Bicycle-Light Rail Transit Integration Study in Kitchener-Waterloo

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Active transportation, such as walking and cycling, are typically considered the first and last mile options for people who live close to transit corridors or transit hubs. Compared to walking, cycling allows faster travel and longer trip distances can help to increase transit catchment area. Bicycle-transit integration has been discussed by many researchers around the world, and it has become a popular topic alongside the movements to reduce carbon emissions. This thesis aims to understand what conditions are necessary for existing LRT riders to use or will be encouraged to use bicycles as a feeder mode to access or egress from the LRT stations, specifically the role of bicycle infrastructure by using the City of Kitchener and the City of Waterloo (KW) as a case study. Studies showed that bicycle infrastructure plays a crucial role in promoting bike-transit integration by providing convenient, fast, and safe access and egress stages during a trip within public transportation. However, a review of the literature identified three gaps where existing LRT-related literature has mostly focused on large cities and rarely on mid-size cities like KW. Minimal research has been conducted on bicycle infrastructure in a mid-sized city context. In addition, most bicycle-transit integration studies have focused on bicycle–commuter rail or bicycle–metro subjects, with less discussion of LRT. A better understanding of bicycle–LRT integration in mid-sized cities is needed.

The thesis study used a quantitative approach in which the researcher designed and distributed online web-based surveys via social media and collected the data during the COVID-19 pandemic, where physical distancing rules and restrictions on face-to-face research was prohibited. The analysis results showed a great potential for promoting bicycle–LRT integration from the participants' feedbacks. Separated bike lanes and on-street painted bicycle lanes were the most important aspects of promoting such actions, along with bicycle parking at LRT stations, cycling network connectivity, designated signages and traffic lights. The study's regression analysis showed that the more important the participants thought that bicycle infrastructure elements affected their decisions to use bicycles as a feeder mode to access or egress LRT stations, the more likely they were to use bicycles, if these bicycle infrastructures satisfied their needs. The overall results are consistent with previous studies examining bicycle infrastructure importance in encouraging people to cycle. The lack of bicycle infrastructures, such bike share, separated bicycle lanes, designated signage, and parking at the current stage, were cited as reasons that discourage people from using bicycles.

Transit accessibility in cities is a topical and urgent issue. Municipal planners should fully embrace denser, mixed-use growth that will support more active and public transportation and transit-oriented developments along the LRT corridor. Planners should play multiple roles in such projects by fulfilling professional duties, providing advice, and advocating for projects that support bicycle–LRT integration. In addition, planners should ensure people with lower-income and minority groups' accessibility of the bicycle and bicycle infrastructure to ensure accessibility equity.

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CBD–Central Business District

GTHA–Greater Toronto and Hamilton Area

KW–The City of Kitchener and the City of Waterloo

LRT–Light Rail Transit

TOD–Transit Oriented Development

TPB–The Theory of Planned Behaviour

Chapter 1: Introduction

1.1 General Background: Cycling and Light Rail Transit Trends

1.1.1 Increasing Cycling Trends

Active modes of transportation, such as walking and cycling, are typically considered as the first- and last-mile options for people who live close to a transit corridor or a transit hub. Active transportation benefits people's health, society, transportation systems, the environment, and economies (Ritchie & Hall, 1999; Blondiau et al., 2016; Deenihan & Caulfield, 2014; Pucher et al. 2010). Moreover, active transportation allows people to be regularly physically active, and simultaneously protects the environment. In 2013–2014, about 12 million Canadians aged 12 or older (41%) reported that they had cycled in the previous year (Statistics Canada, 2017). Cycling has become a popular activity in Ontario in recent years (Government of Ontario, 2013; the Centre for Active Transportation, 2019).

Compared to walking, cycling allows for faster travel and longer trip distances, and it may be a more desirable mode of transportation than car trips (Lumsdon, 2000). Cycling has become a fast-growing transportation method because it promotes healthy lifestyles without carbon emissions (Lumsdon, 2000; Bussière et al., 2010). European cities—such as Copenhagen, Seville, and Amsterdam—provide convenient access to bicycle infrastructures, including bicycle lanes, bike-share programs, and bicycle parking, to promote cycling as an alternative to automobile transportation (Marqués et al. 2015; Gössling, 2013; Nello-Deakin & Nikolaeva, 2020). Traffic congestion has become a major issue in many cities during morning and afternoon peak hours, when many cars move slowly along roads, creating additional carbon emissions and a negative impact on pedestrians (Zhang & Batterman, 2013).

Today, more than half of the world's population lives in urban areas, and this proportion is expected to increase to almost 70% by 2050 (United Nations, 2018). To keep cities healthy and livable, the modes of transportation that move the most people with the least pollution should be encouraged. Transportation accounts for more than 60% of the Waterloo Region's total greenhouse gas emissions (Region of Waterloo, 2019). Cycling will help to save the local government money in the long run by decreasing obesity and diabetes levels, and lower mortality rates (Deenihan & Caulfield, 2014; Pucher et al., 2010). Shifting commuters from cars to sustainable, active forms of transportation can address road congestion issues by reducing pollution and benefitting populations' socioeconomic conditions and health. Cycling can also help to promote positive mental well-being (Heech et al., 2015), which can help people with psychological deposition. Therefore, creating an urban built environment that encourages people to walk and cycle is the key to lowering emissions and creating healthy, livable cities.

Travel time—especially for commuters—is one of the most critical determinants of transport mode choices, and it is balanced against costs, comfort, and safety (Tyrinopoulos et al., 2013). Tyrinopoulos et al. (2013) stated that for trips of 5 kilometres or less in urban areas, cycling rivals with car travel times. Combining the advantages of cycling with the speed of light rail helps create seamless door-to-door journeys that can strategically rival driving's speed and door-to-door convenience. Therefore, the combination of bicycle and light-rail travel offers the potential to shift people from automobiles to a more sustainable form of transportation, as well as the least amount of pollution.

1.1.2 Light Rail Transit

Light rail transit (LRT) is a form of passenger urban rail transit characterized by a combination of tram and metro features. LRT is typically lightweight, generally using electric passenger rail cars on fixed rails and running close to or alongside traffic (Cervero, 1984). It has become a popular option in North America in recent decades in cities seeking rail transportation for which building a subway system is not feasible (Cervero, 1984). LRT is similar to a traditional tram, but it operates at higher capacities and speeds—and often on an exclusive right-of-way. In general, LRT construction is cheaper than heavy rail metro or subway systems (Cervero, 1984). For example, the C-Train in Calgary uses many common light rail techniques to keep costs low, such as minimizing underground and elevated trackage, sharing transit malls with buses, leasing rights of way from freight railroads, and combing LRT construction with highway expansion (Calgary Transit, 2005). Currently, several light rail lines are under construction—or planned to soon begin construction. In Ontario, Metrolinx is constructing projects including Line 5–Eglinton Crosstown and Line 6–Finch West in Toronto, the Hurontario LRT in the Peel Region (Metrolinx, 2020a; 2020b; 2020c). The City of Ottawa’s Confederation Line and Trillium Line Stage 2 are also under construction (OC Transpo, 2020).

1.1.3 Bicycle–Transit Integration Programs

Bicycle-transit integration has been discussed by many researchers around the world, and it has become a popular topic alongside movements to reduce carbon emissions (Krizek & Stonebraker, 2010; Deenihan & Caulfield, 2014; Pucher et al., 2010). A study by the National Academy of Sciences, Engineering, and Medicine (2005) collected survey responses from 56 transit agencies in Canada and the United States, finding that, as early as the 1980s, transit agencies had reported including bicycles on their local bus systems. Buses can accommodate bicycles in several ways, and the most common option per this survey was bicycle racks on the front of buses. Front-mounted racks can typically carry two bicycles, and some transit agencies offer front-mounted racks that can carry more bicycles (Toronto Transit Commission, 2020;

Mississauga Transit, 2020). Some local bus services allow passengers to bring their bicycles on board, although sometimes with restrictions, such as only allowing this option during off-peak hours or in designated areas (Toronto Transit Commission, 2020; Grand River Transit, 2020).

As bicycle use trends upward, many transit agencies have begun to allow bicycles to board their rail services. Only a few urban rail systems in the United States prohibit bicycles at all times (Loutzenheiser, 2005). Most transit agencies have only partial restrictions, such as the Toronto Transit Commission subway and Translink SkyTrain in Vancouver, which allow bicycles on board during off-peak hours and weekends (Toronto Transit Commission, 2020; Translink, 2020). Some other agencies allow bicycles on board at any time of day but only in a designated area (Grand River Transit, 2020; OC Transpo, 2020).

Community characteristics play a role in local differences between bicycle–transit integration programs, such as local transit ridership characteristics, socioeconomic backgrounds, climates, bicycle facilities' quality and connectivity, local government support, local bicycle advocacy groups' influence, transit funding, and government funding (Koglin, 2015; Bagloee et al., 2016). Overall, providing clear signage at transit stations, safe cycling networks that lead to transit stations, and bicycle facilities' comfort and safety at transit stations are three important aspects of integrating bicycles into public transportation (De Sousa et al., 2014; Zuo & Wei, 2019).

1.1.4 Local Context

The City of Kitchener and the City of Waterloo (KW) are two adjacent, lower-tier municipalities within the Region of Waterloo in Ontario, Canada. Cycling trips for under 5 kilometres increased by 1.2% from 2006 to 2019 (Region of Waterloo, 2019). ION Light Rail Transit (LRT) was launched by the end of June 2019, which creates a north-south transit corridor between KW via both city centres. Local governments have been working on creating a bicycle-friendly community to use bicycles as a mode of transportation while setting up plans to better integrate the bicycle with public transit, especially the LRT. Based on the current bike infrastructure that has been implemented by both cities, off-road bike trails have a heavier proportion compared to on-road bicycle lanes or separated bicycle lanes. Designated cycling traffic lights and bike boxes at intersections have only been added in the past two years. There are still many disconnections among bicycle lanes and separated bicycle lanes that do not sufficiently create a safe cycling network. Most of the LRT stations are not connected with bicycle lanes, or the bicycle lanes do not lead to further destinations, which are problems that need to be addressed.

1.2 Research Purpose and Objectives

This research aims to understand what conditions are necessary for existing LRT riders to use or will be encouraged to use bicycles as a feeder mode to access or egress from the LRT stations, specifically the role of bicycle infrastructure using Kitchener-Waterloo as a case study. Three research objectives guided this study in understanding this potential use:

1. Understand LRT riders' sociodemographic backgrounds, their attitudes, and preferences toward bike infrastructure

2. Identify factors associated with increasing the usage of bicycles as a feeder mode

3. Use the findings to inform planning policies and implementation of bicycle infrastructure.

Accordingly, this study developed three sets of research questions to help identify these determinants:

1. What are current LRT riders' attitudes toward bicycle infrastructure (e.g., bicycle lanes, bike-shares, and bicycle parking)?

2. To what extent will the bicycle infrastructure encourage the current LRT riders to use bicycles as a feeder mode of transportation to access or egress light rail stations?
3. What can local governments do to accommodate and encourage this usage?

To address these research questions, this study used a quantitative approach to gather and analyze data gathered from the web-based survey. The research is aimed to understand the role of bicycle infrastructure in encouraging LRT riders to use bicycles as feeder mode to access and egress from LRT stations where quantitative data has a better reflection on overall statistics of respondents' preferences of bicycle infrastructure compared to qualitative research. The local municipal or regional government could use the data to further conduct in-depth qualitative research by using EngageWR website. The survey questions include asking the current LRT riders travel behaviour, bicycle ownership and the purpose of using bicycles. Survey participants were recruited through the social media group "I Support Light Rail Transit in the Waterloo Region" via the Facebook Group function, which this thesis's methodology chapter outlines. This social media group is the largest social media group that is open for light rail transit and bus riders in the Waterloo Region that has over 2500 members in the group. For LRT and transit riders who are not using social media platform or do not have internet access would not be able to participate is one limitation of this study. The data were analyzed using SPSS to conduct frequency, cross-tabulation, and binary logit regression analyses. The study's open-ended question aimed to collect reasons for respondents' future choices to use or not to use bicycles as a feeder mode of transportation. However, the overall response rate was insufficient for content analysis via SPSS. Additional adjustments were applied during the research period to account for the coronavirus disease 2019 (COVID-19) pandemic and the related government restrictions on social gatherings and physical distancing rules to contain the virus. The study's research method also changed due to new research restrictions posted by the University of Waterloo during the pandemic (University of Waterloo, 2020).

1.3 Planning Implications and Study Significance

The literature outlines trends of people increasingly using bicycles as a form of transportation, as several cities are currently constructing, extending, or considering constructing LRT lines. The purpose of this research was to determine LRT riders' willingness to use bicycles as a feeder mode of transportation in the future and what bicycle infrastructure will encourage such actions. Implementing bicycle infrastructure is part of the active transportation planning process, for which the local government council must reach an agreement before implementing any plans. Local active transportation plans must also follow provincial planning guidelines and local official plans.

Physical distancing during the COVD-19 pandemic has disrupted mobility patterns all over the world. With the stay-at-home orders, public transit reductions, and the closures of recreational facilities in Canada, many people opted into active travel such as cycling for mobility and physical activity. The World Health Organization guidelines for getting around during the pandemic stated "whenever feasible, consider riding a bicycle or walking" to help with the social distancing and promote physical activity (World Health Organization, 2020). Many Canadian cities conduct temporary "street reallocation" policy action that help to expand the cycling networks to support social distancing and physical activity demand. In Kitchener-Waterloo, streets such as Westmount Road, Erb Street and others had one lane reallocated temporarily into separated bicycle lanes and received with mixed reviews. In the light of COVID-19 pandemic, our transportation future is facing much faster and more dramatic change than ever could have been anticipated. With the COVID-19 vaccination rate increase in the KW, the restrictions will be lifted step by step, and many people will be back to their usual workplace instead of work from home. With the bicycle ownership increased in the KW in the past year (CBC, 2020), there is a great potential to promote the integration of bicycle and LRT. This study's results will, therefore, allow planning practitioners to assess the impact of the implementation of new bicycle infrastructure in the short term and adjust their processes through future planning. The study will also contribute to filling in the gap of the current literature as base knowledge about bicycle-LRT integration in a mid-sized Canadian city. The knowledge about mid-size city light rail riders' behaviour, attitudes about bicycle infrastructure and how to encourage them to use bicycles as feeder mode will be crucial for policy design, infrastructure implementation and infrastructure management that reduce pollution in these cities.

1.4 Thesis Structure

This thesis comprises five chapters, beginning with this introductory chapter, which discusses the study's general research background as well as its specific research questions and objectives. "Chapter 2: Literature Review" synthesizes the academic literature on topics relevant to the study, including characteristics of LRT riders' travel behaviour, factors affecting transportation mode choices, attitudes toward bicycle infrastructure, bicycle-transit integration, and transportation research methods. "Chapter 3: Methodology" discusses the theoretical and methodological approaches used in this study to gather and analyze data. This study used a quantitative approach involving web-based surveys, and the results of the data gathered from these surveys are described in "Chapter 4: Research Findings." Next, the study's findings are discussed in "Chapter 5: Discussion," which also includes a discussion of how these findings addressed this study's research purpose and objectives. Chapter 5 also outlines the limitations of this study as well as future research opportunities. Chapter 6 provides policy and practice recommendations for the future and concludes the thesis.

Chapter 2: Literature Review

This study's research objectives are to understand what conditions are necessary for existing LRT riders to use or will be encouraged to use bicycles as a feeder mode to access or egress from the LRT stations, specifically the role of bicycle infrastructure. This chapter presents a review of background information on the relevant literature related to this thesis. Gaps are identified in this literature to show the necessity of conducting the current research.

