likely create new cyclists in the short term: summer cyclists and existing cyclists indicated that they would cycle more in winter, while infrequent cyclists and those who never cycle were not more likely to cycle. Therefore, improving winter clearing of bicycle routes would likely benefit existing cyclists and should be seen as a second step to improving cycling rates at a population level. Once an individual begins cycling in fair weather, it is possible that they may transition to winter cycling later.

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[5] The sample size was not stated for the 2000 survey, but 829 questionnaires distributed, with a response rate of 72%. The sample size is therefore 596.88, or about 597.

## 2.7 Neighbourhood Characteristics and Cycling

The built environment is often used as a measurement when assessing neighbourhood choice. For instance, the impact of the following factors have been investigated to identify the impact on cycling rates: network layout (Moudon, Lee, Cheadle, Collier, Johnson, Schmid, & Weather 2005; Zacharias, 2005), city centre/ urban density (Guo et al, 2007; Pucher & Buehler, 2006), intersection density (Dill & Voros, 2007), street connectivity (Dill & Voros, 2007), residential density (Zahran, Brody, Maghelal, Prelog, & Lacy, 2008; Guo et al, 2007), commercial density (Braun et al, 2016), and population density (Guo et al, 2007; Zahran et al, 2008; Parkin, Wardman, & Page, 2008; Braun et al, 2016).

Boone-Heinonen, Gordon-Larsen, Guilkey, Jacobs, and Popkin (2011) caution that neighbourhood choice is also inter-related with other variables. The authors note that residents may select the location of their homes based on their preferences or travel attitudes. Consequently, failing to account for their self-selection can undermine research that examines the relationship between environmental variables and physical behaviour. Therefore, when considering the relationship between infrastructure and neighbourhood choice, it is important to remain cognizant of the potential for bias in the results.

## 2.8 Cycling among post-secondary students

Research on cycling frequently utilizes staff and students commuting to researchers' affiliated university as a subject population. Ease of surveying a university's own population makes them popular and convenient participants. Surveying cycling on campuses, particularly those located in small college towns in the US, because of higher rates of cycling in those environments. More generally, students often have higher rates of cycling compared to older generations, which is convenient because low cycling incidences often prevent the inclusion of cycling in transportation mode choice behavior models.

A university campus is a distinct environment in which to study commute patterns, choices, and preferences. Universities themselves are interesting case studies for consideration because, universities can be a single destination for many commuters, particularly for universities with a high enrollment (Volosin, 2014). They generate trips as the destination (Volosin, 2014), including traffic generation (Balsas, 2003).

In addition to the unique characteristics of a university as a destination, the demographics of the individuals who access it vary greatly. As Balsas (2003) notes, they serve people of many different income levels, ethnicities and races, lifestyles, and attitudes, who navigate their way to campus to work or study. University campuses are often home to migratory attendees who experience the environment for a short amount of time (Balsas, 2003). Yet, these experiences occur on a human scale, as campuses are reflective of a larger city environment (Balsas, 2003).

Despite the noted diversity, university campuses can also be places of homogeneity. As Gatersleben & Appleton (2007) note, the population is likely to skew toward being highly-educated and may not represent very low income groups. Such groups may therefore be under-represented, and for this reason, they indicate that their study on a university campus was not constructed to be representative of the greater population.

Students and staff attending universities are useful microcosms of the wider public in certain senses. Faculty and staff may vary from typical nine-to-fivers, who commute to work at the same time Monday through Friday; they may work fewer or unusual hours compared to other working adults, such as by commuting to campus only to lecture (Volosin, 2014). Students have less reliable schedules (Nankervis, 1999), which vary from semester to semester and may choose to organize their schedules to accommodate their commutes. For instance, early reported findings of the StudentMoveTO (2016) report found that peak travel typically occurs between Tuesday and Thursday because students are grouping their courses together. Students may also have lower access to vehicles (Nankervis, 1999). These various factors make universities a unique setting for a study of cycling behaviour.

## Chapter 3 Methods

This chapter describes the methodological approaches adopted to explore this study's key research question focusing on potential difference in cycling behavior between winter and warmer months. Characteristics of the study area is described first, followed by a discussion of the sources used to collect travel mode choice data. Next, the socio-demographic, travel route and residential environment-related variables that were explored in this study are discussed, which is followed by a detailed discussion of the statistical methods used to analyse these data.

### 3.1 Study Area

Ryerson University, which is the key study area for this study, is located within the City of Toronto. The City has a population of 2.7 million (Statistics Canada, 2017a) and the census metropolitan area (CMA) is home to 5.9 million people (Statistics Canada, 2017b). Toronto is the seat of the provincial government of Ontario and is the main economic powerhouse of Canada (OECD, 2010). As of 2006, nearly 50% of residents were members of an ethnic minority group and nearly 50% were immigrants (Statistics Canada, 2011).

Toronto is home to four universities: OCAD University, Ryerson University, the University of Toronto, and York University; as well as four colleges: Centennial College, George Brown College, Humber College, and Seneca College. Within these eight institutions are over 253,000 students (Universities Canada, n.d.; Government of Ontario, 2017).

A high proportion of Ryerson's students and staff, however, live in the surrounding municipalities, which are part of the Greater Toronto and Hamilton Area (GTHA) (StudentMoveTO, 2015; Nahal, Ryerson University Employee Transportation Survey, 2016, July 22). This pattern is not unexpected, and current research shows that commuters who regularly travel to Toronto are increasingly looking outside the GTA's boundaries to find less expensive housing and urban sprawl has trickled into previously rural areas (Miller, 2009).

For the past 60 years, Toronto, and more broadly the GTHA, has been one of the fastest-growing metropolitan regions in North America (Sorensen & Hess, 2015). At the same time, Toronto has also seen a massive growth in the inner urban neighbourhoods, predominantly through investment in mid-to-high-rise condominium units (Lehrer & Wieditz, 2009).

**Climate of Toronto**: North America has a continental climate that is characterized by cold winters and warm summers (Theobald, Radonjic, Telenta, Music, Chambers, & Young, 2011). Toronto has a "continental-type macroclimate", though this is modified by the Great Lakes (Munn, Thomas, & Yap, 2011, 34).

Summer in Toronto typically begins in late May and the maximum temperatures may exceed 20°C (Munn et al, 2011). Temperatures tend to be their highest in July or August. Humidity can also impact the summer months. In the fall, daily maximum temperatures tend to fall to the upper teens in mid-September. By the first week of November, the mean daily temperature is about 5°C or 6°C (Munn et al, 2011). Snow may begin to fall in October, but it does not begin to accumulate until November. In the winter, which begins by early December, most of the days' mean temperature is around 0°C (Munn et al, 2011). The average temperature from December to February is -3°C. Spring usually occurs in March and by mid-March, the mean temperature tends to be above freezing (Munn et al, 2011).

**Planning for Cycling in Toronto**: Toronto is an interesting city in which to study cycling and winter cycling because it of the city's often tempestuous relationship with cycling and cycling infrastructure. From the removal of the Jarvis St Bike Lane in 2011, only two years after its installation (City of Toronto, 2012) to the adoption of a Ten Year Cycling Network Plan in 2016, the political climate with regard to cycling has shifted. In 2016, the city also implemented a pilot project for bike lanes on Bloor St, almost 40 years since Bloor St was first studied for bike lane feasibility in 1977 (Barton-Aschman Canada Limited, 1977).[6] While the city, its politicians, and its populace have not always taken a kind view of cyclists, new dedicated cycling infrastructure has been introduced on downtown routes, such as on Sherbourne St in 2012 (City of Toronto, n.d.-d), Harbord St in 2014 (City of Toronto, n.d.-e), and Richmond St and Adelaide St in 2014 (City of Toronto, n.d.-f).