This review examined four primary areas of the literature:

1. Rail passenger feeder mode choice
2. Attitudes toward bicycle infrastructure
3. Bicycle–transit integrations
4. Transportation research method

Each subsection presents research on these respective areas and identifies gaps in the existing literature that the current study attempts to address.

2.1 Rail Passenger Feeder Mode Choice

2.1.1 General Factors on Mode Choices

Travel behaviour can be affected by various aspects, such as individual factors, costs for a specific mode of transportation, and surrounding built environments and urban forms. Individual socioeconomic, demographic, and psychological factors influence travel behaviour.

Many works in the literature have identified differences in travel behaviours between men and women. For example, men tended to conduct longer trips using automobiles and active transportation, and cycling was more common among men than women (Kim & Ulfarsson, 2008; Gatersleben & Appleton, 2007). However, Zhou (2012) found that men were more likely to walk or cycle than women, although the author found no gender difference for any other modes of transportation.

Household structures are another factor that affects travel behaviour. Kim and Ulfarsson (2008) reported that families with children were less likely to choose to walk as a mode of transportation than families without children. Delmelle and Delmelle (2012) found the same result, noting that a household's number of children negatively correlated with its probability of walking and cycling. Psychological factors, such as attitudes toward certain modes of transportation and social expectations regarding certain behaviours, have become increasingly important variables that affect individual travel behaviour.

Costs are among the most important components of transportation mode choices. Cervero (2002) stated that including competition for modes' economic attributes—notably, travel time and price variables—in models' specifications is important when testing land-use factors' influence on travel demand. Some works in the literature have suggested that the proportion of travellers who use cars increases rapidly when travel distances increase (Delmelle & Delmelle, 2012; Shannon et al., 2006). Whalen et al. (2013) argued that in transportation mode choice analysis, time or monetary costs are conceptually and practically more useful than distance when evaluating travel costs. The researcher agreed with Whalen et al. (2013) which monetary cost is more practically than distance when discussing about transportation mode choice. The initial cost of certain transportation mode such as automobile and bicycles, and the potential repair cost in the future turned to discourage many people with limited income to choose these methods although both methods will save travel time and give the riders more flexibility compared to public transportation.

Built environment and urban forms also affect commuters' transportation mode choices. Winters et al. (2010) conducted a study on Metro Vancouver and found that the area's built environment significantly influenced choices to use a bicycle instead of a car. This study (Winters et al., 2010) also found that higher intersection densities, higher population densities, and areas with more balanced mixed land use around a point of origin lead to higher cycling use levels. By contrast, larger commercial parking lots were found to reduce the likelihood of bicycle trips. A commuting mode choice study on transit-oriented development (TOD) in Brisbane (Kamruzzaman et al., 2015) found that individuals living in TOD areas were more likely to use more sustainable modes of transpiration and less likely to use less sustainable modes of transportation than individuals living in traditional suburbs. This study (Kamruzzaman et al., 2015) also found that potential TODs or transit-adjacent developments (TAD) with only some TOD neighbourhood features do not effectively motivate desired behavioural changes compared to traditional suburbs.

2.1.2 Mid-sized Cities Transportation Mode Choices

There is a fundamental difference exist between mid-size cities and large cities in transportation mode shares. Bunting et al. (2007) described mid-sized Canadian cities "share a few main components: a flat-line, low-density profile; easy automotive access between dispersed activities; depleted core areas". Filion and Bunting (2004) stated mid-sized Canadian cities generally lack public transportation systems (such as rail service) that are competitive with the automobile in terms of speed and comfort. With the decline of the downtown of the mid-sized cities was particularly detrimental to transit use. The decline in transit usage is associated with a dispersed urban form advanced dispersion and easy of driving in the mid-size cities often insurmountable obstacles to transit-oriented strategies when it comes to transportation planning and policies in mid-sized cities (Filion & Bunting, 2004). The urban from of the mid-sized Canadian cities contributes to the decline of public transportation in most cases, most people would choose to use automobile to navigate around the cities between dispersed activities. In the long run, a specific preference of automobile as the preferred transportation mode will formed in people who live in mid-sized cities.

2.1.3 Behaviours and Attitude Toward Transportation Mode Choices

Researchers have focused on commuters' behaviours and attitudes toward transportation mode choices. Cervero (2002) identified and tested the influence of three blocks of variables on travel modes: (a) travel time, cost, and demographic variables; (b) attitude and lifestyle preference variables; and (c) built-environment factors. Similarly, a later study by Zhou (2012) examined different factors that affected mode choices among commuters and summarized these factors under six more detailed categories: (a) individual-specific factors (e.g., socioeconomic and demographic); (b) psychological factors (attitudes); (c) mode-specific factors (comforts); (d) trip characteristics (e.g., costs); (e) built-environment and urban-form variables (e.g., densities and intersections); and (f) the presence of travel demand measures (e.g., parking costs). Another research by Asensio (2002) on transport mode choices among commuters to Barcelona's CBD defined an "econometric choice model" as monetary costs, travel times, waiting times and transfer distances, access or egress distances, frequency, and density.

The theory of planned behaviour (TPB) (Ajzen, 1991) is among the most popular theories used in many studies on commuters' behaviour. In this model, behavioural achievements depend on motivations (intentions) and ability (behavioural control). One person's intention to perform or not to perform a particular action depends first on their attitude toward the behaviour, which can refer to the person's perspective, including a favourable or unfavourable opinion on a specific question. Secondly, their intention is also affected by subjective norms, which refer to a perceived social pressure to perform or not to perform a particular behaviour. Lastly, the perceived behavioural control involves past experiences of the perceived ease or difficulty of performing the behaviour. The more favourable an attitude and a subjective norm to a behaviour, the likelier the perceived behavioural control will lead to a stronger intention to perform the behaviour.

Ajzen (1991, p. 189) stated, "the role of beliefs in human behaviour can break into three salient beliefs, which are behavioural beliefs that are assumed to influence attitudes toward the behaviour; normative beliefs, which constitute the underlying determinants of subjective norms; and control beliefs, which provide the basis for perceptions of behavioural control." In attitude theory, *attitudes* refer to the behaviour that disposes a person to behave in a certain way toward the behaviour (Parkany et al., 2005). Parkany et al. (2005) stated that *attitudes* develop from the beliefs that people hold about the object of an attitude. Moreover, *attitudes* are conceptualized as positive or negative evaluations of beliefs about something that affects one's behaviour, and they can be categorized into *cognitive*, *affective*, and *behavioural* components (Nairne, 2003). *Normative beliefs* concern the likelihood that an important referent individual or group approves or disapproves of performing a given behaviour, depending on the general public's approval or the approval of a person's family or close group, such as different lifestyles in urban and suburban areas (Krizek, 2005). Human behaviour and attitudes toward certain subjects are based on personal family background, close groups, and the society. The policies and the promotion of certain transportation methods though different media channel will affect local human behaviour though a long period of time.

Control beliefs may be based on the past experience of a behaviour, and they can also be influenced by second-hand information from an individual's close contacts (Ajzen, 1991). Accordingly, the literature reflects a growing interest, in particular, in studying the influence of one or two of the factors influencing a person's behaviour, and some studies have revealed attitude's sole effect on behaviour vis-à-vis commuters' intentions to change transportation mode choices (Hsiao & Yang, 2010; Kroesen et al., 2016;). Fu and Juan (2016) argued, however, that although TPB identifies intention as a significant predictor of behaviours in transportation mode uses, the use of a transportation mode could also be a habitual behaviour due to its daily repetitiveness—which can be carried out automatically, without deliberate thinking. Although Fu and Juan (2016) have a strong argument about habitual behaviour, the researcher believe habitual behaviour could be changed through the overall surrounding environment changes by implementing new infrastructure and policies by the local government.

A study by Whalen et al. (2013) on transportation mode choices among university students in Hamilton, Ontario, suggested that a university population's mode choices often display a higher share of alternative modes compared to the general population for whom all modes were well represented in the study's analysis. This study also suggested that instead of discouraging a behaviour, the enjoyment of active travel may facilitate the promotion of a desirable behaviour (Whalen et al., 2013).

2.1.4 City Rail Transit Feeder Mode Choices

City rail transit includes metro or subway, light rails, and commuter rails that provide a stop-to-stop service rather than door-to-door service that typically requires passengers to use another form of transportation mode to access the rail station, such as walking, cycling, using public transportation, and driving. A study by Guo et al. (2020) in Shenzhen, China, showed that walking was the most frequently used feeder mode, followed by bicycles and buses. Vehicle-related crash risks discourage metro passengers from walk to/from the station but encourage them to use bicycles and buses as feeder modes. Another study conducted by Giansoldati et al. (2020) in Italy showed that the main feeder mode to the local train station was mainly car-based (63.2%), followed by cycling (18.4%) and walking (9.7%); the others used either the bus or the scooter.

As mentioned in the previous paragraph, socio-demographics will affect people's mode choice. Ji et al. (2017) conducted a study in Nanjing, China, and concluded that female, older, and lower-income metro commuters are less likely to use public bicycles. Chan and Farber (2019) conducted a study in the Greater Toronto and Hamilton Area on rail transit and showed that population density, proportion of residential land, age, automobile ownership, and median income are some key factors in the decision of rail transit passengers' feeder mode choices. Guo et al. (2020) also mentioned that, for transit stations, different feeder modes usually correspond to different distance ranges. If there are more cycling-related facilities, such as secured bike parking and cycling lanes, it will attract more people to use bicycles as a feeder mode. However, more car parking spaces will attract more people to use cars as a feeder mode.

LRT has gained popularity in many cities around the world, and 104 LRT systems have been built or are currently under construction in the world as of November 2019, compared to 89 LRT systems in 2006 (LRTA, 2019). These systems entail significantly lower capital costs than heavy rail transit systems, and LRT appeals more to mid-size cities that need rail transit but lack a large population and the investments necessary to support heavy rail systems (Hensher, 1999; Parkinson & Fisher, 1996).

The distance between LRT riders' homes and LRT stations affects these riders' decisions about their feeder modes of transportation. Riders who only walk to and from a station have the shortest travel distance, and their average travel distance is around 800 metres, according to two studies (Kim et al., 2006; O'Sullivan & Morrall, 1996). A study by Kim et al. (2006) about LRT riders' travel behaviour in St. Louis, the United States, revealed that direct bus feeder systems connecting homes with LRT stations are important and would increase the number of people who use bus services as their feeder mode of transportation to access or egress LRT stations. This study (Kim et al., 2006) also found that female riders who own automobiles are less likely to use buses or walk due to safety concerns.

2.1.5 Weather

Beside the psychological effects on people's travel behaviour, weather is also considered one of the major factors affecting how people use different transportation mode. (Nosal & Miranda-Moreno, 2014; Saneinejad et al., 2012; Liu et al., 2015; Zhao et al., 2018). Previous studies suggested that cycling activities are more sensitive to adverse weather conditions compared to automobile and public transit; however, barriers in cycle usage and promotion still exist (Liu et al., 2015; Sabir, 2011). Zhao et al. (2018) conducted a study on bicycle–weather relations by using big data in Seattle, United States. The study context focused on off-road trails and protected bicycle lanes. The results of the study suggested that rainfall and snowfall have a significant negative impact on cycling on both trail and bicycle lanes at both daily and hourly scales across all seasons (Zhao et al., 2018). Another study conducted by Liu et al. (2015) in Sweden showed that the impacts of weather differ in different seasons and regions, and the findings highlight the importance of incorporating individual and regional unique anticipation and adaptation behaviours within planning policy design and infrastructure management. The study (Liu et al., 2015) further concluded that snow has a strong influence on non-motorized modes, causing shifts from cycling to walking when ground is covered with snow. On the other hand, cycling share increases as mean temperature rises. Hong et al. (2020) conducted a study in Glasgow, United Kingdom, and found that although safe cycling paths could encourage people to cycle more on dry days, they saw a larger reduction in the volume of cycling on rainy days.

Nosal and Miranda-Moreno (2014) conducted a study on the effect of weather on the use of bicycles in four North American cities, as well as on the Green Route in Quebec. They found that temperature and humidity were positively and negatively associated with cycling. Precipitation had a significant negative impact on cycling flows, and its effect was observed to increase with rain intensity. Urban bicycle flows are more sensitive to weather on weekends than on weekdays. The study by Saneinejad et al. (2012) in the City of Toronto showed that the use of the bicycle was sensitive to temperature when the temperature was below 15 degrees. Precipitation in the form of showers was found to affect cyclists more than pedestrians.

Although weather will impact people's decisions on transportation modes, it is an uncontrollable factor. By providing good infrastructure and policy measures will help to ease the negative impacts that are created by the weather. Transit riders' overall attitudes toward a transport mode can be interpreted as their specific attitudes toward a transport facility's various attributes. In Section 2.3, many attributes increase people's likelihood of using bicycles, such as separate bicycle lanes, secured bicycle parking, a well-connected cycling network, and a bike share program. De Sousa et al. (2014) studied the perceptions of barriers to the use of bicycles in three Brazilian cities. Their study asked participants about their scale of agreement with some statements to investigate the control beliefs about commuting by bicycle among participants. The data then addressed TPB to determine the real obstacles to commuting by bicycle.

2.2 Bicycle Infrastructure

2.2.1 Barriers to Increasing Cycling Use

Local cultural, demographic, and economic changes play an important role in increasing cycling use (Assunçao-Denis & Tomalty, 2018). Car remains the most preferred mode of everyday transportation among people (Duany, Speck, & Lydon, 2010). The dominance of car has enormous implication for how cities were planned, built, and experience (Loukopoulos et al. 2005; Filion & Bunting, 2004), and it resulted more (re)investment in car-oriented infrastructure and either knowingly or unintentionally discouraging other forms of transportation (Aldred & Jungnickel, 2014). However, the culture has started to change with the increase of oil price, growth of public transit, and culture of urbanism and sustainability influences the way in which people travel and commute (Walks, 2014) and bicycles has become popular among people to use as the primary transportation mode over the world (Mayers & Glover, 2019). Mayers and Glover (2019) stated in their study that the car culture and previous bicycle branding as a "children's toy" or a "poor man's" mode of transportation was still existing in the Waterloo Region. Furthermore, the study showed that mixed cycling experience from the participants they interviewed where some of the participants encountered hostility while cycling and talked about their sense of fear and stress at the times when they are cycling on the roads. Mayers and Glover (2020) conducted a second study related to cyclists' experience on cycling in the Region of Waterloo by using qualitative method and concluded that it is critical to invest in dedicated cycling infrastructure, where cyclists feel safe, to encourage more participation in cycling.

Some researchers have used TPB (Ajzen, 1991) to understand cyclists' behaviours (De Sousa et al., 2014). However, Han et al. (2017) argued that TPB failed to consider some elements that influence individuals' decision-making. Moreover, the literature also identified barriers distinct from infrastructure that can affect people's decisions to bicycle to a destination, such as weather and temperature (Sears et al., 2012). Female cyclists were found to prefer some bicycle facilities—or at least designated bicycle lanes—which made them feel safer when cycling (Deenihan & Caulfield, 2015) since they were more likely to carry items with them on their bicycles. Moreover, an adequate cycling network was found to help provide a fast, convenient, easy, and comfortable experience for commuters (De Sousa et al., 2014; Marqués et al., 2015). Additionally, a more connected cycling network was found to encourage bicycle use (Caulfield et al., 2012). Separate bicycle lanes provide better protection for cyclists and may reduce total crashes on a system level. However, without government policies and rapid investments in installing separate bicycle lanes, motorists' behavioural adaptions to such new facilities have been found to be slow (Thompson et al., 2017; Caulfield et al., 2012).