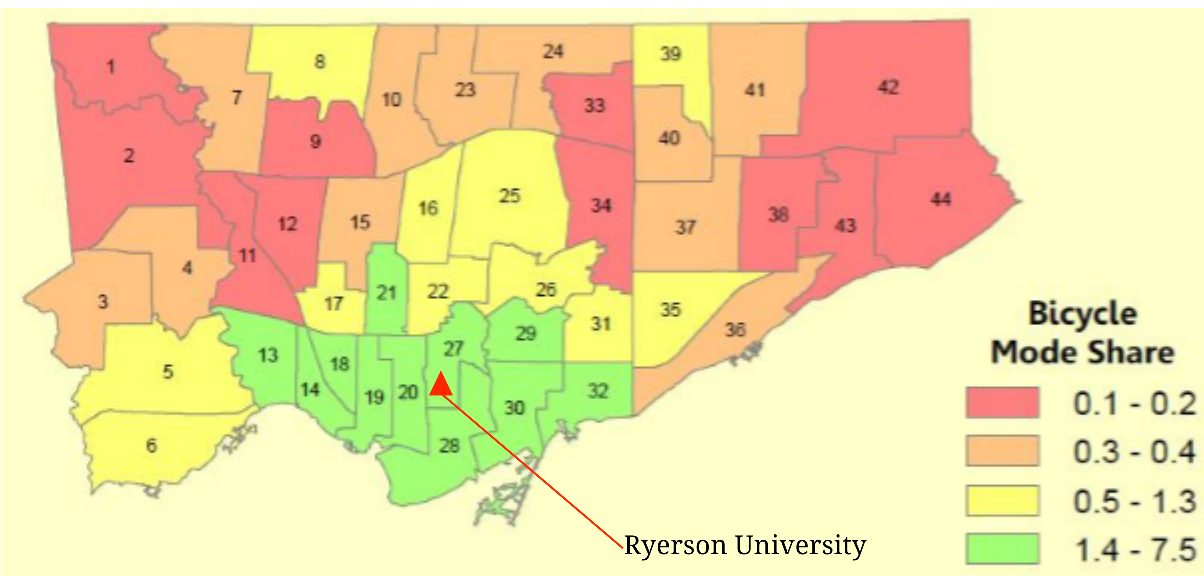
The City of Toronto has 243 km of dedicated cycling infrastructure[7] plus 300 km of off-road trails (City of Toronto, 2016b). In the early 2010s, Toronto made gains in improving the cycling infrastructure in the city, such as introducing painted bicycle lanes to Bay Street and a cycle track pilot project to Richmond and Adelaide Streets (Vijayakumar & Burda, 2015). In 2016, the City of Toronto adopted a Ten Year Cycling Network Plan, which outlines the work to be done studying and building new cycling infrastructure in the city (City of Toronto, 2016b). Yet, compared to other major cities in Canada, specifically Montreal, QC; Vancouver, BC; Calgary, AB; and Ottawa, ON; Toronto lags

[6] While Bloor St was proposed, it was ultimately rejected in the working paper, due to a desire to retain the arterial status of the road and concerns about retail business viability.
[7] Dedicated cycling infrastructure includes cycle tracks (18.7km), white bicycle lanes (216.8km), and yellow 'contra-flow' bicycle lanes (7.5km) for a total of 243km.

behind with the lowest rate of cycling infrastructure per capita (Vijayakumar & Burda, 2015).

**Cycling Rates in Toronto**: In the GTHA, the current mode share of cycling compared to other rates is 0.98% (Mitra et al, 2016). The combined walking and biking commute modal share is 6.1%, which is higher than most large urban regions in North America. Cars take up the largest share, at 78.06%, while transit follows at 14.05%; GO Transit (regional transit) at 1.65%, and other at 0.16%. While the cycling modal share is low, cycling trips increased from 79,000 to 126,000 over the span of the last ten years, indicating a 61% increase in the number of cycling trips made by residents and a 37% increase in the modal share of cycling. In the City of Toronto, cycling rates are slightly higher, at 1.9% (Mitra et al, 2016). Additionally, the bicycle modal share is higher in downtown wards, as shown in Figure 3-1 and **Error! Reference source not found.**.

**Figure 3-1: Bicycle mode share by ward (Ledsham, Liu, Watt, & Wittann, 2013).**




It is commonly argued that cycling rates in Toronto neighbourhoods decline significantly in winter months due to colder climate and snowy conditions. Representative data on the seasonal difference in day-to-day cycling behavior does not exist. However, in a City of Toronto survey found that in 2009, 10% of Toronto's residents (n=1000) indicated that they cycled in the winter. The survey asked participants to indicate the seasons in which they cycle; responses are outlined for spring, summer, fall, and winter (City of Toronto, 2010).

The number of respondents who used a bicycle for utilitarian purposes has increased from 1999 to 2009 (City of Toronto, 2010). While 20% of respondents in 1999 (n=1001) indicated that they cycled for utilitarian reasons, this increased to 29% in 2009 (n=1000).

**Ryerson University**: Ryerson University is a major commute destination located in downtown Toronto and has a large commuter-shed spread across the surrounding region. As of 2016, 41,900 students were enrolled at the university.[8] (Universities Canada, n.d.)

This setting is novel, as other existing studies conducted on student and staff cycling are often conducted in college towns (Hu & Schneider, 2015; Akar & Clifton, 2009; Delmelle & Delmelle, 2012; Thigpen et al, 2015), and only a limited literature has explored post-secondary students' cycling behaviour in large cities (Zhou, 2012; Gatersblen & Appleton, 2006; Nankervis, 1999).

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[8] According to Universities Canada, Ryerson University has 25,800 full-time undergraduate, 2,200 full-time graduate, 13,500 part-time undergraduate, and 400 part-time graduate students.

## 3.2 Data

Two transportation surveys were combined to create a dataset describing travel behavior, and its seasonal variation, among students and employees at Ryerson University.

**Students**: Data relating to student travel was taken from The StudentMoveTO survey, which was conducted in Fall 2015, among students studying at four Toronto area universities: OCAD University, Ryerson University, York University, and the University of Toronto. The survey was the largest of its kind studying student transportation mode and patterns (Christie, 2015). All students registered at one of these four universities received an email from their university's administration containing a link to complete an online survey. The survey requested participants complete a travel diary for one full day, e.g., the previous day's travel. Emails were sent randomly to students over the course of one and a half months to randomize the distribution of travel among respondents. The total response rate was 8.3%, with 15,226 completed surveys.

Questions in StudentMoveTO included: socio-demographic characteristics of respondents, travel attitudes, residential location, activity locations, as well as a travel diary section in which respondents indicated the stops they made for all trips the previous day.

Out of the four surveyed universities there are seven campus locations, with three in suburban neighbourhoods (University of Toronto's Mississauga and Scarborough campuses and York University's Keel and Glendon campuses), while the remaining four campuses are located in the core of the City of Toronto. Since the sample ranged across the urban and suburban scales, this resulted in a dataset with both breadth and depth of student travel. The dataset is useful in examining student behaviour in a large agglomerated city and millennial students in particular.

StudentMoveTO has 2,925 responses from students at Ryerson University, for a total response rate of 8.8%.[9]

**Employees**: A survey on employee transportation choices and preferences was developed using StudentMoveTO as a base. The Ryerson University Employee Transportation Survey gathered detailed demographic data, trip origins, and transportation choices in the summer of 2016. The survey was issued by email to 4,789 email addresses, which included 98.6% of all 4,857 Ryerson University employees.[10] 1,313 employees completed the survey with a response rate of 27%.

**Combined dataset**: From the two surveys, detailed travel and socio-demographic characteristics of current cyclists were combined into one database to be used in this study. This pooled dataset also included information relating to travel and residential preferences. The dataset used for this study included 279 students, staff, and faculty who self-reported cycling to school on a typical weekday in Fall/ Spring. The sample sizes for students and employees are roughly the same, at 155 and 168 respectively. Seasonal variation in cycling was identified by a key question: “On a typical winter day, what main mode of transportation do you use when travelling to and from the university?” Those who indicated a seasonal switch in travel mode were identified as “Fall/Spring cyclists” and the rest were identified as “All season cyclists”.

[9] As of 2015, Ryerson University’s student enrollment number was 40,851.
[10] The email was sent to active employees only, as it does not include employees who take a leave of absence. The number of active and total employees fluctuates as employees join and leave the university. The numbers are as of July 27, 2016.

Results from the two surveys indicate that public transit is the most common form of transportation for both students and staff at Ryerson University. As shown in Table 3-1, local transit is the most common form of transportation in the fall/ spring months among students at all the universities in Toronto. The percentage of students who use local transit as their main mode ranges from 43% at the University of Toronto St. George campus to 59% at the University of Toronto Scarborough campus (UTSC). Ryerson University sees 54% of students relying on local transit to get to campus. Furthermore, among the universities surveyed in StudentMoveTO, Ryerson has the highest rate of usage of regional transportation (GO Transit) at 23%. OCAD University is the second-highest at 19%, while the University of Toronto Mississauga (UTM) campus has the lowest GO transit ridership at 4%.

Cycling rates at universities ranges from a low of 1% at York University Glendon and Keele campuses and UTM to a high of 12% at the University of Toronto St. George Campus and OCAD University (see Table 3-1 and Table 3-2). Comparatively, Ryerson has a cycling rate of 5% among students and 13% among employees (see Table 3-2). At Ryerson University, among those who cycle as their main commute mode, 32% of students and 24% of employees reported that they continue to cycle in the winter months.

**Table 3-1: Main mode of transportation in the Fall among students attending universities in Toronto, ON**

| University and campus[11] | Bike | Local Transit | Other[12] | Regional Transit | Rideshare | Solo Driver | Walk | Total |
|---|---|---|---|---|---|---|---|---|
| University of Toronto, St. George campus | 755 (12%) | 2664 (43%) | 67 (1%) | 603 (10%) | 85 (1%) | 160 (3%) | 1829 (30%) | 6163 |
| York University, Glendon campus | 2 (1%) | 188 (58%) | 10 (3%) | 33 (10%) | 17 (5%) | 33 (10%) | 41 (13%) | 324 |
| York University, Keele campus | 45 (1%) | 1796 (55%) | 26 (1%) | 512 (13%) | 149 (5%) | 388 (12%) | 327 (10%) | 3243 |
| University of Toronto, Mississauga (UTM) | 9 (1%) | 542 (58%) | 41 (4%) | 38 (4%) | 109 (12%) | 129 (14%) | 76 (81%) | 943 |
| OCAD University | 54 (12%) | 223 (47%) | 3 (1%) | 90 (19%) | 3 (1%) | 11 (2%) | 86 (18%) | 470 |
| Ryerson University | 153 (5%) | 1571 (54%) | 20 (0%) | 659 (23%) | 43 (1%) | 77 (3%) | 400 (14%) | 2923 |
| University of Toronto, Scarborough campus (UTSC) | 16 (2%) | 625 (59%) | 6 (0%) | 58 (5%) | 111 (10%) | 117 (11%) | 130 (12%) | 1063 |
| Total | 1034 (7%) | 7608 (50%) | 173 (1%) | 1993 (13%) | 517 (3%) | 915 (6%) | 2889 (20%) | 15129 |

**Table 3-2: Comparison of cycling rates among employees and students at universities in Toronto.**

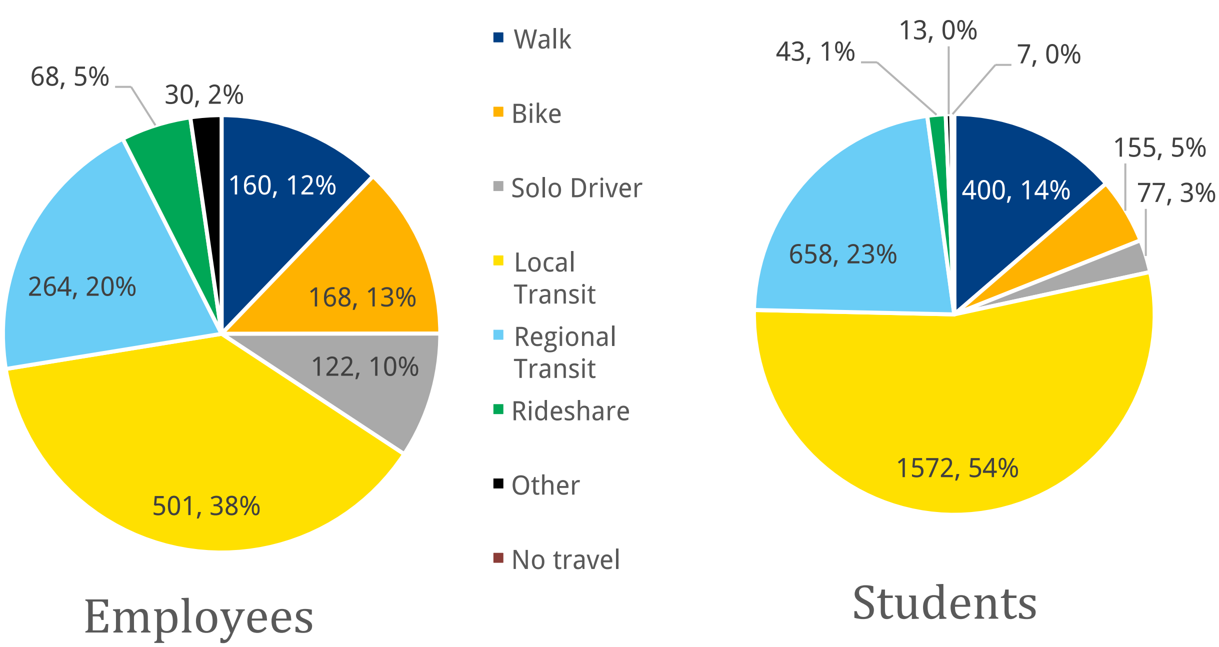
| University | Campus type | Student vs Employees | Cycling rate | All-season cycling rate | All-season cyclist sample size[13] |
|---|---|---|---|---|---|
| OCAD University | Urban | Students | 12% | 26% | 51 |
| Ryerson University | Urban | Employees | 13% | 24% | 168 |
| | | Students | 5% | 32% | 155 |
| University of Toronto, St. George Campus | Urban | Students | 12% | 40% | 750 |
| University of Toronto, Mississauga Campus (UTM) | Suburban | Students | 1% | 11% | 9 |
| University of Toronto, Scarborough Campus (UTSC) | Suburban | Students | 2% | 33% | 15 |
| York University, | Suburban | Students | 1% | 50% | 2 |

[11] Respondents were asked to identify the university they currently attend and respondents who selected the University of Toronto and York University were asked two further questions: the campus at which they are registered and the campus at which they spent the majority of their time. This table uses answers from the campus at which they spend the majority of their time because its sample size is slightly higher than the former option.
[12] The "other" and "no travel" categories were combined for "other."
[13] Sample size for winter cyclists is lower than the total number of respondents who cycle because not all respondents indicated their main mode of transportation in winter months.

| | | | | | |
|---|---|---|---|---|---|
| Glendon Campus | | | | | |
| York University, Keele Campus | Suburban | Students | 1% | 25% | 48 |

At Ryerson University, while the number of students who reported travelling by local transit was higher than those of employees, both populations reported similar rates of travel by regional transit. Figure 3-2 shows the differences of reported fall commute mode between the two populations. Additionally, while employees reported higher driving rates – both as solo drivers and as passengers in a rideshare – they were also more likely than students to report cycling to campus.

**Figure 3-2: Main fall commute mode among Employees and Students at Ryerson University**




## 3.3 <u>Variables Explored</u>

Variables tested were a mix of categorical survey responses, which were incorporated as dummy variables; and location data, land use data and network characteristics from the

2006 or 2011 Canadian census. The variables examined are summarized in Table 3-3, along with a short description.