2.2.2 Equity Matters

Although equity is often mentioned in many active transportation plans, it is usually not clear how equity is being defined and measured, or how it will be implemented in the practice (Battista & Manaugh, 2019; Lee et al. 2017). The study that overlooked 15 years of social-spatial inequities in Vancouver bike lanes by Firth et al. (2017) showed that areas with more children and areas where more Chinese people live have less access to protected bicycle lanes. On the other hand, areas with more university-educated adults had more bicycle infrastructure. The study that was conduced by Braun et al. (2019) in 22 American cities found that census block groups with lower education attainment and a higher proportion of Latino residents has lower access to bicycle lanes. The French study (Vietinghoff, 2021) in Grenoble finds that racism, financial precarity, lack of accessible information about services, and spatial inequities may prevent some people from cycling despite the city has advanced bicycle infrastructure and services. The study by McCullough et al., (2019) and Lubitow et al., (2019) also point out that the significance of racial identity, gender discrimination and stereotyping in cycling includes both how individuals are seen as cyclists and their experience while cycling. Literatures on cycling and race often leads to broader social issues and concerns that extend beyond the bicycle, assuming intersectional complexity.

In terms of cycling and access to bicycle infrastructure, there are numbers of priority populations to consider, including lower income group, visible minority, children, and older adults. Safety outcomes that relate to bicycle infrastructure show inequities by income and race, studies showed that there is a higher likelihood of cyclist collisions in lower income neighborhoods (Marshall & Ferenchak, 2017; Morency et al., 2012) and predominantly visible minority neighborhoods. The provision of bicycle infrastructure could help address some of the inequities. However, even with the provision of bicycle infrastructure, visible minority populations face other barriers to cycling such as harassment, micro aggressions, and racial profiling (Agyeman, 2020). In contrast, the study conducted by Winter et al. (2018) in Victoria and Kelowna, two mid-sized Canadian cities showed the lower income areas have a greater access to cycling infrastructure compared to higher income areas. Local government policies and planning are keys to the success to overcome the inequality of accessing cycling infrastructure.

As a result, when in pursuit of designing cycling-friendly cities for all, it is imperative to monitor inequities in access to bicycle infrastructure and support policies that reduce socio-spatial disparities. In the White Paper that was published by the Pacific Southwest Region University Transportation Center (McCullough et al., 2019) on making cycling equitable, the researchers made four recommendations:

- Extend what it means to embrace difference.
- Recognize that the streets are not equally safe for all.
- Engage with marginalized communities and share decision-making power.
- Acknowledge local and national histories of injustice.

Meaningful cycling justice investment need to tackle community concerns that go beyond bicycle infrastructure (Golub et al., 2016). Local government should integrate recommendations from researchers into policy and planning can lead to a greater equity in representation, distribution of resources, and decision-making in promoting cycling. A system-wide implementation will create the excellent impact on improving issues of equity, diversity, and inclusion in cycling. This requires broad-scale interventions by the local government, including some training on equity, diversity and social-inclusion, changes to funding on programs that support these activities, changes in decision-making structures, valuing long-term community engagement and community knowledge, broadening measure to street safety for active transportation especially for cycling.

2.2.3 Preferences for Bicycle Infrastructure

Infrastructure plays a key role in both perceptions and realities of cyclists' safety, and bicycle infrastructure directly affects cycling rates. Generally, more bicycle lanes have been found to contribute to a higher probability of cycling (Griffin & Sener, 2016; Akar & Cliford, 2009; Duthie et al., 2010; Iseki & Tingstorm, 2014). Larson and El-Geneidy (2011) suggested that bicycle facilities' location within a 400-metre radius of both people's homes and destinations made their odds of using such facilities rise by 129%. The literature also indicated that a good city infrastructure for cyclists can help decrease overall congestion in busy areas (Burke & Scott, 2018; Kalašová & Krchová, 2011). A study compared the same street before and after a separate bicycle lane was implemented on an arterial road, which only resulted in a small delay for motorists (Kalašová & Krchová, 2011). Another study in Winnipeg showed that integrating priority bicycle lanes in a busy, congested area is possible; however, a specific policy must be enforced. Obstructions on bicycle lanes, such as objects or people who occupied the bicycle lanes, were found to cause safety issues for cyclists (Basch et al., 2018). A report published by the Centre of Active Transportation (Verlinden et al., 2019) showed that having nearby safe places to cycle is an important factor in people's cycling adoption. Residents of neighbourhoods with a higher density of bicycle lanes or a higher density of on-street cycling routes are also more likely to take trips on bicycles (Heesch et al., 2005).

Bicycle lanes should be designed for people with different experiences in cycling. Experienced and recreational cyclists who bicycle around a city have specific preferences that can also be applied to new cyclists since they are most likely to fall under either the experienced or recreational cyclist category. More experienced cyclists are more likely to select more challenging routes; however, a lack of basic bicycle facilities was found to decrease their likelihood of biking (Chen & Chen, 2013). The City of Vancouver constructed "All Age and Ability" (AAA) bicycle lanes around the city, designed for people with different cycling experience levels (City of Vancouver, 2017). Similarly, a Brisbane study showed that government investments in bicycle infrastructure within inner city areas appear to increase cycling activities (Heesch et al., 2015). Another study on Toronto's Bloor Street showed that people prefer bicycling on separate bicycle lanes. Since the Bloor Street separate bicycle lane project was completed, the average bicycle volume increased, while the nearby Dupont Street and Harbord Street, which both have painted bicycle lanes, saw average bicycle volumes decrease (City of Toronto, 2020).

Cyclists were also shown to value off-street, multi-use trails and enhanced neighbourhood bikeways with calming features and bridge facilities, and a positive correlation was also found in the literature between bicycle lanes and overall biking levels. Research shows that higher levels of on-street cycling infrastructure, such as protected or separate bicycle lanes, are preferred for general transportation—specifically for accessing transit stations—by both genders (Taylor & Hahmassani, 1996; Dill et al. 2015; Griffin & Sener, 2016). Researchers suggested that providing safe and exclusive bicycle parking sites at transit stations also contributes to a higher rate of bicycle-transit trips (Krizek & Stonebraker, 2010; La Paix & Geurs 2015).

Moreover, street connectivity and cycling have also been shown to have a positive relationship (Wang & Wen, 2017; Schoner & Levinson, 2014). A better bicycle lane network also encourages and welcomes more people to cycling, providing benefits from different perspectives, such as health and economic. Additionally, street connectivity for bicycle-specific infrastructure provides a safer built environment for cyclists where car volumes or speeds are high. Continuous bicycle paths that connect bike share stations with various destinations and transit stops have been shown to be essential in promoting bicycle-transit integration (Zuo & Wei, 2019). Throughout the research, the results showed that separated bicycle lanes and well-connected cycling network are the key solutions to encourage people to start cycling, however, on the practical side, these require years of careful planning and financial support which require the commitments from the local municipal government.

2.2.4 Bike Share

Bike shares or *bike sharing* is an on-demand transportation service that allows users to access bicycles for a fee and then use them for point-to-point connections to local destinations (National Academy of Sciences, Engineering, and Medicine, 2018). The bike sharing concept originated in the Netherlands in the 1960s (National Academy of Sciences, Engineering, and Medicine, 2018). Bike share has since evolved to become the third most-common docked and fourth most-common dockless bike share in the past ten years. The third generation of bike shares is Information Technology (IT)-based automated bike-shares, and the system comprises a dedicated docking station and an IT-based payment collections platform that requires a credit card or other form of payment (Bike Share Toronto, 2020). These features create a financial commitment that reduces the risk of theft and vandalism. However, the third generation of bike share systems create some inconvenience, such as dock availability—especially during morning peak times, when cyclists use bicycles to commute into central business districts, where a large number of bicycles need docks to park in. Vice versa, during afternoon peak hours, when cyclists take bicycles home, the demand for bicycles increases, creating difficulties in finding bicycles. It requires operators to closely monitor and react quickly to identify overflows and shortages during different periods.

Dockless bike shares (fourth generation) have built on the third-generation systems by including demand-responsive rebalancing that system automatically informs the operation company the location bikes are in high demand (Shaheen et al., 2014). GPS-enabled bicycles allow for even more detailed user data collection to improve rebalance efforts and system monitoring. These bicycles can be locked in a standard bicycle rack and in designated bike-share parking spaces

(National Academy of Sciences, Engineering, and Medicine, 2018). Users can use smartphone apps to locate bicycles and pay for their use.

Bike shares are a popular alternative for people who do not own a bicycle themselves. They provide convenient access to bicycles to the general public. Cities such as Vancouver, Toronto, and Montreal include bike-share stations near their subway or metro stations to solve passengers' last-mile problems, so passengers are able to use bike share services to arrive to their destination. As the previous paragraphs mentioned, bike shares can benefit high-density urban areas, where they can serve as a feeder mode of transportation for commuters' first and last trip miles. They can promote cycling as a more frequent feeder option, with mobility and health benefits for individuals and society (DeMaio & Gifford, 2004; DeMaio, 2009; Duvall & Main, 2012). Younes et al. (2019) conducted a study in Washington, D.C metropolitan area and conclude that with in 0.25 miles (0.4 kilometers) of a rail station and with a rail station spacing less than 3 miles (4.8 kilometers), bike share can be sued as a mechanism for low-carbon mobility to complement transit. Ma and Knaap (2019) also conducted a study in Washington, D.C. and suggest a collaboration between its metro and bike share to add more bike share stations within 0.25 miles (0.4 kilometers) of peripheral metro stations to increase the ridership of both systems. Kim and Cho (2021) suggested that the relative efficiency of bikeshare compared to public transit is highly associated with bikeshare demand and help to increase the utility of bike share system in response to several limitations of existing public transit networks.

A study of bike share integrations in transit conducted by the National Academy of Sciences, Engineering, and Medicine (2018) included five U.S. transportation agencies (Los Angeles, California; Dayton, Ohio; Chicago, Illinois; Phoenix, Arizona; and Birmingham, Alabama) included in case studies, identifying the following common best practices:

- Bike share stations' placement at or near transit stations or stops.
- Transit services shown on bike share service maps and bike-share services shown on transit maps.
- Bike share co-branding as an extension of a transit agency.
- Co-marketing bike-share and transit services in marketing materials, including links to bike-share services on transit agency websites and vice versa.

For Los Angeles and Dayton, bike share systems were noted to operate under transit agencies, which can provide better integration through agency control over bike share operations and flexibility in integrating supply and demand (LA Metro, 2020; Dayton RTA Link, 2020). TransLink used the same strategies in the Greater Vancouver Area to operate a bike share within the transit agency (TransLink, 2020). However, some common challenges were also identified among transportation agencies in integrating bike-share systems, such as:

- Fare systems that were not integrated or different bus and bike-share fare payment systems.
- Funding for bike share operations detracting from transit operations.
- Differing operations styles between the two modes of transportation.

In Phoenix and Birmingham, bicycle and transit integrations were found to be very limited, with both transportation modes operating through their own organizations and did not work together to provide integrating services for transit riders (Grid, 2020; ZYP, 2019). Further, transit underutilization was identified as one of the challenges for bike share companies to work with a transit agency. The author believes that integrating bike share with major transportation stations or stops will increased the likelihood of transit riders to use bike share. The best practice of integrating public transportation and cycling such as TransLink in Greater Vancouver Area should be considered by municipalities that are interested in providing bike share service in the future by operating both under the same transit agency where information sharing has less barriers that will help to forecast the volume and increase the overall efficiency and usage of bike share. However, this practice will require a large capital investment at first and may not turn into profit for the first few years. With all the benefits that bikeshare can bring to the public transit, the author would argue that bikeshare may add financial costs towards daily transit riders. In most Ontarian cities, transit riders only need to pay for a single fare to ride for transit and they can transfer between different local transit routes for up to two hours one way. Frequent transit riders usually purchase a monthly pass or weekly pass the allow unlimited access to the public transit. Mentioned in Section 2.1.1, costs are among the most important components of transportation mode choices. As a result, if the local government wants to integrate the bikeshare with the public transit services, a detailed policy and financial plan should be discussed, and consultation should be held before further implementation.

2.3 Bicycle–Transit Integrations

2.3.1 The "First/Last Mile" Problem among Transit Users

Recent research has focused on transit accessibility in transit systems across countries (Chandra et al., 2013; Koh &Wong, 2013; Moniruzzaman & Paez, 2012). Accessibility to bus stops or transit stations has become a barrier to some people's use (Chandra et al., 2013). Transit operators have used different ways to increase ridership through promotions on various media platforms such as signs on highway. Yang et al. (2015, p. 180) stated that accessing and egressing public transit occupy the majority of the trip time and can "lower a commuter's satisfaction level" and "reduce the attractiveness of a [public transportation] system." Providing convenient, fast, and safe access and egress stages during a trip within public transportation can help satisfy existing commuters' demands and potentially attract new riders (Andersson et al., 2012).

Much of the recent literature commonly refers to the "first/last mile problems" (Chandra et al., 2013; Koh & Wong, 2013). The first- and last-mile problems mostly focus on how people access a departure transit station from their trip origin point (i.e., home to a transit station) and from their destination transit station to their trip destination (i.e., transit station to work). Since commuters typically re-access their destination stations and take transit back to the same originating station, this issue can also occur vice versa (Koh & Wong, 2013).

In some of the literature, researchers have identified solutions to the first- and last-mile problems. Such solutions included using another transportation method as a feeder mode—for example, using smaller community buses to connect riders from locations closer to their homes to subways or metro stations. Feeder transit services in the North American context typically serve low-density residential areas (Chandra & Quadrifoglio, 2013). They typically operate as a "demand-responsive … shared-ride mode" model that shuttles passengers to a major transit node (Chandra & Quadrifoglio, 2013, p.1). Grand River Transit also provides the same type of service in the Waterloo Region as flexible transit services to serve this neighbourhood of winding streets, cul-de-sacs, and limited connections to major roads, with a lack of sidewalks and buildings set far back from the street (Grand River Transit, 2020). Some researchers have suggested intensifying the population density along major transit routes, such as implementing a transit-orientated development (TOD), which may help solve the first- and last-mile problems (Moniruzzaman & Páez, 2012). TOD neighbourhoods typically feature a centre with a transit station or stop to handle the needs of a large ridership. Kamruzzaman et al. (2015) found that individuals living in TODs were more likely to use more sustainable modes of transportation and less likely to use less sustainable transportation modes compared to residents of traditional suburbs in Brisbane, Australia.

Researchers have also investigated active transportation as a feeder mode to access and egress from major transit stations. However, walking distance and times spent walking during a commute were found to be very limited, since commuters were only willing to walk around 1 to 1.5 kilometres to access a transit station (Griffin & Sener, 2016; Kim et al., 2007). Some research has shown that walking often solves the first- and last-mile problems due to its convenient access as a transportation mode. Moniruzzaman and Páez (2012) found that people usually walk from their trip's origin to the nearest transit stop.

Bicycles, as a feeder mode of transportation to a transit station, can effectively extend catchment areas of transit stops far beyond walking range at a lower cost than a neighbourhood supported by feeder buses (Krizek & Stonebraker, 2010; Pucher & Buehler, 2009). Moreover, bicycles also provide flexibility in time for commuters departing from their original destinations. Transit services can also provide convenient alternatives when cyclists encounter bad weather, steep hills, gaps in the bicycle network, and mechanical failures. The literature revealed that bicycles, as a transportation mode to access transit station catchment areas, can range between 1.2 and 5 kilometres or 15 to 20 minutes in biking distance from a subway station (Griffin & Sener, 2016; Djurhuus et al., 2014; Zuo & Wei, 2019; Wu et al., 2019; Bracher, 2000; Rietveld, 2000; Hochmair, 2015); this expanded range allows more people to access transit stations, which benefits transit operations. However, many studies (Givoni & Rietveld, 2007; Pan et al., 2010; Martens, 2004; Bachand-Marleu et al., 2011) found that bicycles are most commonly used to access the “home” end rather than the “destination” end of a trip. Several reasons for this trend were noted, but this trend is most likely due to a lack of bike share services or riders’ inability to bring bicycles on board transit, preventing passengers’ easy access to a bicycle when they arrive at their destination (Chan & Faber, 2020).

2.3.2 Bicycle Integration with Rail Transit

In recent years, bike sharing has become an effective travel and feeder mode to connect city rail transit in the first/last mile. Many studies from Section 2.3 have shown that bike infrastructure has a significant contribution to make bicycle-rail transit integration available to more people. Cervero (2013) concluded that the adage “built it and they will come” holds for bicycle improvements from his study of Bay Area Rapid Transit (BART) in San Francisco, United States. Cervero (2013) also found the increased number of secure and protected bicycling parking at the stations, and the extensions of the separated bicycle lanes from the stations explained the growing use of bicycles for accessing BART stations.

Personal socio-economic characteristics, and structural context, including built environment, transportation infrastructure, and transit service, also had an impact on an individual's decision of using bicycle to access or egress metro stations (Liu et al., 2020). Chen et al. (2012) found that the land use of surrounding neighborhoods, bike share services, and the availability of transit services affect the decision to use the bicycle to access or egress the metro. Wang and Liu (2013) analyzed bicycle-transit integration tips in the US from 2001 to 2009 and found that commuters, younger individuals, and individuals that are living in large and high-density urban areas are more likely to use bicycles as a feeder mode to transit. Ma et al. (2018) also found that metro-bicycle travel patterns vary across users, but young users are the largest group. Zhao and Li (2017) indicated that a moderate transfer distance may encourage a connection between the metro and bicycles, such as bike share. Similar to the accessibility of transit stations, easy-to-access bus stops encourage their connection with the mode of walking rather than cycling (Kerr et al., 2016). Tang et al. (2018) found that bike sharing systems can help commuters solve their first/last mile travel and stimulate more people to use public transit.

2.3.3 Successful Integration

Successful bicycle-transit integrations were found to help increase overall catchment areas and subsequent transit patronage, as well as the overall demand for cycling (Krizek & Stonebraker, 2010). However, no one-size-fits-all method can be applied to every city due to their different settings and local cultures (Martens, 2004). For example, many European and Asian cities have different transit commuting patterns, habits, and cultures compared to North American cities due to their high population densities in urban areas. Many Canadian cities were planned to be car-oriented, with a lack of public transit and low bicycle usage in the past. Moreover, many cities in the Greater Golden Horseshoe in Ontario began to limit city sprawl within their current municipal boundaries by intensifying some areas through implementing high-rise residential buildings to prioritize efficient land use and support transit viability, guided by the Growth Plan (Government of Ontario, 2020). With higher population densities, the likelihood of using public transit and bicycles increases if sufficient infrastructure is implemented through development.

Kager et al. (2016) identified the supply components of bicycle–transit integrated transportation modes in Figure 2.1.

Figure 2.1 Supply components of bicycle-transit integration

*Origin → (Bicycle parking → Bicycle infrastructure → **Bicycle parking) * → Access stop → Transit services, facilities, and transfer locations → Egress stop → (**Bicycle parking → Bicycle infrastructure → Bicycle parking) * → Destination*

*A *bicycle–transit trip chain* is defined as including a bicycle trip segment either before or after a transit trip segment or on both sides of a trip.

**Bicycle parking at an access and egress stop is not used for a bicycle transit trip if a bicycle is taken on board.

Kager et al. (2016)

Bicycle parking and bicycle infrastructure play important roles in bicycle-transit integrations, and good bicycle infrastructure has been found in the literature to encourage people to bicycle more often (Griffin & Sener, 2016; Duthie et al., 2010). Stations in different communities within a city with different urban forms require various infrastructures, and policies must promote biking in local communities. For example, a low-density community may require more off-street bicycle paths or traffic-calming measures on streets that lead to LRT stations, particularly for users seeking added personal safety on the road. Secure bicycle parking may also entice riders who want added security at stations. On the other hand, a high-density, walkable urban area may benefit from a public bike share system or a network of on-street separate bicycle infrastructure within LRT stations' vicinities.

2.4 Transportation Research Methods

2.4.1 Surveys' Benefits and Limitations

Surveys are widely used in various research subjects, including transportation research as a data collection method (Neuman, 2007; Gideon, 2012). Researchers can collect a large amount of data in a fast, cost-efficient way through surveys. With technological developments, more researchers are using web-based surveys to conduct research (Neuman, 2007). Surveys offer flexibility in questioning techniques, the number of questions asked, and covered topics (Gideon, 2012). Web-based surveys provide many benefits, such as flexibility, ease of administration, lower costs compared to paper-based surveys, the ability to target a larger population, all-day accessibility and availability to a target population, and confidentiality and privacy for participants (Neuman, 2007; Gideon, 2012).

However, conducting a web-based survey also involves some limitations. For example, not all of a target population may have access to the internet or feel comfortable using technology, which can affect the resulting representation of a demographic group in a target sample (Neuman, 2007). Neuman (2007) suggested that survey designs must endeavour to ensure that participants understand the content and easily follow instructions.

Moreover, some disadvantages are associated with both paper- and web-based surveys. Low response rates are a common challenge among researchers who conduct surveys (Farthing, 2016). Providing incentives to survey participants encourages participants' willingness to participate in a survey-based study (Gotriz, 2006; Frick et al., 2001; Tuten et al., 2004; Heerwegh, 2006). Therefore, the incentivization strategy for this survey study is discussed in "Chapter 3: Methodology." Low response rates also threaten the validity of survey results because non-responses may not be random, since non-responders in the same samples sometimes share similar characteristics (Manzo & Burke, 2012). Besides low response rates, researchers conducting surveys also face data accuracy challenges, since respondents' answers may not reflect what they say, do, or will do (Neuman, 2007).

2.4.2 Stated-Preference Surveys

Stated-preference (SP) surveys have been widely applied in marketing and travel demand modelling studies (Ho et al., 2020; Shams et al., 2017), both separately from and jointly with revealed-preference (RP) surveys observing product purchase or service use choices. Stated-preference surveys are an efficient method to analyze commuters' evaluation of multi-attributed products and services, especially when hypothetical choice alternatives and new attributes are involved. Extensive research has used SP surveys to identify preferences or choices for the cycling infrastructure and cycling routes, levels of cycling confidence, and socioeconomic characteristics (Richie & Hall, 1999; Caulfield et al., 2012; Wang & Chen, 2017; Stinson & Bhat, 2003; Deenihan & Caulfield, 2005; Pritchard, 2018).

2.4.3 Aggregate and Disaggregate Models

Aggregate models were first developed for transportation modelling (Ortúzar & Willumsen, 2012). Aggregate demand transport models are based on either observed relations between groups of travellers or average relations at a zone level. However, disaggregate models are based on the observed choices made by individual travellers or households, and disaggregate models enable more realistic models to be developed. (Ortúzar & Willumsen, 2012). It has been criticized for its inflexibility, inaccuracy, and costs.

Ortúzar & Willumsen (2012, p.19) stated that "A major shift from aggregate models to disaggregate models occurred in major transportation projects during the 1980s". Disaggregate models demand that analysts have a higher level of statistical and econometric knowledge to use the model correctly compared to aggregate models (Tan & Ma, 2020).

Both models have advantages and disadvantages. With the technology having improved over the past 30 years, disaggregate models can be calculated by computer to simplify the process and provide better, simpler information for decision makers in transportation projects (Ortúzar & Willumsen, 2012).

2.4.4 Discrete Choice Models

Discrete choice models theoretically or empirically model people's choices among a finite set of alternatives, such as which car to purchase, which mode of transportation to take to work, and where to attend university, among numerous other applications (Train, 1978). Several studies have used a discrete choice model to conduct studies on transportation-related topics (Kim et al., 2007; Hunt & Abraham, 2007; Chen & Chen, 2013; Ji et al., 2017). This model statistically relates each person's choice to his or her attributes and to the attributes of the alternatives available to the person (Uncles et al., 1987). For example, people's choice of a mode of transportation for commuting is statistically related to each person's income, age, and lifestyle, as well as the other attributes of each available mode (Train, 1978). Discrete choice models estimate the probability that a person will choose a particular alternative (Puan et al., 2019).

Based on the number of dependent variables' available values, two types of logit models are common in the literature: the binary logit model and the multinomial logit model (MNL). Ji et al. (2017) used multinomial models to examine the factors that influence rail transit commuters' access modes in Nanjing, China. They revealed a gender gap in private versus public bicycle use for rail transit access, in which female commuters were more likely to use private bicycles to access rail transit stations (Ji et al., 2017). The same study also found that the choice to use public bicycles as a feeder mode of transportation to rail transit was higher among younger commuters and commuters with higher incomes (Ji et al., 2017). Few elderly users used this option due to public bicycles' requiring a smartphone application to scan a QR code to unlock the bicycles (Ji et al., 2017).

2.4.5 The Binary Logit Model

The binary logit model estimates the relationship between one or more explanatory variables and a single output binary variable (Tranmer & Elliot, 2008). In practice, many researchers have used binary regression to evaluate the factors that influence commuters to choose one mode of transportation over another. They typically used one group as a base group to compare to another group across many dependent variables (Tranmer & Elliot, 2008). A Danish study by Djurhuus et al. (2014) used the binary logit model to ask about participants' socioeconomic characteristics and reasons for transportation choices. A recent study by Tan and Ma (2020) also used the binary logit model to conduct a regression analysis of commuters' rail choice behaviour during the COVID-19 pandemic in China.

The binary logit model is useful when research can categorize variables into only two categories (Tranmer & Elliot, 2008). However, using this is difficult for many transportation researchers since it requires more than two categories to summarize variables. The choice probabilities of a regression equation can be explained as follows:

Logit (P) = Log [P / (1-P)]

Let: Pi = Pr (Y = 1 | X = x_i)

Then:

$$Log\left(\frac{P_i}{1-P_i}\right) = logit\ (P_i) = \ \beta_0 + \ \beta_1 x_i$$

where P or (P_i / 1-P_i) is the probability varies from 0 to 1, $\beta_1 x_i$ refers to independent variables.

2.5 Research Gaps and Aims of the Current Study

To the researcher's knowledge, and based on this chapter's literature review, overall bicycle infrastructure implementations in the local context significantly affect people's decisions to use bicycles. Moreover, physical availability and weather conditions also affect these decisions. However, most of the existing research about bicycle-light rail or bicycle-metro integration in the Canadian context has focused on large cities, such as Toronto, Montreal, Vancouver, and Calgary, while mid-sized Canadian cities have received less focus. In addition, most of the Canadian mid-sized cities do not have any light rail or metro system. There are only two other cities (Edmonton and Ottawa) that have light rail systems beside KW. The current research, therefore, aims to resolve the gap in the literature concerning mid-sized Canadian cities by using Kitchener-Waterloo as a case study.

Public transportation in mid-sized Canadian cities is typically less frequent compared to large cities, and bicycle infrastructure projects have only begun in these cities recently. A need to better understand the many factors and nuances, such as socio-demographic characteristics, distance travelled and frequencies of travel, that influence transit riders' behaviour and choice of feeder mode in mid-sized cities and why bicycles are not chosen as a feeder mode of transportation, is apparent. Further, most works in the literature examining feeder transportation mode choices in North America have focused on metros or subways with buses, walking, and personal vehicles. Although LRT was mentioned as a major transportation mode and bicycles were also mentioned as one such feeder mode, both of the subjects and their integrations were hardly discussed in the reviewed literature.

The hypothesis of this thesis is that bicycle infrastructure is one of the controllable determinants in promoting bicycle-LRT integration. Offering more bicycle infrastructure—such as secure bicycle parking at LRT stations, separate bicycle lanes, connections to LRT stations, better cycling network connectivity, and expanded bike share services—would increase people's likelihood of bicycle use as a feeder mode of transportation to access or egress from LRT stations in Kitchener-Waterloo. This thesis intends to resolve some of the gaps in the existing literature identified above. Based on the research findings discussed later in Chapter 4 and Chapter 5, the thesis study will offer recommendations for future infrastructure interventions and implementation specific to the Kitchener-Waterloo context.

2.6 Conclusions

This chapter reviewed the existing literature related to the use of bicycles as a feeder mode of transportation. The first section of this literature review discussed different factors affecting general transportation mode choices, such as individual factors, the costs of certain modes and the built environment and urban form. Individual factors, such as gender, play a role in mode choices (Kim & Ulfarsson, 2008; Gatersleben & Appleton, 2007). Family structures also affect mode choices (Kim & Ulfarsson, 2008). Importantly, cost factors must be included when testing land-use factors' influence on travel demand. Built environments and urban forms also affect commuters' transportation mode choices. Many studies have found built environments to significantly influence decisions to use or not to use sustainable transportation modes (Winters et al., 2010; Zhou, 2012). Researchers have broken down psychological factors—such as behaviours and attitudes toward a transportation mode choice—into different variables through various perspectives, such as experiences, social status and the approval of the general public or a person's family (Ajzen, 1991; Krizek, 2005). The literature has also suggested that instead of discouraging a behaviour, creating enjoyment of a particular travel mode may facilitate the promotion of desirable behaviour (Whalen et al., 2013).

Among different transportation modes, city rail transit provides a stop-to-stop service rather than a door-to-door service, which typically requires passengers to use a feeder mode to access or egress from the rail transit stations. Factors that impact decisions on feeder mode choices are similar to those affecting the general transportation mode choice, which includes individual factors, built environment, and psychological factors (Chan & Farber, 2019; Guo et al., 2020). Mid-sized cities' current urban form and the decline in downtown areas negatively affects public transportation usage and encourage local residents to use automobile to travel between dispersed activities. Weather is also considered one of the major factors in changing how people choose transportation mode. Precipitation such as rain or snow will have a significant negative impact on cycling (Nosal & Miranda-Moreno, 2014; Hong et al., 2020), where the increase in temperature will help to increase the cycling volume (Saneinejad et al., 2012). However, weather is an uncontrollable factor for which good infrastructure and policy measures can help ease its negative impacts.

The second section of this literature review discussed general attitudes towards bicycle infrastructure. This section also discussed barriers, preference for bicycle infrastructure, and bike share. Bicycle infrastructure plays a crucial role in both the perception and the reality of safety for cyclists. A well-supported bicycle infrastructure—such as a well-connected cycling network or separate bicycle lanes—reduces barriers and encourages people who are not cycling often and who worry about sharing the road with automobiles to use bicycles (Deenihan & Caulfield, 2015). Bicycle lanes should be designed for people with different experiences and of all ages. Bike share also plays a key role in promoting cycling, providing flexibility for people who do not own a bicycle, and integrating bike share systems with transit systems helps transit riders reach their destinations faster (DeMaio & Gifford, 2004; DeMaio, 2009; Duvall & Main, 2012).

The third section of this literature review discussed the first- and last- mile problems among transit users. Providing convenient, fast, and safe access and egress stages during a trip within public transportation can help satisfy existing transit riders and, potentially, attract new riders. Additionally, bicycle use as a feeder mode of transportation to a transit station can effectively extend transit stops' catchment areas far beyond walking ranges at a lower cost, which leads to successful bicycle–transit integration that helps increase overall demand for both cycling and transit (Krizek & Stonebraker, 2010; Pucher & Buehler, 2009). However, local governments should be aware of bicycle infrastructure settings, depending on transit stations' geographical areas (Putcher et al., 2011). Local government should integrate recommendations from researchers into policy and planning can lead to a greater equity in representation, distribution of resources, and decision-making in promoting cycling. The final section of this literature review discusses transportation research methods and the models used in the following chapters of this study.