**Table 3-3: Variable Descriptions**

| Variable | Description |
|---|---|
| **Demographics** | |
| Gender (Female) | Gender of the respondent, either female (1) or not female (0, male, other, or gender non-conforming). |
| Age | Age of the respondent. |
| Employee | Whether the respondent is an employee (1, staff, faculty, employee, etc) or a student (0). |
| **Travel Choices** | |
| Bike Share member | 1 if the respondent is a Bike Share Toronto member, 0 otherwise. |
| Possess a transit pass | 1 if the respondent owns a transit pass, 0 otherwise. |
| Possess a driver's license | Indicates that the respondent possesses a driver's license; 1 if yes, 0 otherwise |
| Car owner | Indicates that the respondent owns a car; 1 if yes, 0 otherwise |
| Number of cars owned | Number of cars owned by the household, 0 = No car, 1 = 1 car, 2 = 2 cars, 3 = 3 or more cars |
| **Travel Experiences and Preferences** | |
| Difficulty finding parking | Difficulty in finding bicycle parking on/around campus: 1 if yes, 0 otherwise. |
| Parking location: indoors | Typical parking location on campus: 1 if indoors, 0 otherwise. |
| *Most important factor in choice to commute to university:* | |
| Exercise | Cycling is a good form of exercise; 1 if yes, 0 otherwise |
| Faster | Cycling is faster than other means of transportation; 1 if yes, 0 otherwise |
| Environment | Cycling is good for the environment; 1 if yes, 0 otherwise |
| Cost | Cycling is less expensive than other means of transportation; 1 if yes, 0 otherwise |
| Pleasant | It is a pleasant ride (nice bike paths, attractive neighbourhoods, …); 1 if yes, 0 otherwise |
| *Highest influence on choice of residence:* | |
| Walk and bike | Ability to walk and bike; 1 if yes, 0 otherwise |
| Amenities | Amenities of neighbourhood (shops, parks, houses, …); 1 if yes, 0 otherwise |
| **Cycling Infrastructure en-Route** | |
| Travel Distance | Measured shortest path distance from home to campus using current road transportation network (KM) |
| Cycling infrastructure en-route | Dedicated on street cycling infrastructure (cycle track and painted bicycle lane) within a 500m buffer of the shortest path, per km of travel distance using the shortest path. |
| Accessibility Index | The ratio of shortest path distance between home and school, and the shortest path if using dedicated cycling infrastructure (bicycle lanes and cycle tracks). |
| **Built Environment Near Home** | |
| Business density | Number of businesses/ $km^2$ in the dissemination area (DA) of residence: retail, commercial uses, and personal services. |
| % Residential land use | Percentage of land use dedicated to Residential Use, in the DA of |

| | |
|---|---|
| | residence.* |
| Housing < 10 years | Proportion of housing built in last 10 years, in the DA of residence. |
| Housing > 35 years | Proportion of housing that is older than 35 years, in the DA of residence. |

* Open Space/ Farmland not included.

Variables were sorted into the following categories: demographics, travel choices, travel experience and preferences, cycling infrastructure and travel routes, and built environment near home.

### *3.3.1 Demographics*

Demographic variables included three key variables for comparison: gender, age, and employee vs student status. Data came from StudentMoveTO and the employee transportation survey.

Anyone who answered the StudentMoveTO survey was set to a student, while anyone who answered the employee survey was set as an employee.

### *3.3.2 Access to Alternative Transportation Options*

Travel options were reported by respondents in StudentMoveTO and the employee transportation survey. Both surveys had additional questions about travel choices, but not all matched. Therefore, the five variables selected were: bike share membership, possess a transit pass, possess a driver's license, car owner, and number of cars owned by the household, which were common across the two surveys. Detailed descriptions are provided in Table 3-3.

### *3.3.3 Travel Experience and Preferences*

Both surveys included questions relating to the stated travel experiences and preferences of respondents as they related to bicycle parking and factors that contributed to their commute mode to the university. The variables include: difficulty finding bicycle parking, bicycle parking location on campus, and the most important factor in their choice to commute to university (Table 3-3).

Respondents were also asked in both the student and employee surveys to identify the most important factors in their choice to commute to the university. Only the first choice was selected for analysis. The following options were offered in both surveys:

- Cycling is a good form of exercise
- Cycling is faster than other means of transportation
- Cycling is less expensive than other means of transportation
- It is a pleasant ride (nice bike paths, attractive neighbourhoods, …)
- Cycling is good for the environment
- I live close to campus
- Other

All factors, except for 'Other', were converted into dummy variables. Respondents who selected an option were recoded to '1' whereas respondents who did not select the variable were recoded to '0'.

### 3.3.4 *Estimated Travel Routes and Cycling Infrastructure*

The Distance variable was constructed using Network Analyst to calculate the shortest path from home to campus (KM) using the current road network, based on a respondents' nearest major intersection or postal code. Both the employee and student surveys also asked respondents to estimate the travel time in minutes for their main commute. However, due to unreliability issues with self-reported travel time, estimated shortest-path distance was used as a more reliable variable.

The access to two types of cycling infrastructure was explored: dedicated cycling infrastructure, which was defined as on-street painted bicycle lanes and cycle tracks; and soft infrastructure, which was defined as to include sharrows, off-street trails, and designated routes.

First, the presence of cycling infrastructure within a 500m buffer of the shortest path travel route was estimated. Within the buffered distance, the total kilometres of cycling infrastructure was estimated and normalized based on the total kilometres of travel distance (i.e., the shortest path distance).

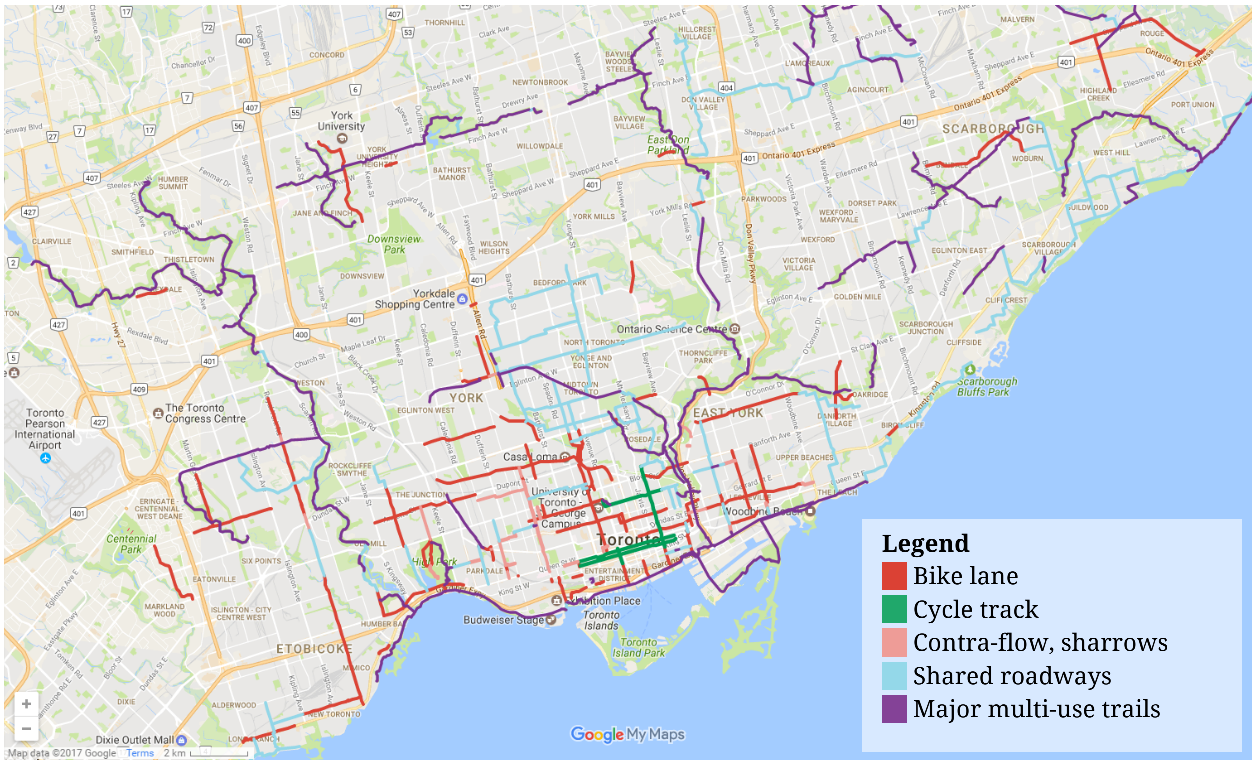
Second, the relative accessibility to university campus (from home location) using a bicycle network was also estimated. This was termed the Accessibility Index. To calculate the Accessibility Index, a new shortest path using dedicated cycling infrastructure, was calculated, for those who had access to a cycling infrastructure within 500m of their home location. Next, we calculated the ratio of the shortest-path distance to this estimated total route length using cycle infrastructure, to standardize the values in an index. The values ranges from 0 to 1, where 0 indicated that an individual cannot commute to university campus using a cycling infrastructure (i.e, no cycling infrastructure within 500m of home location), and 1 indicating the presence of a cycling infrastructure all the way along the shortest path. In some instances, the resulting path was still shorter than the Distance because the ‘generate near table’ function calculates a straight line from the home to the beginning of the route because it does not account for street properties. To accommodate for this, all values in the index over ‘1’ were re-coded to ‘1.0’.