Many cities over the world have good practice bicycle-train, or bicycle-metro integration program. However, not all the practices can be applied on a mid-sized car dominant Canadian city. The city of Nanjing, China (Ji et al, 2017) was able to provide excellent bicycle-metro integration program also since a large proportion of the population use public transit for their commute to work and the population of Nanjing is greater than any city in Canada. The larger population creates the large economic of scale which creates large demand to use bike share where it provides flexibility and conveniently located near both end of the commuting trips. There is an existing bicycle culture in China, although many people opt to purchase car when they can afford. However, the overall congestion of the road and the time consumed creates challenges for people to use car to commute. This also creates opportunities for bike share to grow. In the Canadian context, Vancouver has the best bicycle-metro integration program among all Canadian cities, where the transit riders and bike share riders are using the same fare system (Translink, 2020) where it helped the transit agency to forecast the supply and demand during different peak hours where they can quickly adopt the demand and sending personnel to distribute more bicycles in a short period of time. However, such practice by Vancouver does not work on mid-sized cities at the current stage. The bicycle culture and the sustainable city planning in Vancouver has been established for a long time (City of Vancouver, 2020) where many of the mid-sized cities such as Kitchener-Waterloo were only just starting to focus on active transportation and sustainability planning. Although overall car culture in the mid-sized cities is still dominating in the local contexts (Myers & Glover, 2019; Fillion & Buting, 2004), some cities were starting to see the culture changes by implementing long term transportation plan that focused on active transportation.

This review identified three gaps in the literature. First, the existing LRT literature has mostly focused on large cities and rarely on mid-sized cities. Secondly, minimal research has been conducted on attitudes toward bicycle infrastructure in a mid-sized city context. Thirdly, most bicycle-transit integration studies have focused on bicycle–commuter rail or bicycle-metro subjects, with less discussion of LRT. Finally, this chapter revealed a need to better understand the many factors and nuances that influence light rail riders' behaviour in mid-sized cities.

The next chapter outlines the theoretical and methodological approaches used in this study.

Chapter 3: Methodology

3.1 Overview

A quantitative method approach was chosen for this study. Accordingly, web-based surveys were distributed to potential participants. This chapter discusses the theoretical context of the current research, provides some background on the study's sites, reviews regional and local policies, and describes the study's survey design, data collection, and data analysis using a quantitative method.

3.2 Research Purpose and Theoretical Approach

3.2.1 Research Purpose and Objectives

This research aimed to understand what conditions are necessary for existing LRT riders to use or will be encouraged to use bicycles as a feeder mode to access or egress from the LRT stations, specifically the role of bicycle infrastructure. Three research objectives guided this study in understanding this potential use:

1. Understand LRT riders' sociodemographic backgrounds, their attitudes, and preferences toward bike infrastructure

2. Identify factors associated with increasing the usage of bicycles as a feeder mode

3. Use the findings to inform planning policies and implementation of bicycle infrastructure.

3.2.2 Theoretical Approach

This research adopted a relativist ontological position, and the researcher's epistemological position was positivist. This position means that this research examined the extent of the influences on current LRT riders' future decisions to use bicycles as a feeder mode of transportation. Ontology regards the existence of facts and objects, while epistemology regards whether people can know them or not, whether objectively or subjectively. The researcher selected an interpretive position to understand influences on participants' attitudes toward bicycle infrastructure and influences on participants' future choices to use bicycles as a feeder mode of transportation to access and egress LRT stations.

This research was a quantitative study, and it used a deductive approach. This research examined the role of bicycle infrastructure on either supporting or refuting the theory of the planned behaviour (TPB). As discussed in Chapter 2, TPB is predominately a cognitive theory. It is an influential theoretical approach applied to understanding and predicting behaviour. In the current research, the studied event was the future potential of using bicycles as a feeder mode to access or egress from LRT stations in Kitchener-Waterloo. This research examined bicycle infrastructure's effect on current riders' intentions to either support or refute the TPB that more bicycle infrastructure would positively influence people's intention and perceptions of bicycles by conducting discreet choice model analysis on surveys. A deductive approach was used to conduct a web-based survey and to test the hypothesis. This research hypothesized that building more bicycle infrastructure would increase current LRT riders' likelihood of using the bicycle as a feeder mode of transportation. Once this hypothesis was tested and developed, a case was selected to generate and analyze data, and enhance further understanding of the research questions (Farthing, 2016).

3.3 Study Area

The City of Waterloo and the City of Kitchener are two adjacent, lower-tier municipalities within the Region of Waterloo in Southwestern Ontario, Canada. These two cities have a combined population of 338,208 (Statistics Canada, 2017), comprising more than half of the Waterloo Region's population. Kitchener-Waterloo (KW) is also home to two universities, one college, and 65,000 post-secondary students. The Region of Waterloo is the approval authority for the lower-tier municipalities in the region, whose planning, at the regional level, for transportation issues can cross local municipal boundaries (Region of Waterloo, 2020).

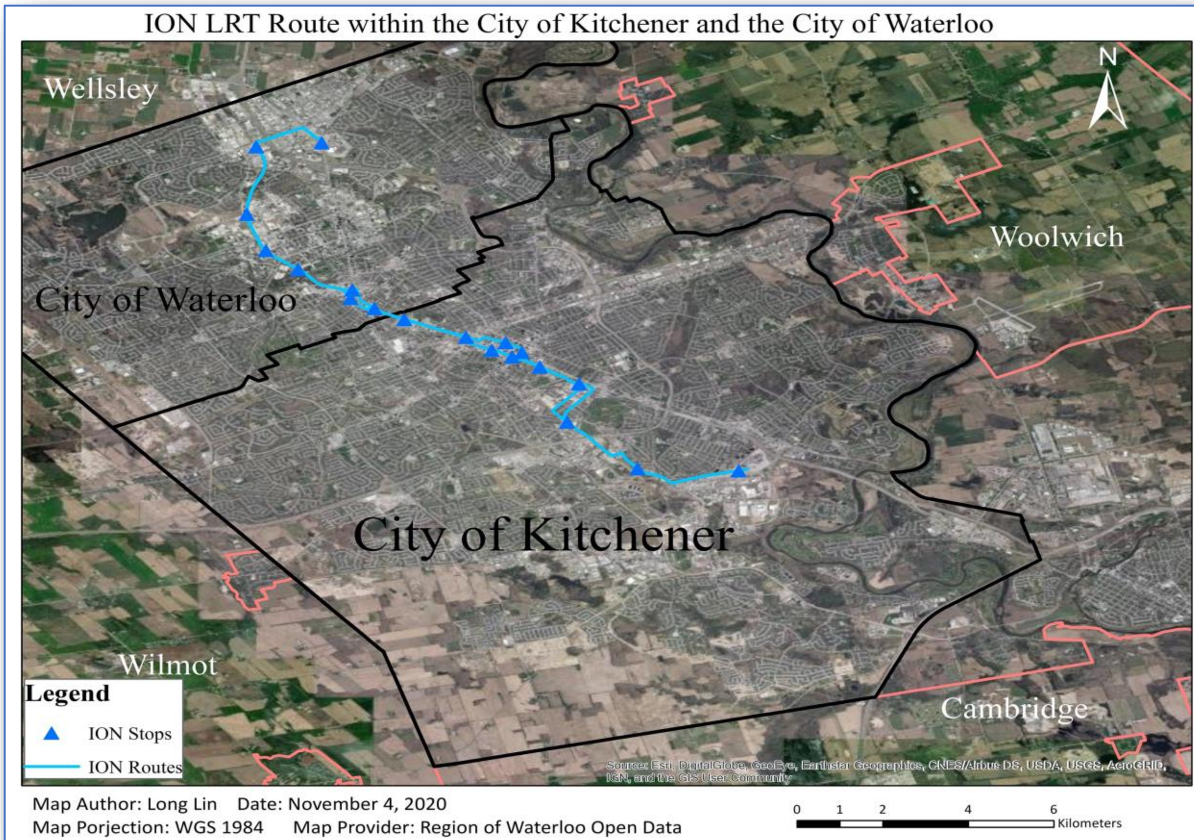
Between 2006 and 2016, a growing number of residents took short trips (less than 2 kilometres in length) by using transit, bicycles, or walking, whereas car use for short trips (for both drivers and passengers) fell during the same period (Region of Waterloo, 2019). Moreover, cycling accounted for 2.9% of total trips under 2 kilometres and 2.1% of total trips between 2 and 5 kilometres, a 1.2% increase from 2006 (Region of Waterloo, 2019). The growth of using transit, bicycles, or walking reflects a positive trend that may relate to regional investment in active transportation, transit, and land-use changes, including the Central Transit Corridor's population intensification.

3.3.1 Public Transportation in Kitchener–Waterloo

Grand River Transit (GRT) serves the Waterloo Region with scheduled local bus services and express bus services. GRT also provides MobilityPlus buses for wheelchair users and people with physical disabilities, by appointment. It currently provides services in Waterloo, Kitchener, Cambridge, Elmira, and Wilmot (Grand River Transit, 2020).

The ION Light Rail Transit (ION LRT) was launched by the end of June 2019, connecting Conestoga Mall in Waterloo in the north and Fairview Mall in the south through both downtown Kitchener and uptown Waterloo along King Street. Figure 3.1 shows the current LRT route. ION LRT is currently operated by Keolis—a multinational company that operates public transportation systems. When this LRT was launched, many east-west–bound GRT buses rerouted to connect to these LRT stations as part of the transit integration process (Grand River Transit, 2019). Figure 3.1 illustrates the current ION LRT route in the City of Kitchener and the City of Waterloo.

Figure 3.1 ION Light Rail Transit route in the City of Kitchener and the City of Waterloo



3.3.2 Bicycle Infrastructure in Kitchener–Waterloo

As mentioned in "Chapter 1: Introduction", the studied area's regional and municipal governments have implemented and constructed many bicycle infrastructures over the past few years, and more of such projects have been proposed or planned, or are currently under construction (Region of Waterloo, 2020). The region has significantly progressed in its plan for an integrated, active transportation network, including on-road bicycle facilities. Bicycle lanes nearly doubled across the region, to almost 300 kilometres, from 2006 to 2014 (Region of Waterloo, 2019). However, a large proportion of the region's existing bicycle lanes are off-road, multi-use pathways.

Kitchener and Waterloo currently host five secure bicycle parking areas, with four in Downtown Kitchener and one in Uptown Waterloo. However, users of these secure bicycle parking must complete a registration process to obtain a security pass to access these facilities (City of Kitchener, 2020; City of Waterloo, 2020). The City of Kitchener has also installed "fix-it" stations where bicycle users can perform small repairs and conduct general maintenance (City of Kitchener, 2020). Further, both municipalities have painted signages, such as bicycle boxes, on roads and added traffic lights dedicated to cyclists to provide clear guidance at intersections (City of Kitchener, 2020).

The Region of Waterloo established a partnership with Drop Mobility that offers a dockless bike-share pilot project in Kitchener, Waterloo, and Cambridge in May (Drop Mobility, 2019). This pilot project was planned to end by December 2019 for evaluation and reporting to the regional and municipal councils. Although Drop Mobility expressed interest in operating a reduced area, fewer bikes, and with a monthly service fee in Waterloo Region in 2020, both regional and municipal governments decide to decline the proposed plan from Drop Mobility (Region of Waterloo, 2020). The regional government is currently working with the municipal government to develop a micro-mobility plan to introduce e-scooter and re-introduce bike-share in 2021.

3.3.3 Regional and Municipal Policies Review

The Waterloo Region's "2018 Transportation Master Plan" established four goals: to promote travel choice, foster a strong economy, support sustainable development, and optimize the region's transportation system (Region of Waterloo, 2019). One strategy for achieving the plan's goals is to build a transportation network that supports all travel modes. Enhancing walking and cycling connections to ION LRT stations and frequent transit corridors is one of the plan's targets. Six road diets were planned, in which one- or two-car lanes were removed from overbuilt corridors to accommodate new cycling facilities or dedicated transit lanes (Region of Waterloo, 2019).

As part of the "2018 Regional Transportation Master Plan" (Region of Waterloo, 2019), the region conducted an "Alternative Transportation Modes Study" to identify barriers, behaviours, and attitudes that influence transportation mode choices within the region. The study's survey categorized respondents into four categories: *fearless and strong*, *enthused, and confident*, *interested but concerned*, and *no way, no how* (Region of Waterloo, 2019).

The survey's results revealed that 66% of respondents had shown an interest in using cycling as an alternative option, but nonetheless harboured concerns (Region of Waterloo, 2019). The top three barriers identified for cycling becoming the region's primary travel mode were: long distances and travel times between destinations, safety concerns, and the lack of an ability to carry items on a bicycle (Region of Waterloo, 2019). The safety-concerns barrier can be mitigated through enhanced designs, including bicycle lanes and multi-use trails that are physically separated from traffic, to enhance user comfort, as well as more education for drivers and cyclists. Moreover, using bicycles as a feeder mode of transportation to public transit instead of a primary mode for a whole trip can help resolve the long-distance barrier and decrease travel times between destinations, while offering some flexibility.

The City of Kitchener and the City of Waterloo both set goals in their transportation master plans that follow the "Regional Transportation Master Plan" vision (Region of Waterloo, 2019). The

City of Kitchener recently approved a new “Cycling and Trails Master Plan” from the existing “Kitchener Integrated Transportation Master Plan” to provide detailed planning guidance for the city in creating a bicycle-friendly community. Section 4, Strategy 1E of the current master plan, stated that the City of Kitchener is aiming to integrate cycling with other modes of transportation and provide cycling facilities at major transit stations to encourage bicycle-transit integration as a viable mode of transportation for longer trips (City of Kitchener, 2020). Additionally, in the city’s “Official Plan” (2014, p. 132), under the Section 13.C.1.1, the city set out a guideline to require “new, multi-unit residential, commercial, industrial, office and intuitional developments to provide secure bicycling parking and will encourage, where appropriate, shower/change facilities for cycling commuters.”

The City of Waterloo “Transportation Master Plan” (2011) provides guidelines for the city in creating more bicycle lanes or multi-use trails and connecting the city’s existing bicycle lane network to encourage people to use bicycles and create a bicycle-friendly community. In the current City of Waterloo “2019 to 2022 Strategic Plan,” one strategic goal is to improve all sustainable transportation modes to make Waterloo more mobile, accessible, and connected; additionally, one objective is “to facilitate a model shift, enable increased use of active transportation and public transit” (City of Waterloo, 2019, p. 10). Under Chapter 6 of the City of Waterloo “Official Plan” (2012), the city set out guidelines to support building cycling networks by connecting the city’s high-density, transit-oriented area with a lower-density neighbourhood.

Different levels of government have been worked creating bicycle-friendly communities to encourage people to use bicycles or public transportation as their primary method of transportation, rather than automobiles. However, before encouraging more people to change their primary mode of transportation, infrastructure must be implemented so that people can feel comfortable and more willing to make this change. The Region is currently working on a coordinated 2021 micro-mobility (bike share and e-scooter) plan and implement in the City of Cambridge, the City of Kitchener, and the City of Waterloo that will overall improve micro-mobility service quality and efficiency.

3.4 Survey Development

3.4.1 Introduction and Survey Development

The sole component of this study's data collection was a self-administered, web-based survey examining current LRT riders' sociodemographic backgrounds, travel behaviours, bicycle ownership and usage, attitudes toward bicycle infrastructure and potential future use of bicycles as feeder mode of transportation. Surveys allow researchers to ask questions for examination about, for example, behaviours, attitudes, self-classification, and knowledge (Neuman, 2007). This study's survey comprised a mix of different types of questions, including multiple-choice questions, which were closed-ended, asking participants to choose only one of a set of answers. Multiple-choice questions allow participants to provide quicker responses, but they face challenges in capturing individual perceptions and feelings (Neuman, 2007). Multi-response questions allow participants to select as many answers as they think apply to them and are able to capture respondents' views and attitudes through pre-formatted information (Santos, 2000). This study's survey also included a Likert question that asked participants to rate the importance of listed elements. At end of the survey, an open-ended question allowed participants to provide their reasons for choosing their answers to the previous question. Open-ended questions allow participants to expand upon their answers to multiple-choice questions to reflect their feelings and perceptions (Neuman, 2007).