Respondents of the student and employee surveys are spread out across the city. Except for a handful of students and employees, and mostly live within comfortable biking distance of Ryerson University (mean=4.704 km, SD=2.492, min=0.483 km, max=16.61

km). Mitra et al (2016) found that a distance of 1 to 5km is a “reasonable cycling distance” based on their analysis of cycling behaviour in the GTHA.

Finally, while dedicated cycling infrastructure and off-road trails exist throughout the City of Toronto, they only begin to form a network of cycling facilities in the wards with higher cycling rates. Figure 3-3 shows the distribution of dedicated cycling infrastructure and off-road trails.

**Figure 3-3: Dedicated cycling infrastructure and off-road trails in Toronto (City of Toronto, n.d.-b)**




### *3.3.5 Built environment near home*

The land use near home location of a Ryerson student or employee was also examined. This is because research has found that the built environment and land use characteristics can influence cycling rates (Pucher & Buehler, 2006; Stinson & Bhat, 2005; Begström & Magnusson, 2003). The variables examined were neighbourhood characteristics, such as the population density, percentage of land use types (residential, commercial, and industrial), proportion of single-family homes, age of housing in the neighbourhood (housing over 35 years old and housing under 10 years old), road block density per squared kilometre, street density, intersection density, and factors that had the highest influence on the respondents' choice of residence.

The 2011 population census data was used to determine the population density of the dissemination area (DA) of residence. Street network data available from Open Data Toronto was analyzed in ArcGIS to estimate street network density and the intersection density. DMTI's 2015 land use data set was used to identify the percentage of land types. Environics Analytics Demographics Estimates were used to determine proportion of single-family homes and the age of housing in the neighbourhood.

## 3.4 Data Analysis

Scale variables were tested using Analysis of Variance (ANOVA) and categorical variables were tested using Chi Square to determine if socio-demographic characteristics and preferences were different between all-season cyclists and spring/summer cyclists.

Following that, a Binomial Logistic regression model was estimated to explore statistically significant correlates of all-season cycling (in reference to cycling only in warmer months). This regression model included variables that were found to demonstrate statically significant difference in our preliminary analysis. Factors tested included survey results, such as: demographics, travel choices, travel experiences and preferences, estimated travel route and cycling infrastructure, including distance between residence and campus, and built environment near home. Additional variables were calculated, including: the total amount of infrastructure along their shortest route to campus within 500km and a ratio of the infrastructure of the buffered zone to the total shortest path (accessibility index). Coefficients from a logistic regression show the quantifiable impact that increasing each variable by 1 unit would have on cycling behaviour. More specifically, for every 1 unit change in a variable, the log odds of an individual cycling All Season is expressed by the amount shown in the coefficient (B) column. The results are also shown in terms of Odds Ratios (OR = $e^{\beta}$). The odds ratio demonstrates that, for every 1 unit increase in an explanatory variable, the odds of a respondent being an All-Season cyclists (versus a Fall/Spring cyclist) increases by the factor shown in the OR column. The results from the logistic regression are discussed further in 0.

## Chapter 4 Results

Seasonal variation in cycling was explored using a sample of 278 students and staff from Ryerson University. Of these current cyclists, 28% (n=77) cycled throughout the year, and the rest, 72% (n=201), only cycled in warmer months. More specifically, 24% of employees and 32% of students continue to cycle in the winter months.

When examining the larger dataset of all 4,235 respondents and not the sample of 278 cyclists, we find that cycling has the most significant drop in respondents commuting during Winter months, while local transit and drivers have high rates of maintaining their commute modes. 98% of student ridesharers and 96% of student solo drivers continued driving in winter months. 88% of employee ridesharers and 93% of employee solo drivers continued driving in winter months. In comparison, cyclists are the most likely to change their commute modes: 31% of students and 23% of employees continue cycling in the winter. Local transit also sees high maintenance of commute mode in the winter, at 99% for students and 96% among staff.

**Table 4-1: Percentage of students and staff that maintain their Spring/Fall commute mode in Winter months.**

| | Student (n=2,925) | | Employees (n=1,310) | | Students and employees (n=4,235) | |
|---|---|---|---|---|---|---|
| | Fall | Winter | Fall | Winter | Fall | Winter |
| **Bike** | 155 | 48 (31%) | 168 | 39 (23%) | 323 | 87 (27%) |
| **Local transit** | 1572 | 1560 (99%) | 514 | 491 (96%) | 2086 | 2051 (98%) |
| **Other** | 20 | 18 (90%) | 9 | 7 (78%) | 29 | 25 (86%) |
| **Regional transit** | 658 | 652 (99%) | 265 | 250 (94%) | 923 | 902 (98%) |
| **Rideshare** | 43 | 42 (98%) | 72 | 63 (88%) | 115 | 105 (91%) |
| **Solo driver** | 77 | 74 (96%) | 122 | 113 (93%) | 199 | 187 (94%) |
| **Walk** | 400 | 358 (90%) | 160 | 132 (83%) | 560 | 490 (88%) |
| **Total** | 2925 | 2752 | 1310 | 1095 | 4235 | 3847 |

## 4.1 Descriptive Analysis: Difference between Two Cyclist Groups

The difference between seasonal and all-season cyclists, regarding their socio-demographic characteristics and travel-related preferences, were explored first using the analysis of variance (ANOVA) and chi square ($x^2$) tests. Travel experiences and preferences were also explored. Results are summarized in Table 4-2. Some differences exist between the two types of cyclists and an overview is provided below.

**Demographics**: A higher proportion of men were All-Season cyclists; winter cycling rate was lower among women. Also, a higher proportion of students were all-season cyclists compared to staff (α=0.1).

**Travel Choices**: Overall, transit pass ownership is low among cyclists. Rates of car ownership, bike share membership and driving license ownership were not different between these two groups, but when the number of cars owned were considered, the differences were moderately significant (α=0.1). Fall/Spring cyclists on average owned slightly more cars (mean=.70, sd=.081) than All Season cyclists (mean=.55, sd=.639).

**Travel Experiences and Preferences**: Variables within the travel experiences and preferences category were not statistically significant when examining the differences between All-Season and Fall/Spring cyclists.

**Table 4-2: Crosstabs, ANOVA Analysis, and significance of all tested variables**

| | **All-Season** | **Fall/ Spring** | **Test Results** | | |
|---|---|---|---|---|---|
| **Variable** | **Mean (SD) %** | **Mean (SD) %** | **F / $x^2$** | **df** | **p** |
| Demographics | | | | | |
| Gender (Female) | ***36.4%*** | ***53.7%*** | ***$x^2$= 6.720*** | ***1*** | ***.010*** |
| Age | 33.40 (12.282) | 32.52 (11.097) | F= .334 | 1 | .564 |
| Employee | ***42.9%*** | ***54.2%*** | ***$x^2$= 2.881*** | ***1*** | ***.090*** |
| Travel Choices | | | | | |
| Bike Share member | 6.5% | 8.5% | $x^2$= .295 | 1 | .587 |
| Possess a transit pass | **1.3%** | **8.5%** | **$x^2$= 4.712** | **1** | **.030** |

| Variable | All-Season Mean (SD) % | Fall/ Spring Mean (SD) % | Test Results F / $x^2$ | df | p |
|---|---|---|---|---|---|
| Possess a driver's license | 77.9% | 81.1% | $x^2$=.353 | 1 | .552 |
| Car owner | 31.2% | 34.8% | $x^2$= .333 | 1 | .564 |
| Number of cars owned | ***.55 (.639)*** | ***.70 (.081)*** | ***F= 1.237*** | ***1*** | ***.093*** |
| Travel Experience and Preferences | | | | | |
| Difficulty finding parking | 18.2% | 19.4% | $x^2$= .054 | 1 | .817 |
| Parking location | 75.3% | 79.6% | $x^2$= .602 | 1 | .432 |
| Most important factor in choice to commute to university: | | | | | |
| Exercise | 7.8% | 9.5% | $x^2$=.188 | 1 | .665 |
| Faster | 53.2% | 46.8% | $x^2$=.936 | 1 | .333 |
| Environment | 5.2% | 5.0% | $x^2$=.006 | 1 | .940 |
| Cost | 23.4% | 32.8% | $x^2$= 2.362 | 1 | .124 |
| Pleasant | 6.5% | 3.0% | $x^2$= 1.803 | 1 | .179 |
| Highest influence on choice of residence: | | | | | |
| Walk and bike | 27.7% | 72.3% | $x^2$=.246 | 1 | .620 |
| Amenities | 78.1% | 75.3% | $x^2$=.246 | 1 | .620 |

Results that are significant at p<.05 are highlighted in bold font; results that are significant at p<0.1 are highlighted in bold-italic font, representing practical significance. For Chi Square, significance was determined using asymptotic significance (2-sided) with Pearson Chi-Square.