The study's survey questionnaire, titled "Bicycle-LRT Integration in Kitchener-Waterloo Area," was designed by using Qualtrics. Qualtrics is a web-based survey platform compatible with quantitative analysis programs, such as IBM SPSS Statistics and Microsoft Excel, both of which were used to analyze this study's data. Before the survey was submitted to the University of Waterloo Research Ethics Committee, the researcher conducted a pilot study with 15 university student volunteers from different programs to test the survey's completion time, to adjust any errors, and to ensure consistency with the timeframe indicated on its information page. The survey was found to be easy for potential participants to understand. The only limitation of the pilot project was that the volunteers were all younger adults who were studying in the university and may have a better understanding of the subjects or vocabularies compared to the public. Upon completion of the pilot project, the survey was refined, based on the pilot study's comments. One question was eliminated, and a few new options were added to the existing questions.

This study was approved by the University of Waterloo Research Ethics Committee (ORE#42052). After the project had received this clearance, the survey was distributed online, and participants could access the survey through a link provided on the electronic survey flyer or a recruitment message. They could enter themselves into a draw for one of ten $20 Tim Hortons gift cards as an incentive for participation.

3.4.2 Survey Design

The survey questionnaire comprised 18 questions and was five pages in length, requiring approximately 10–15 minutes to complete. The first page contained information for participants, explaining the study's purpose, the ethics committee's clearance, the total number of questions, and the estimated time needed to complete the survey.

In the first section of the survey, participants were asked to provide sociodemographic information, including gender, age, family structure, education level, age, and household income. In the second section, respondents were then asked to provide answers related to ION LRT, such as their frequency of using this LRT service, their primary purpose in using the service, the feeder mode of transportation they used to access and egress the service's LRT stations, and the distance between their homes and the service's LRT stations.

The survey's final section asked participants questions about cycling aspects, such as their ownership of any bicycles and cycling frequency, as well as the primary reason for discouraging participants from using bicycles to access or egress stations. Participants were then asked to state their opinions on the importance of different cycling infrastructures, different cycling experiences, and different travel motivation–related statements. A five-point agreement scale ranging from *very important* to *not at all important* was used for these questions. The final two questions asked participants if they would be willing to use bicycles as a feeder mode of transportation in the future in good weather conditions, given all the local governments' efforts to install bicycle infrastructure over the past few years, and to state their reasons for their choices. As previously mentioned in Chapter 2.1.4, low temperature, and precipitation, such as rain or snow, have a significant negative effect on people's willingness to choose bikes as the mode of transportation. For the purpose of the study, the researcher determined the willingness of people to use bikes as feeder mode to the LRT stations in good weather conditions instead of during all weather conditions. It will be difficult to encourage people to try biking during bad weather conditions even with the cycling infrastructures available (Hong et al., 2020). Upon completing the survey, participants were encouraged to submit their email addresses to the researcher if they wanted to participate in the incentive draw or obtain a copy of the results upon completing the thesis's completion.

3.4.3 Data Collection

The survey questionnaire was administered to a sample of LRT riders over 18 years of age in the Kitchener-Waterloo area. The original survey distribution plan was to hand out survey flyers on the street, near LRT stations. However, due to the COVID-19 outbreaks and social distancing measures implemented by all levels of governments (Government of Canada, 2020; Government of Ontario, 2020), and also due to new research restrictions posted by the University of Waterloo during the pandemic (University of Waterloo, 2020), this original plan was cancelled. The researcher instead distributed the survey through social media via the Facebook Group function. A recruiting message was created along with a link to the survey, and a survey flyer was posted digitally on the Facebook Group "I Support Light Rail Transit in the Region of Waterloo", which included more than 2,500 members. This group was the largest and most active group related to LRT topics in the Waterloo Region context. The advantages of using this special Facebook group were that many active members were current LRT riders who shared LRT news concerning the Waterloo Region and discussed the current system, and who may more likely participate in this study and provide more detailed feedback. The Facebook group had more than 2,500 members, and the recruitment message would have a larger media exposition. However, current LRT riders who were not using Facebook or who did not join the Facebook group would not be able to see the recruitment message and were not able to participate in the study.

Upon receiving the approval of the administrators of the Facebook Group and approval of the University of Waterloo Research Ethics Committee (ORE#42052), a survey recruitment message was posted on August 17, 2020, and left active for two weeks. On the survey's completion date, the researcher removed the survey link by the end of the day at 11:59 p.m. and downloaded all participants' responses to the researcher's laptop for data analysis.

3.4.4 Potential Selection Bias

Selection bias is systematic error due to a non-random sample of a population, causing some members of the population to be less likely to be included than others, resulting in a biased sample, defined as a statistical sample of a population in which all participants are not equally balances or objectively represented. Examples including self-selections, pre-screening of the participants. Failing to control for self-selection will result in overestimation of the effect of built environment on travel behavior (Cervero, 2004). In this research, the participants were recruited from the Facebook group "I Support Light Rail Transit in the Region of Waterloo", which the group members have common interests in the light rail transit and transit related topics. The overall result may be slightly more positive compared to total random sampling. However, with the research focus on sampling LRT riders, the overall self-selection bias was able to be minimized.

3.5 Incentivization Recruitment Strategy

In recent years, telemarketing surveys and customer service satisfaction surveys have become common, and they can negatively affect potential volunteers' willingness to participate in any other types of surveys due to privacy and personal data concerns (Yu et al., 2017). Many researchers have found that incentives help increase response rates, including in online surveys (Gotriz, 2006; Frick et al., 2001; Tuten et al., 2004; Heerwegh, 2006). Offering incentives is becoming popular among researchers who use surveys as tools to conduct research. Gotriz (2006) found a 19% increase in response rates from offering incentives to participate in surveys. Frick et al. (2001) found that a lottery incentive significantly decreased the percentage of respondents who prematurely dropped out while answering an online survey. Tuten et al. (2004) and Heerwegh (2006) also found that providing incentives through a lottery significantly increased participation compared to a group that did not offer any incentives. Further, researchers have found that material incentives are generally more effective compared to not offering incentives, especially bonus points, because of the difficulty of delivering money to each respondent, and prepaid incentives are more effective than promised incentives (Su et al., 2008). Many researchers now rely on incentives to encourage survey participation and to increase overall response rates (McGovern et al., 2018). Offering incentives can also help establish connections between a researcher and potential participants, which can encourage involvement in a study (Sherrod et al., 2003).

The current study's data collection involved surveying current LRT riders using an online flyer and a recruitment message that directed potential participants to the survey, along with a description of the remuneration they were eligible to receive following their completion of the survey. Upon completing the survey, participants could enter a lottery draw by providing their email addresses and choosing to participate in the draw. The email address provided by the participants to enter this draw was not affiliated with their survey responses. Upon completing the study's data collection, the researcher downloaded these email addresses into a separate Excel file and reorganized them chronologically by the participants' response times. The researcher then used a random number generator to select winning participants for the gift card draw, and each winning participant received one of ten $20 Tim Horton gift cards.

3.6 Data Analysis

3.6.1 Descriptive Analysis

The descriptive statistics tools Excel and SPSS were used to analyze the survey data’s basic features, which demonstrated participants’ sociodemographic information, characteristics in their current travel behaviour, and attitudes towards bicycle infrastructure. Besides looking into the frequencies and proportions of participants’ selections for each question, a few cross-tabulation analyses were also conducted. Cross-tabulation is a method used to quantitatively analyze the relationship between multiple variables and show how correlations change from one variable grouping to another. Cross-tabulation is useful in statistical analysis for finding patterns, trends, and probabilities within raw data. Moreover, it can help determine whether a significant association has occurred between variables. Furthermore, variables with significant associations can also be tested using regression analysis to determine whether such relationships are positive or negative.

Questions 14 and 15 asked survey respondents to select all the options that applied to them. The results of these two questions were obtained using the multi-response function in SPSS software for frequency and further cross-tabulation analysis. Question 16 asked the survey respondents to rate the level of importance of each of the bicycle infrastructure lists in the question. As Table 3.1 shows, each level of importance was assigned a score ranging from 5 (*very important*) to 1 (*not at all important*). The mean score among the samples for each question was measured using SPSS, which helped reflect the participating LRT riders’ overall thoughts about bicycle infrastructure.

Table 3.1. Likert scale scoring

Score Assignment	5	4	3	2	1
Level of Importance	Very Important	Somewhat Important	Neutral	Somewhat Not Important	Not at All Important

3.6.2 Regression Analysis

As mentioned in "Chapter 2: Literature Review", regression models have been widely used by researchers to examine the significance levels of factors related to bicycle transit integration topics (Djurhuus et al., 2014; Tan & Ma, 2020; Caulfield et al., 2012; Ji et al., 2017). The current research aimed to identify and understand what will affect current LRT riders' future decisions to use a bicycle as a feeder mode of transportation. The binary logit model was selected to conduct this analysis, since the dependent variable Y1 in Question 17 was designed with only two outcomes. The survey data collected from responses to Questions 1–13 and 16 were input into SPSS for modelling as independent variables. Both Questions 13 and 16 asked multiple sub-questions, and each sub-question was identified as an independent variable. Table 3.2 illustrates the dependent and independent variables used for the study's binary logit regression.

To produce a more accurate regression analysis, the researcher then grouped some of the options for each question because of lower response counts or similarities between these options. The researcher also removed the data that represented the "non-binary or third gender" and "I prefer not to identify" options for Question 3, as well as the "I prefer not to answer" option for Question 4 to Question 7 and reported those data as missing data for the regression analysis. The categorical variables were categorized into different groups and coded using *3*, *2*, *1*, and *0* values, where *0* was used as the reference category in the analysis. The *3*, *2*, *1*, and *0* in this analysis are not numerical values; rather, they were used to distinguish between different groups.

Table 3.2: Descriptions of dependent variables (*Y*) and independent variables (*X*)

Descriptions of Dependent Variables (*Y*) and Independent Variables (*X*)				
# (Q)	**Name**	**Type (and Options)**	**Coding**	**Note**
Y (Q17)	Future use of bicycles as a feeder mode	Categorical Variables: – Yes – No	0 for "No"; 1 for "Yes"	Dependent Variable
X_1 (Q1)	Location	Categorical Variables: – Kitchener – Cambridge – Waterloo – Woolwich – Wellesley – Wilmot – North Dumfries – Out of the Waterloo Region	0 for "Kitchener"; 1 for "Waterloo"; 2 for "Out of the Waterloo Region"	Most respondents who used LRT were within the City of Kitchener and Waterloo.
X_2 (Q2)	Age	Categorical Variables: – 18 to 24 – 25 to 29 – 30 to 34 – 35 to 39 – 40 to 49 – 50 to 59 – 60 or older	0 for "18 to 29"; 1 for "30 to 39"; 2 for "40 to 59"; 3 for "60 or older"	
X_3 (Q3)	Gender	Categorical Variables: – Female – Male – Non-Binary – Third Gender – Prefer not to Answer	0 for "Female"; 1 for "Male"; 2 for "Non-Binary" and "Third Gender"	"Prefer not to Answer" data were removed and reported as missing data.
X_4 (Q4)	Education	Categorical Variables: – Master's Degree or Ph.D. or M.D. – Bachelor's Degree or Similar – College Diploma or Certificate – High School – Prefer not to Answer	0 for Graduate Level: "Master's Degree or Ph.D. or M.D."; 1 for Undergraduate Level: "Bachelor's Degree or Similar" and "College Diploma or Certificate; 2 for "High School"	"Prefer not to Answer" data were removed and reported as missing data.

X_5 (Q5)	Family structure	Categorical Variables: – Single or Live Alone – Live with Parent(s) – Live with Roommate(s) – Lone Parent with Child(ren) – Live with Partner with No Child – Live with Partner and Child(ren) – Prefer not to Answer	0 for Living Alone: "Single or Live Alone"; 1 for Living with Others without Children: "Live with Parent(s)," "Live with Roommate(s)," and "Live with Partner with No Child"; 2 for Living with Children: "Lone Parent with Child(ren)" and "Live with Partner and Child(ren)"	"Prefer not to Answer" data were removed and reported as missing data.
X_6 (Q6)	Household income	Categorical Variables: – Less than $29,999 – $30,000 to $49,999 – $50,000 to $69,999 – $70,000 to $99,999 – More than $100,000 – Prefer not to Answer	0 for Low Income and Income around Median Household Income: "Less than $29,999" and "$30,000 to $49,999"; 1 for Higher than Median Household Income: "$50,000 to $69,999"; 2 for High Income: "$70,000 to $99,999" and "More than $100,000"	"Prefer not to Answer" data were removed and reported as missing data.
X_7 (Q7)	Primary purpose for LRT use	Categorical Variables: – Commute to Work – Commute to School – Grocery Shopping – Visit the Hospital – Drop Off or Pick Up Child(ren) – Visit Family Members – Access Entertainment or Recreation or Leisure Facility – Others	0 for "Commute to Work"; 1 for "Commute to School"; 2 for All Other Purposes: "Grocery Shopping," "Visit the Hospital," "Drop Off or Pick Up Child(ren)," "Visit Family Members," "Access Entertainment or Recreation or Leisure Facility," and "Other."	