## 4.2 Model Results: Correlates of All-Season Cycling

Results from the multi-variate logistic regression are shown in Table 4-3. The dependent variable in this model was a cyclist's likelihood of cycling through winter. The results are presented in terms of odds ratios (OR = $e^{\beta}$), which represent the odds of being all-season cyclist, in relation to an independent variable used in the model. The model produced a reasonable model fit (McFadden $\rho^2$= 0.113).

**Demographics**: With regards to socio-demographic characteristics, gender appeared to be statistically related to the likelihood of All-Season cycling. Women (OR=0.38) were less likely to continue cycling in the winter compared to other surveyed genders. Students (OR=1.69) were more likely to be all-season cyclists compared to staff, although the statistical significance of this association was relative moderate (α=0.1).

**Travel Choices**: Transit pass holders (OR=0.12) were less likely to continue cycling in the winter.

**Cycling Infrastructure and Route**: Shortest path distance between home and school was not associated with seasonal variation in cycling. Relative travel distance to campus using cycling facilities (Accessibility Index) also did not show a statistical association. The cycling infrastructure en-route, which describes the density of bicycle facilities (cycle tracks and bicycle lanes) within 500m of the shortest route, was positively associated with all-season cycling (OR = 1.57). This suggests that while distance in itself may not be a significant enabler or barrier to winter cycling, the location of a respondent's residence in relation to cycling infrastructure may be more relevant.

**Built environment near home**: Regarding neighbourhood qualities, the percentage of residential land use and business density were not statistically significant when tested against All-Season cycling. However, a cyclist living in a more stable neighbourhood (i.e., higher proportion of buildings are older than 35 years) was more likely to bicycle through winter (OR=4.33).

**Table 4-3: Binomial logistic regression model**

| **Variable** | **SE** | **B** | **OR** | **2.5%** | **97.5%** | **Sig** |
|---|---|---|---|---|---|---|
| Demographics | | | | | | |
| Gender: female (ref: male) | **.299** | **-0.96** | **0.385** | **0.211** | **0.686** | **.001** |
| Student (ref: faculty and staff) | ***.295*** | ***0.52*** | ***1.689*** | ***0.951*** | ***3.032*** | ***.076*** |
| Travel Choices | | | | | | |
| Possess a transit pass (ref: no transit pass) | **1.068** | **-2.16** | **0.116** | **0.006** | **0.627** | **.043** |
| Cycling Infrastructure and Route | | | | | | |
| Travel Distance | .086 | 0.05 | 1.055 | 0.889 | 1.247 | .535 |
| Cycling infrastructure en-route | **.220** | **0.45** | **1.574** | **1.023** | **2.436** | **.040** |
| Accessibility Index | .478 | 0.15 | 1.166 | 0.465 | 3.068 | .748 |
| Built Environment near Home | | | | | | |
| % Residential land use | .630 | 0.53 | 1.692 | 0.505 | 6.079 | .404 |
| Business density | .000 | 0.00 | 0.999 | 0.998 | 1.001 | .333 |
| Housing > 35 years | **.703** | **1.47** | **4.329** | **1.151** | **18.465** | **.037** |
| (Intercept) | **.956** | **-3.27** | **0.038** | **0.005** | **0.225** | **.000** |

| Model Fit: | |
|---|---|
| Null deviance: -2L[0] | 328.08 (df =277) |
| Residual deviance: -2L[B] | 291.11 (df= 268) |
| -2(L[0]-L[B]) | 36.97 |

| **Variable** | **SE** | **B** | **OR** | **2.5%** | **97.5%** | **Sig** |
|---|---|---|---|---|---|---|
| McFadden $\rho^2$ | | .113 | | | | |
| AIC | | 311.11 | | | | |

Results that are significant at $p<.05$ are highlighted in bold font; results that are significant at $p<0.1$ are highlighted in bold-italic font, representing practical significance.

## Chapter 5 Discussion

Results from the model indicate that socio-demographic characteristics, transit pass ownership, dedicated cycling infrastructure along the shortest path route, and living in a neighbourhood with old housing stock all factor in to whether a cyclist will commute throughout the year or only in the fall and spring months.

Almost all drivers in both StudentMoveTO and the employee surveys indicated a preference to remain with their existing mode of transportation. Cyclists tended to shift mode choices to public transit during winter months, whereas motorists' transit choices remained steady (see Table 4-1). It remains to be explored if improvements to winter cycling routes could convince some motorists to shift commute choices, but from the model results, it appears that improvements to cycling infrastructure would at least benefit Spring/Fall cyclists to cycle through winter, similar to what has been reported elsewhere (Begström & Magnusson, 2003). People who walk and bicycle to campus are more likely to alter their commute choices in the winter, and therefore, they may be the best group to target to shift to winter cycling. On the contrary, convincing drivers to shift their commute to cycling in winter months could be a big change for them, so policy and programs on commute mode shifts should instead focus on a gradual change. For instance, commuters who live near campus might be willing to shift to cycling in fair weather, and later, might consider cycling in the shoulder season, and finally, in the winter. Therefore, when planning for cycling, it should be seen as less of a contest between cyclists and motorists and more of a decision-making process that weighs cyclists' needs with public transit users and pedestrians' needs.

**Demographics**: Women are often seen as an "indicator species" in cycling literature and are depicted as the stick against which to measure the safety of cycling infrastructure

(Baker, 2009, cited in Akar, et al, 2013). The notion is that if a woman chooses to cycle on a road, it is safe; and that building cycling infrastructure with female cyclist's needs in mind will in fact benefit all cyclists. Snow clearing and improved infrastructure could improve cycling rates among women, which ultimately contributes to a higher overall cycling rate.

Another demographic group that has a higher all-season cycling rate are students. Students are more likely than employees to cycle to Ryerson University throughout the year. Students may continue to cycle in the winter because they are captive users who are seeking cheaper transportation options: specifically, the bicycle. However, their current behaviour of cycling to campus could be encouraged through planning and programming. This could help induce higher rates of cycling among students throughout the year.

**Travel choices**: Transit pass ownership was statistically significant when considering whether a respondent would cycle throughout the year (OR=0.12) or only in the Fall/Spring seasons. This is unsurprising because for respondents who already purchase a transit pass every month, it might be easier to switch to public transit during winter months. The cost of a transit pass may also be a dissuading factor. A post-secondary student Toronto Transit Commission (TTC) pass costs $116.75 CAD per month, which is discounted 20% off the adult price of $146.25 (Toronto Transit Commission, 2017). Once a student or staff has made this investment, it is likely, at least hypothetically, that they would take advance of it in winter months and use transit more often.

**Travel experience and preferences**: Factors related to bicycle parking were not statistically significant on whether a respondent cycled to campus throughout the year. Other studies have investigated whether bicycle parking was statistically significant for determining whether respondents chose to cycle. Some have found that there is no significant relationship (Akar et al, 2013; Akar & Clifton, 2009), some find the opposite (Stinson & Bhat, 2005; Braun et al, 2016), while one survey found that in stated preference questions, respondents are interested in bicycle parking, but the researchers did not model these questions (Agarwal & North, 2012). While bicycle parking may not have a significant effect on cycling, it does appear to be important to cyclists (Heinen et al, 2010). Thus, the relationship between parking and cycling rates is unclear.

**Estimated travel route and cycling infrastructure**: Travel distance was not statistically significant in determining whether a respondent would cycle throughout the year. It is worth noting that some respondents included in the model cycled long distances up to 16.61 km (mean=4.704 km, SD=2.492, min=0.483 km). Within the respondents included in the model, distance was not significant, even though intuitively it seems as though it ought be, and considering previous studies have found a link between winter cycling and distance (Agarwal & North, 2012; Begström & Magnusson, 2003; Flynn et al, 2012) and cycling and distance (Braun et al, 2016).

Figure 5-1 plots the residential locations of current cyclists in relation to Ryerson University campus. From Figure 5-1 and Table 5-1, it is clear that the majority of respondents (85%) do not live within 2km from campus. However, since the mean distance for respondents is 4.704km, this suggests that the majority of respondents live within comfortable cycling distance i.e., 1-5 km (Mitra et al, 2016). From the map, residents living within 1 and 2km of Ryerson University do not appear to be more or less likely to cycle in the winter. This confirms that distance itself is not alone an indicator of whether someone will or will not cycle.

**Figure 5-1: All-Season versus Fall/Spring Cyclists by 1km and 2km buffer from Ryerson University to respondents' homes**

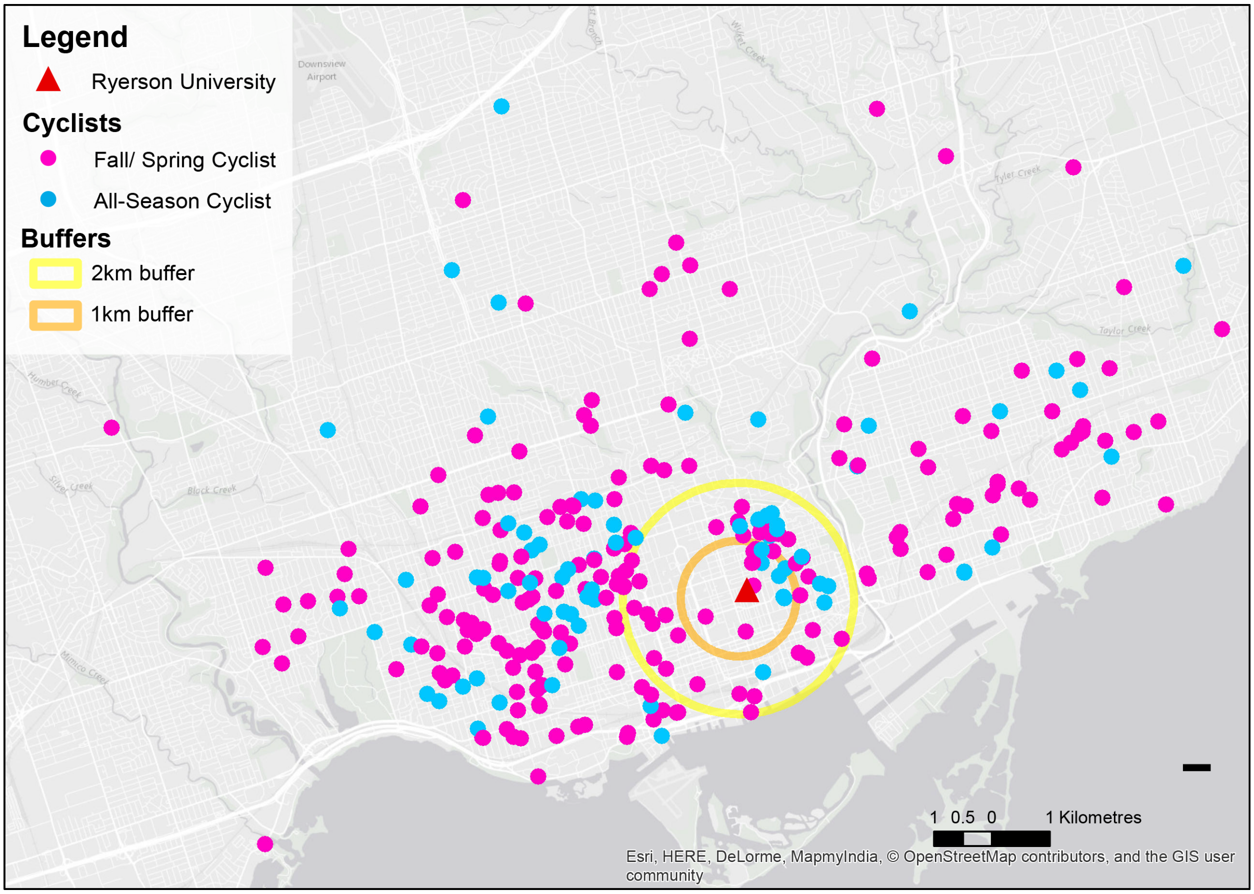



**Table 5-1: All-Season versus Fall/Spring Cyclists by distance of 1km and 2km from campus**

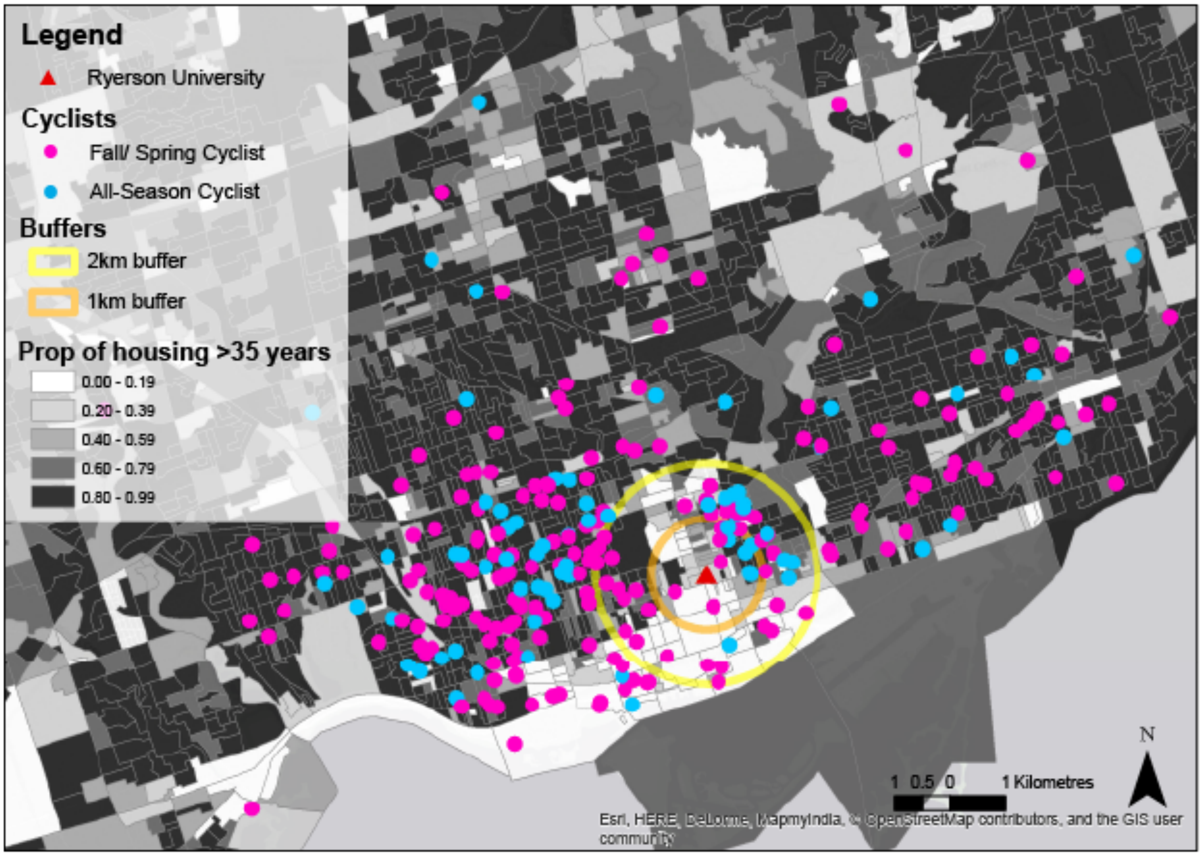
| | All-Season Cyclist | Fall/Spring Cyclist | All cyclists |
|---|---|---|---|
| 1km buffer | 4 (1%) | 1 (0%) | 5 (2%) |
| 2km buffer | 15 (5%) | 22 (8%) | 37 (13%) |
| Outside of buffer | 61 (22%) | 175 (63%) | 236 (85%) |
| Total | | | 278 (100%) |