X_8 (Q8)	Frequency of LRT use	Categorical Variables: – Daily – More than 3 Times a Week – 1 to 3 Times a Week – Less than Once a Week	0 for "Daily"; 1 for "More than 3 Times a Week"; 2 for "1 to 3 Times a Week"; 3 for "Less than Once a Week"	
X_9 (Q9)	Feeder mode to access LRT	Categorical Variables: – Walk – Bicycle – Bus (GRT, GO Transit, Greyhound, etc.) – Automobile or Car Drop-Off (Private Vehicles, Taxi, Uber, Carpooling, etc.)	0 for "Walk"; 1 for "Bicycle"; 2 for "Bus" and "Automobile or Car Drop-Off"	
X_{10} (Q10)	Feeder mode to egress LRT	Categorical Variables: – Walk – Bicycle – Bus (GRT, GO Transit, Greyhound, etc.) – Automobile or Car Drop-Off (Private Vehicles, Taxi, Uber, Carpooling, etc.)	0 for "Walk"; 1 for "Bicycle"; 2 for "Bus" and "Automobile or Car Drop-Off"	
X_{11} (Q11)	Distance between home and LRT	Categorical Variables: – Less than 500 Metres – 501 to 1,000 Metres. –1,001 to 1,500 Metres – 1,501 to 3,000 Metres – 3,000 to 5,000 Metres – More than 5,000 Metres	0 for Comfortable Walking Distance: "Less than 500 Metres" and "501 to 1,000 Metres"; 1 for Comfortable Biking Distance: "1,001 to 1,500 Metres" and "1,501 to 3,000 metres"; 2 for Longer Distance: "3,000 to 5,000 Metres" and "More than 5,000 Metres"	
X_{12} (Q12)	Bicycle ownership	Categorical Variables: – Yes – No	0 for "No"; 1 for "Yes"	

X_{13} (Q13-1)	Frequency of using a bicycle for work or school	Categorical Variables: – Three Times a Week or More – Once a Week or More – Once a Month or More – Less than Once a Month or Never	0 for Frequent User: "Three Times a Week or More" and "Once a Week or More"; 1 for Infrequent User: "Once a Month or More" and "Less than Once a Month or Never"	
X_{14} (Q13-2)	Frequency of using a bicycle for recreation or exercise	Categorical Variables: – Three Times a Week or More – Once a Week or More – Once a Month or More – Less than Once a Month or Never	0 for Frequent User: "Three Times a Week or More" and "Once a Week or More"; 1 for Infrequent User: "Once a Month or More" and "Less than Once a Month or Never"	
X_{15} (Q13-3)	Frequency of using a bicycle for any other purpose	Categorical Variables: – Three Times a Week or More – Once a Week or More – Once a Month or More – Less than Once a Month or Never	0 for Frequent User: "Three Times a Week or More" and "Once a Week or More"; 1 for Infrequent User: "Once a Month or More" and "Less than Once a Month or Never"	
X_{16} (Q16-1)	Opinion on on-street bicycle lane	Categorical Variables: – Not at All Important – Somewhat Not Important – Neutral – Somewhat Important – Very Important	0 for "Not at All Important"; 1 for "Somewhat Not Important"; 2 for "Neutral"; 3 for "Somewhat Important"; 4 for "Very Important"	

X_{17} (Q16-2)	Opinion on separate bicycle lane	Categorical Variables: – Not at All Important – Somewhat Not Important – Neutral – Somewhat Important – Very Important	0 for “Not at All Important”; 1 for “Somewhat Not Important”; 2 for “Neutral”; 3 for “Somewhat Important”; 4 for “Very Important”	
X_{18} (Q16-3)	Opinion on off-street bicycle trails	Categorical Variables: – Not at All Important – Somewhat Not Important – Neutral – Somewhat Important – Very Important	0 for “Not at All Important”; 1 for “Somewhat Not Important”; 2 for “Neutral”; 3 for “Somewhat Important”; 4 for “Very Important”	
X_{19} (Q16-4)	Opinion on cycling network connectivity	Categorical Variables: – Not at All Important – Somewhat Not Important – Neutral – Somewhat Important – Very Important	0 for “Not at All Important”; 1 for “Somewhat Not Important”; 2 for “Neutral”; 3 for “Somewhat Important”; 4 for “Very Important”	
X_{20} (Q16-5)	Opinion on bicycle signage or designated bicycle traffic light	Categorical Variables: – Not at All Important – Somewhat Not Important – Neutral – Somewhat Important – Very Important	0 for “Not at All Important”; 1 for “Somewhat Not Important”; 2 for “Neutral”; 3 for “Somewhat Important”; 4 for “Very Important”	
X_{21} (Q16-6)	Opinion on secure bicycle parking at LRT	Categorical Variables: – Not at All Important – Somewhat Not Important – Neutral – Somewhat Important – Very Important	0 for “Not at All Important”; 1 for “Somewhat Not Important”; 2 for “Neutral”; 3 for “Somewhat Important”; 4 for “Very Important”	

X_{22} (Q16-7)	Opinion on bike share availability	Categorical Variables: – Not at All Important – Somewhat Not Important – Neutral – Somewhat Important – Very Important	0 for "Not at All Important"; 1 for "Somewhat Not Important"; 2 for "Neutral"; 3 for "Somewhat Important"; 4 for "Very Important"	
X_{23} (Q16-8)	Opinion on bicycle repair station	Categorical Variables: – Not at All Important – Somewhat Not Important – Neutral – Somewhat Important – Very Important	0 for "Not at All Important"; 1 for "Somewhat Not Important"; 2 for "Neutral"; 3 for "Somewhat Important"; 4 for "Very Important"	

In binary logit regression, one category variable can be set as a base group for comparison with the other categories of variables in order to identify differences. In this thesis, the categorical variables assigned the value "0" were established as the base group for comparison with the other categories. For example, for Question 1, the "Kitchener" category was established as the base group for comparison against "Waterloo" and "Out of the Waterloo Region."

3.6.3 Variable Selection and Model Calibration in Logistic Regression

Zellner et al. (2007) identified three different variable selection methods in logistic regression models: *forward selection*, *backward selection*, and *stepwise selection*. *Forward selection* variables are added to a model one at a time; the variable with the highest correlation is added first. In the *backward selection* method, variables are all included in a model, and then the variable with the lowest correlation is eliminated after running the model. The regression analysis will run until only one variable is left or until a stopping rule is satisfied for the research. The third method, *stepwise selection*, is based on the forward selection procedure. However, at each step after running the model, the backward method is used to determine whether the variables can be dropped from the model (Zellner et al., 2007). Sperandei (2014) suggested that less significant variables should be dropped one after the one. If too many variables are included all at once in a model, significant variables may drop due to lower statistical power.

In this study, SPSS software performed binary logit regression for this project's data analysis. The study's 23 independent variables (X_1 to X_{23}) were used to conduct the first run. The model was refined by dropping some of the independent variables and conducting a few more runs with different independent variables after conducting a "bivariate" function to determine significant associations between each independent and dependent variable. The researcher also used the backward variable selection method to conduct model calibration, which eliminated the variable with the highest *p*-value—or the most statistically insignificant variable—from each run until all the variables left in the model were statistically significant after running the model. Pseudo *R*-squared and 2 log-likelihood values were compared for each model. The better model with the highest goodness-of-fit was selected for further interpretation. Each independent variable was assigned a *p*-value and an odds ratio so that the factor's significance level and the extent to which respondents would choose bicycles as a feeder mode of transportation could be measured.

Chapter 4: Research Findings

This chapter presents the results of this study's data analysis. These findings were sufficient to answer the project's research questions. As the following sections explain, the findings discussed in Section 4.1.1 answered the first research question, "What are the characteristics of current LRT riders? What is their current travel behaviour? Do their households own any bicycles? For what purposes do they use bicycles?", while Sections 4.1.2 to 4.1.4 answered the second research question, "What are current LRT riders' attitudes toward bicycle infrastructure (e.g., bicycle lanes, bike-shares, and bicycle parking)?" and Section 4.2 present findings that answer the third research question, "To what extent will it encourage the current LRT riders to use bicycles as a feeder mode of transportation to access or egress light rail stations? What can local governments do to accommodate and encourage this usage?".

4.1 Descriptive Statistical Analysis

4.1.1 Participants' Sociodemographic Characteristics

At the end of the data collection period, a total of 265 surveys were collected via the online survey platform Qualtrics, and a total of 250 surveys were valid after the data were imported into the SPSS system. The 250 surveys represent about 10% of the total members of the Facebook Group "I Support Light Rail Transit in the Region of Waterloo." Table 4.1 summarizes participants' sociodemographic characteristics.

Among the 250 validated participants, at the time of their responses, 231 resided within Kitchener and Waterloo, eight lived in Cambridge, four lived in the rest of the Waterloo Region, and seven lived outside the Waterloo Region. The majority of participants were young adults between the ages of 18 and 35, representing 210 responses.

Because this survey was conducted via the social media platform Facebook, many of the older adults who ride LRT in the region—that is, riders who are older adults over 65—may not have been approached effectively. Therefore, the study's sample group may not reflect the actual age demographics of the KW LRT ridership.

One hundred and ten validated participants were female, and 118 were male. Eighteen validated participants were non-binary or third gender, and four participants did not disclose their gender.

The majority of participants had attended post-secondary institutions and received a diploma or a degree. Of the participants, 12.4% had received a master's degree or higher-level degree. In comparison, 4.4% of the participants had only completed high school, and 0.8% of the participants did not disclose their educational backgrounds.

The data also indicated that 36.8% of participants lived with their parents at the time of their responses, while 24% lived with roommates. Further, 9.6% of participants lived alone, 8.8% lived with partners and no children, and 20% lived with at least one child in their household.

In the annual household income before tax category, 61.6% of participants reported an annual household income below $49,999, 22.4% of participants earned $50,000 to $69,999, and 12.4% of participants' annual household income exceeded $70,000.

Table 4.1. Participants' sociodemographic characteristics

Sociodemographic Characteristics		**All Participants (n = 250)**
Q1: Location	Kitchener	69.6%
	Cambridge	3.2%
	Waterloo	22.8%
	The Rest of the Waterloo Region	1.6%
	Outside of the Waterloo Region	2.8%
Q2: Age Group	18–24	34.0%
	25–29	30.0%
	30–34	20.0%

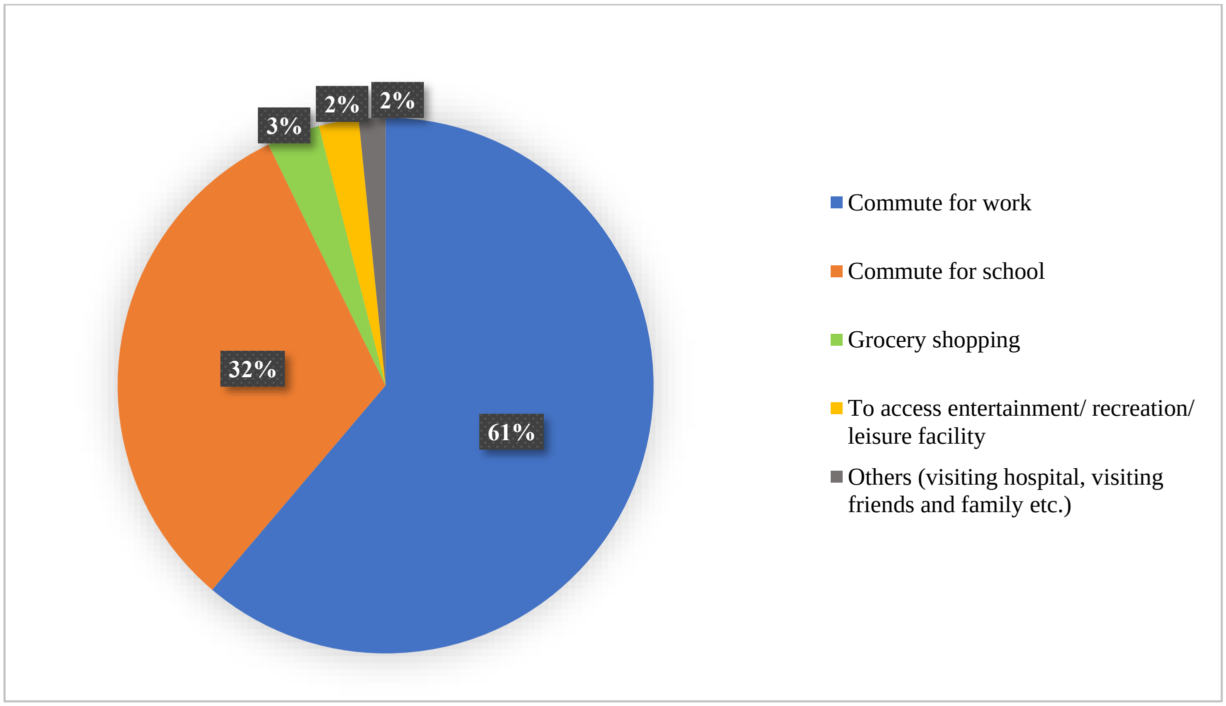
	35–39	11.2%
	40–49	3.6%
	50–59	0.8%
	60 or over	0.4%
Q3: Gender	Female	44.0%
	Male	47.2%
	Non-Binary or Third Gender	7.2%
	Prefer Not to Answer	1.6%
Q4: Education	Master's Degree or Ph.D.	12.4%
	Bachelor's Degree or Similar	51.6%
	College Diploma	30.8%
	High School	4.4%
	Prefer Not to Answer	0.8%
Q5: Household Structure	Single or Live Alone	9.6%
	Live with Parent(s)	36.8%
	Live with Roommate(s)	24.0%
	Lone Parent with Child(ren)	11.6%
	Live with Partner but No Child	8.8%
	Live with Partner with Child(ren)	8.4%
	Prefer Not to Answer	0.8%
Q6: Household Income	Less than $29,999	28.8%
	$30,000–$49,999	32.8%
	$50,000–$69,999	22.4%
	$70,000–$99,999	7.6%
	$100,000 or More	4.8%
	Prefer Not to Answer	3.6%

4.1.2 Participants' Intercity Travel Behaviour

The study's survey asked participants about their intracity travel behaviour using LRT before the COVID-19 pandemic had begun. During the COVID-19 pandemic, many people's travel behaviours changed due to many restrictions, such as public agencies' closure, social distancing rules, and working from home instead of commuting to a workspace.

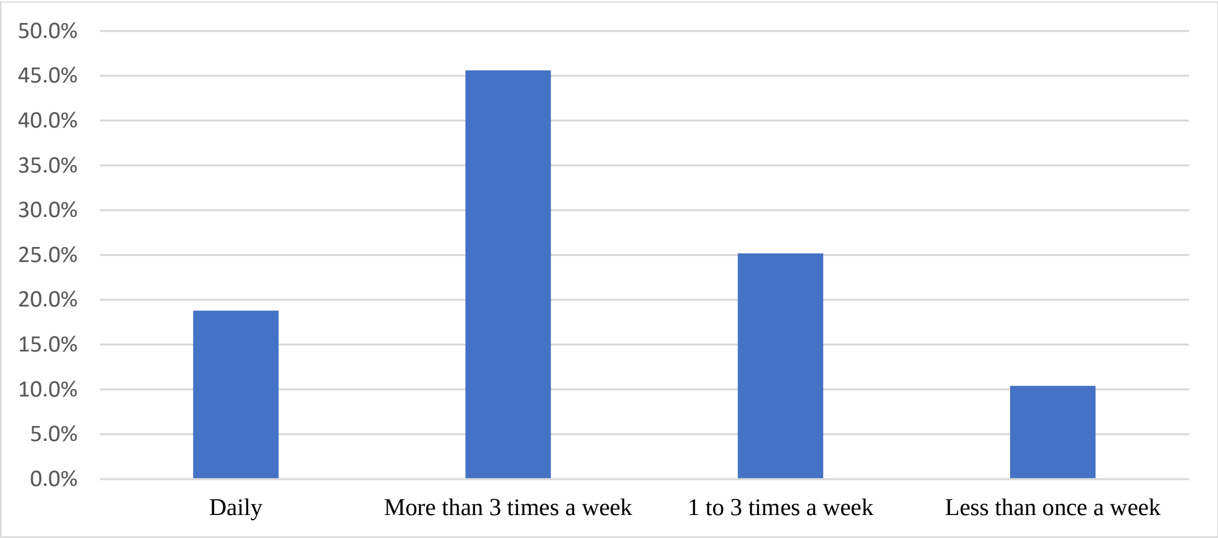
Figure 4.1 shows participants' primary purpose in using LRT services, and 92.8% of participants used LRT primarily for work or school. In comparison, the remaining 7% of participants indicated that they used LRT for other activities, such as grocery shopping, accessing entertainment, recreation, leisure facilities, visiting the hospital, and visiting friends and family.

Figure 4.1 Participants' primary purpose in using light rail transit services



The survey also asked participants how frequently they used LRT, and Figure 4.2 below illustrates this usage frequency. More than 64% of participants used LRT more than three times a week or daily, 25.2% of participants used LRT between one and three times a week, and 10.4% of participants used the service less than once a week. Participants who used LRT for work or school purposes typically tended to use the service more. However, some participants who chose primary purposes other than work or school were also using LRT services frequently—for example, for health purposes, such as visiting hospitals or accessing recreation facilities (gym, sports complexes, etc.).

Figure 4.2 Frequency of participants' light rail transit usage



The survey asked participants to indicate how they arrived and departed from LRT stations. Table 4.2 displays the proportion of participants who used different modes of transportation for such access and egress. Of the participants, 29.6% walked to LRT stations while 27.6% cycled to LRT stations. Moreover, 40.4% of participants stated that they used public transit—such as GRT, GO Transit, or other regional transit—to access LRT stations. Only 2.4% of the participants indicated that they used private cars or rideshares. This study's finding that many LRT riders use public transit to access LRT stations was unsurprising; GRT, one such public transit option, had changed some of its bus routes and networks to better integrate with LRT stations since the region's LRT service launched in 2019, improving riders' transfer experience between these two different modes of transportation. For egress modes of transportation, 31.2% of participants walked to their destination from LRT stations, while 28% cycled. 36.4% of participants used public transit to reach their destinations, and 4.4% used private cars or rideshares.