Previous research has found that for commuters travelling by both bicycle and car, respondents sometimes took detour outside of the shortest path to use paths that were more suitable for the travel mode. In a Metro Vancouver study of utilitarian bicycle and car trips, the authors found that motorists added a mean 0.54 km to their route, while cyclists added a mean 0.35 km to their route (Winters, Teshke, Grant, Setton, & Brauer, 2010). Results from my model suggest similar findings: respondents were more likely to cycle throughout the year if there was a high amount of dedicated cycling infrastructure near the shortest path (OR=1.57). For every 1 unit increase in dedicated cycling infrastructure en route, the odds of cycling throughout the year increased by 57%. Also interestingly, the accessibility of destination (in this case, the University campus) using dedicated cycling infrastructure was not a statistically important factor in this context. From the results it appears that the availability of cycling infrastructure near the shortest path, which would enable a cyclist to use cycle tracks of bicycle lanes at least part of the way to School, is perhaps more important than being able to travel completely on a dedicated cycling infrastructure, which sometimes come at the cost of an increased travel distance.

**Built environment near home**: Currents cyclists who commute to Ryerson University predominantly live in areas with low business density and high residential density. Downtown Toronto's land use is dominated by activities including services to businesses, public service, and services to consumers; while residential land was further away (Simmons et al, 2009).

Respondents who lived in areas where the housing stock was older than 35 years were more likely to cycle in the winter (OR=4.330) (see Figure 5-2). This result suggests that older, stable residential neighbourhoods could encourage winter cycling. This may be because older, residential neighbourhoods are also walkable, with easy access to shops, schools and other non-residential uses, which could enable residents to do their shopping and errands without leaving their neighbourhood or relying on a car. Similarly, those who would prefer to rely less on cars for their everyday travel could self-select to live in those neighbourhoods. This less-car-dependent lifestyle can then be reflected in a grater willingness to bike throughout the year for commuting purposed.

**Figure 5-2: Percentage of housing over 35 years of age by dissemination area measured in quintiles compared to Fall/Spring and All-Season Cyclists**




## 5.1 Challenges and Limitations

Although the employee and student surveys followed similar methods, they were not the same and were not conducted at the same time. Differences in response rate suggest that there might be sampling bias. The response rate for the employee survey, 27%, may be higher than the student survey, 8.8%, for three reasons. First, the email was sent from a Ryerson University Human Resources email account. Since the employer was issuing the survey, rather than a relatively unknown source in the students' case – it is unlikely that many students knew of StudentMoveTO prior to receiving their email – there may have been a greater willingness to complete the staff survey. Second, the employee survey was significantly shorter than the student survey, which might have impacted the willingness to complete the survey. Finally, Ryerson University employees are surveyed less frequently than students. Students receive many surveys throughout their time at university, so they may be less willing to dedicate time to completing every survey they receive, particularly if the survey is long and/or complex or if it is a topic about which they do not care.

A limitation of this research is that the employee survey did not include a substantial section on stated preferences. Therefore, we could not investigate why respondents made some of their decisions. In addition, the data on seasonal variation in travel was self -reported; it is unclear whether every current cyclist that would truly continue to cycle in winter months. It is possible that they use a bicycle as their mode of transportation for some days of the winter, but not all. This is a nuance that could be explored with further study, particularly investigating how cyclists commute using different modes in winter months.

We could not explore some potential influences on cycling behaviour, such as snow clearance. We hypothesize that improved snow clearance could improve cycling throughout the seasons, but explicitly asking survey respondents this question could garner interesting results.

Finally, when calculating travel distance, or the presence of cycling infrastructure en-route, we assumed that a cyclist would typically use the shortest path. The actual route of travel was not known. A travel diary that would also collect route data would have allowed a better estimation of the availability of cycling infrastructure, relative accessibility using cycling infrastructure, and their impact on seasonal variations in cycling.

## 5.2 Future Research

To investigate the topic of winter cycling further, future research could address some of the challenges and limitations outlined above while also building upon the current literature. For instance, this research has found that residential characteristics and dedicated cycling infrastructure along the shortest path are statistically significant in determining whether a respondent will cycle throughout the year. Finding ways to begin testing these variables would be a means through which to investigate this topic further. For instance, a new survey with more in-depth stated preference questions could investigate the relationship between the built environment – particularly the age of housing in a respondents' neighbourhood. An intercept survey or a revealed preferences survey would be useful in interrogating the relationship between bicycle infrastructure and all-season cycling. For instance, a future project could study cycling rates and snow clearance in dedicated bicycle lanes in the City of Toronto to determine the level of service required to maintain cycling all year. Finally, future research should investigate daily weather patterns in addition to seasonal climate changes to build a comprehensive dataset.

## Chapter 6 Conclusion

This study investigated factors influencing winter cycling among students and staff at Ryerson University in Toronto, Canada. Demographic characteristics and access to cycling infrastructure were significant in explaining whether a respondent would cycle during the winter or not.

The findings support our hypothesis relating to the potential influence of demographics, travel/residential preferences and cycling infrastructure on the choice of cycling as a transportation mode for commuting in the winter. Our findings indicate that a host of factors can potentially influence whether someone is more or less likely to continue cycling as their main mode of transportation in the winter. However, further research is needed: a better data set collected specifically with winter cycling in mind would allow for deeper analysis. Further surveys could ask questions related to perceptions and preferences to begin to explore why respondents cycle in the winter, not just to the statistical correlates of this behaviour. Finally, measuring actual travel routes using GPS would allow for a more nuanced comparison of the relationship between the shortest path and how far commuters are willing to detour to access dedicated cycling infrastructure. It would also help determine whether soft infrastructure is used as a main route to campus or a means of accessing dedicated cycling infrastructure.

However, the dataset used in this study produced robust results within the scope of this work, because it is a random sample of students and staff and was not targeted to only cyclists. It did not, therefore, skew toward dedicated cyclists, who may be more interested in having their interests represented and therefore taking the time to complete a survey. The sample size of is also comparable to existing research on cycling behaviour.

The findings reported in this study can be useful for city planners who are considering how to encourage winter cycling to urban university campuses and/or major downtown employment centres. Overall, the results reveal that many factors may explain winter cycling. These findings will also be useful for universities because they have a limited range of policy tools to promote and enable active and sustainable transportation to and from campuses. For instance, while they cannot build dedicated cycling infrastructure to campus, they can work with their city partners to identify high-traffic corridors to campus and engage with the municipality to push for cycling infrastructure. Furthermore, they can often control the environment on their campuses. While Ryerson University is located in downtown Toronto, it can enforce its own policies on university-owned property, such as by developing gender-specific programs to encourage cycling among students and employees or finding new ways to encourage cycling among employees, broadly speaking.

Finally, universities can work in tandem with city partners as new municipal by-laws increase the focus on cycling. In Toronto, chapter 230 of zoning by-law 569-2013 requires that new buildings and major renovations include bicycle parking under a set of conditions (City of Toronto, 2016c). As universities are increasingly becoming city-builders, the impact of cycling provisions in city by-laws means that they are not only obligated in Toronto to provide for the needs of cyclists, but also that they have the opportunity to create a hospitable environment for these commuters. For winter cyclists, this might mean providing snow clearing on campus or around bike racks.

In conclusion, post-secondary institutions have a part to play in encouraging and facilitating winter cycling. Working with municipal partners to improve infrastructure could help increase winter cycling and improving the destination facilities on campus could make cycling more enjoyable for those who already commute throughout the year.

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