Table 4.2 Proportion of each access and egress mode

Access mode	Frequency	Percentage	Egress mode	Frequency	Percentage
Walk	74	29.6%	Walk	78	31.2%
Bicycle	69	27.6%	Bicycle	70	28.0%
Bus (GRT, GO Transit, Greyhound, or other regional transit)	101	40.4%	Bus (GRT, GO Transit, Greyhound, or other regional transit)	91	36.4%
Automobile or car drop-off (Private Vehicles, Taxis, Uber, Carpooling, etc.)	6	2.4%	Automobile or car Drop-Off (private vehicles, Taxis, Uber, carpooling, etc.)	11	4.4%
Total	250	100.0%	**Total**	250	100.0%

Table 4.3 presents a cross-tabulation analysis of participants' access and egress modes of transportation to and from LRT stations ($p = 0.000$). A p-value less than 0.05 indicates a statistically significant association between two variables. Among all participants, only 63.2% (158) used the same feeder mode to access and egress LRT stations. Among these participants ($n = 158$) who used the same mode on both ends of their LRT trips, 25.9% used bicycles to access and egress LRT stations. The remaining 36.8% of participants used mixed feeder modes such as combing bus and walk or bicycle and walk for this purpose ($n = 92$). Among the 92 participants who used mixed feeder modes on both ends of these trips, 28% used bicycles ($n = 23$), 30.4% walked ($n = 28$), 41.3% used bus ($n = 38$), and 3.3% used automobile or car drop-off ($n = 3$) to either access or egress LRT stations. By breaking down into specific feeder mode combinations, the five most used mixed feeder mode combinations for access-egress the LRT stations are bike-bus ($n = 18$), bus-walk ($n = 17$), walk-bike ($n = 15$), bus-bike ($n = 13$), and bike-walk ($n = 10$).

Table 4.3 Cross-tabulation of participants' light rail transit station access and egress

		Egress mode to destination				Total
		Walk	Bicycle	Bus (GRT, GO Transit, Greyhound, or other regional Transit)	Automobile or car drop-off (private vehicles, taxis, Uber, carpooling, etc.)	
Access Mode from Home	Walk	51	15	8	0	74
	Bicycle	10	41	18	0	69
	Bus (GRT, GO transit, Greyhound, or other regional transit)	17	13	63	8	101
	Automobile or car drop-off (private vehicles, taxis, Uber, carpooling, etc.)	0	1	2	3	6
Total		78	70	91	11	250

Table 4.4 demonstrates participants' sociodemographic differences and four identified access modes of transportation to LRT stations by comparing sociodemographic data corresponding to each access mode with the overall responses data (Table 4.1). Buses, including local and regional buses, were the most popular option among the 40.4% of the study's total participants. Among the participants who used buses to access LRT (n = 101), 42.6% were aged 18 to 24, 8.6% more than such users across all the survey's age groups. Additionally, 73.3% of participants who used buses to access LRT stations lived in the City of Kitchener—3.7% more than such users across all of the survey's places-of-residence groups. Lastly, 43.6% of participants who used buses to access LRT stations lived with a parent or parents—6.7% more than such users across all of the survey's household groups.

Walking was participants' second-most-popular mode of transportation to access LRT stations, representing 29.6% of total participants. Among these participants, 31.1% lived in the City of Waterloo, 8.3% more than the overall sampled population's percentage. Compared to the City of Kitchener, the survey results indicated that the City of Waterloo is home to a higher proportion of participants who choose to walk as their mode of transportation to access LRT stations. By further conducting a cross-tabulation analysis among the access mode, location, and the distance between home location and LRT stations, the results showed that a higher proportion of the participants in Waterloo lived within 1 kilometre from the LRT stations. Participants who lived with a partner but not a child represented 17.6% of the participants who walked to LRT stations—8.8% more than participants with such households than the overall data's group. Moreover, the participants who "lived with a partner but no child" accounted for the highest proportion of those who chose walking as a LRT access mode among all types of family structures included in the survey, and this proportion was more than two times higher than the corresponding proportion of participants who lived with a partner and a child or children.

Biking was the third-most popular mode of transportation among the four identified access modes, representing 27.6% of the total sampled population. Participants' genders among the bicycle riders were very closely aligned with the overall sampled population. Male participants accounted for a slightly higher proportion of this group than female participants. Participants who were lone parents with a child or children accounted for a higher proportion of bicycle use compared to participants with other types of family structures and compared to the overall sampled population. Using automobiles, carpools, or car sharing to access LRT stations, unsurprisingly, ranked last among all access modes, representing only 2.4% of the total sampled population.

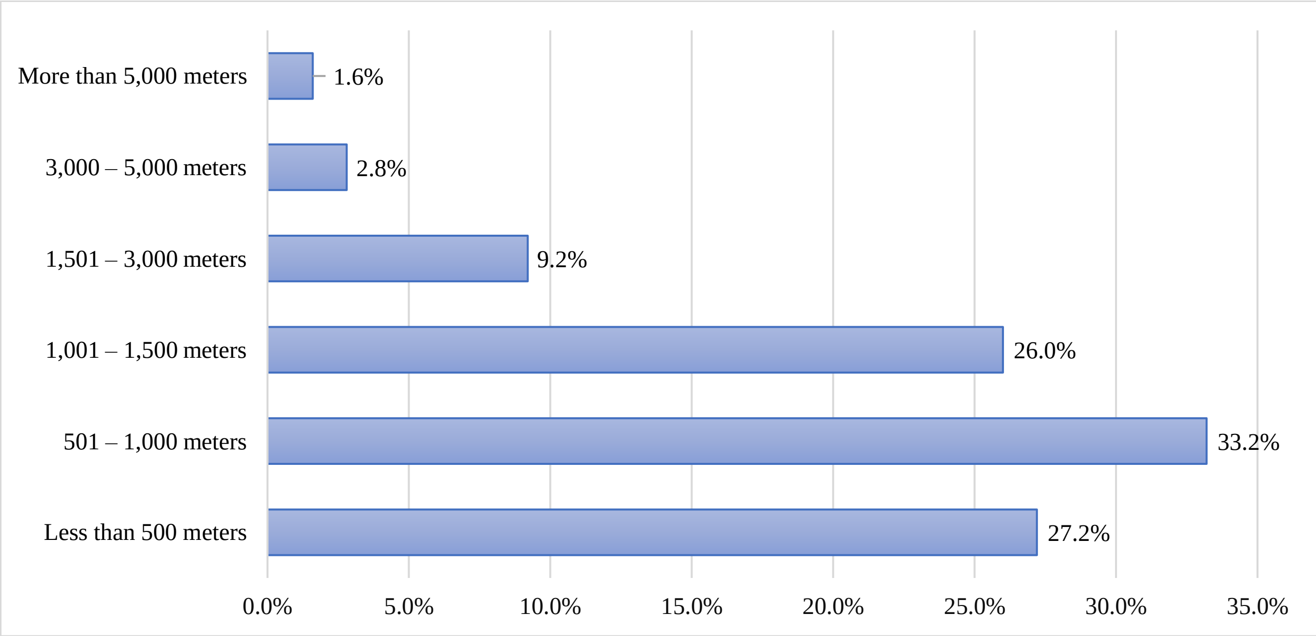
Table 4.4. Light rail transit access modes by participants' sociodemographic characteristics

Sociodemographic Characteristics		Light Rail Transit Access Mode from Home			
		Walk (n = 74)	Bicycle (n = 69)	Bus (n = 101)	Automobile or Carpool (n = 6)
Q1: Location	Kitchener	63.5%	69.6%	73.3%	83.3%
	Cambridge	1.4%	7.2%	2.0%	0.0%
	Waterloo	31.1%	23.2%	16.8%	16.7%
	The rest of the Waterloo Region	5.4%	0.0%	4.0%	0.0%
	Outside of the Waterloo Region	2.7%	0.0%	5.0%	0.0%
Q2: Age group	18–24	32.4%	23.2%	42.6%	33.3%
	25–29	32.4%	31.9%	26.7%	33.3%
	30–34	20.3%	24.6%	15.8%	33.3%
	35–39	8.1%	15.9%	10.9%	0.0%
	40–49	5.4%	1.4%	4.0%	0.0%
	50–59	1.4%	1.4%	0.0%	0.0%
	60 or Over	0.0%	1.4%	0.0%	0.0%
Q3: Gender	Female	45.9%	43.5%	42.6%	50.0%
	Male	48.6%	46.4%	46.5%	50.0%
	Non-binary or Third gender	4.1%	7.2%	9.9%	0.0%
	Prefer Not to Answer	1.4%	2.9%	1.0%	0.0%
Q4: Education	Master's or Ph.D.	18.9%	10.1%	7.9%	33.3%
	Bachelor's Degree or Similar	48.6%	44.9%	58.4%	50.0%
	College Diploma	24.3%	37.7%	31.7%	16.7%
	High School	6.8%	7.2%	1.0%	0.0%
	Prefer Not to Answer	1.4%	0.0%	1.0%	0.0%
Q5: Household structure	Single or Live Alone	14.9%	8.7%	5.0%	33.3%
	Live with Parent(s)	31.1%	36.2%	43.6%	0.0%

	Live with Roommate(s)	20.3%	23.2%	28.7%	0.0%
	Lone Parent with Child(ren)	8.1%	17.4%	8.9%	33.3%
	Live with Partner but No Child	17.6%	5.8%	5.0%	0.0%
	Live with Partner with Child(ren)	6.8%	8.7%	7.9%	33.3%
	Prefer not to Answer	1.4%	0.0%	1.0%	0.0%
Q6: Household income	Less than $29,999	31.1%	23.2%	30.7%	33.3%
	$30,000–$49,999	28.4%	33.3%	35.6%	33.3%
	$50,000–$69,999	17.6%	26.1%	23.8%	16.7%
	$70,000–$99,999	6.8%	10.1%	5.9%	16.7%
	$100,000 or More	9.5%	4.3%	2.0%	0.0%
	Prefer Not to Answer	6.8%	2.9%	2.0%	0.0%

The survey also asked participants to indicate the distance between their home and LRT stations, and Figure 4.3 below illustrates the answers to this question. Only 4.4% of participants lived more than 3 kilometres away from LRT stations. Additionally, 68.4% of participants lived between 501 metres and 3,000 metres away from LRT stations, which was considered a comfortable biking distance. The 27.2% of participants living within 500 metres of LRT stations were most likely to walk to LRT stations, due to their close proximity. The majority of participants lived within 3 kilometres of LRT stations, a proximity that provides great potential to promote bicycles as an alternative mode of transportation, offering timing flexibility compared to buses.

Figure 4.3 Distance between participants' homes and light rail transit stations



4.1.3 Bicycle Ownership and Frequency of Use

This study's survey asked participants whether they owned a working bicycle and, if so, their use frequency of that bicycle. Tables 4.5 ($p < 0.01$) and 4.6 ($p < 0.01$) show the bicycle ownership results among participants and their frequency of use. Of the participants, 35.2% stated that they owned a working bicycle, while 64.8% stated that they did not own a working bicycle. An examination of the participants' sociodemographic data revealed that, among the 110 female participants, 40.9% owned a bicycle, compared to 31.4% of the male participants.

Moreover, an examination of participants' household structures revealed that only 33.9% of participants who lived with a parent or parents, a roommate or roommates, or a partner owned a bicycle, while 48% of participants who lived with a partner and a child or children owned a bicycle. The lowest bicycle ownership percentage by household structure type correlated with participants who were single or lived alone, of whom only 20.8% owned bicycles. Participants' bicycle ownership proportion increased with their income levels; 58% of participants with a household income of $70,000, or more per year owned a bicycle in their household.

Table 4.6 shows the frequency of participants who used bicycles for different purposes. More than 67% of participants (*n* = 247) used a bicycle more than once a week to commute to work or school, and almost 64% of participants (*n* = 242) used a bicycle more than once a week for recreational or exercise purposes. Only 53.2% of the participants (*n* = 239) stated that they used bicycles more than once a week for other trips, such as shopping or visiting friends and family.

Table 4.5. Selected sociodemographic data and participants' bicycle ownership cross-tabulation

		Bicycle Ownership	
		No	**Yes**
Gender	Female	59.09%	40.91%
	Male	68.64%	31.36%
Household structure	Single or Live Alone	79.17%	20.83%
	Live with Parent(s), Roommate(s), or a Partner	66.09%	33.91%
	Parent(s) Who Live with Child(ren)	52.00%	48.00%
Household income	Less than $49,999	70.13%	29.87%
	$50,000–$69,999	62.50%	37.50%
	$70,000 or More	41.94%	58.06%

Table 4.6. Participants' frequency of bicycle uses for different purposes

Frequency of bicycle use	Purposes of bicycle use (Percentage)		
	Work or School (n = 247)	Recreation or Exercise (n = 242)	Other Activities (n = 239)
Three times a week or more	23.5%	19.8%	17.6%
Once a week or more	43.7%	43.8%	35.6%
Once a month or more	11.3%	22.7%	28.0%
Less than once a month or never	21.5%	13.6%	18.8%

4.1.4 Bicycle Infrastructure and Attitudes towards Bicycles

Survey participants were asked to rank different bicycle infrastructure elements' importance according to their own opinions, with five options: *very important*, *somewhat important*, *neutral*, *somewhat not important*, and *not at all important*. Likert values were applied to these options, with *very important* assigned a score of 5 and *not at all important* assigned a score of 1. Table 4.7 below shows the mean scores for participants' attitudes towards bicycle infrastructure.

Both on-street painted bicycle lanes and separate bicycle lanes received scores higher than 4, which shows that these infrastructure elements received a higher score among participants who stated *somewhat important* as the original statement. Therefore, participants thought that on-street painted bicycle lanes and separate bicycle lanes were the most important elements among all the survey's bicycle infrastructure elements. Off-street bicycle lanes (multi-use trails), cycling network connectivity, bicycle lane signage, and designated signals for bicycle lanes received mean scores between 3.9 and 4—only slightly lower scores than the two on-street bicycle lanes' scores. Secure bicycle parking, bike shares availability, and bicycle repair stations received scores between 3.6 and 3.8. These values show that participants considered these elements less important than the other bicycle infrastructure included in the survey. However, these scores nonetheless exceeded 3.5, skewing slightly toward the *somewhat important* category.

Overall, participants assigned all bicycle infrastructure elements a higher-than-neutral score. This result was unsurprising because active transportation and movement have been actively promoted in the Region by the regional government (Region of Waterloo, 2019). More participants considered bicycle infrastructure essential because they currently used bicycles or might consider using bicycles in the future. The mean score tables' Cronbach's alpha (reliability statistics testing) was 0.775, which indicates that the data may be considered reliable (Glen, 2020).

Table 4.7. Mean scores for participants' attitudes towards bicycle infrastructure

Bicycle infrastructure elements	**Mean**	**Standard deviation**
On-street painted bicycle lanes	4.19	0.818
Separate bicycle lanes	4.07	1.017
Off-street bicycle lanes (multi-use trails)	3.95	1.11
Cycling network connectivity	3.98	1.103
Bicycle lane signage and designated traffic signals for bicycle lanes	3.9	1.019
Secure bicycle parking	3.76	1.03
Bike-share availability	3.69	1.077
Bicycle repair stations	3.6	1.096
Cronbach's alpha (reliability statistics)	**0.775**	

Figure 4.4 Participants' household incomes and attitudes towards designated bicycle signage and traffic signals

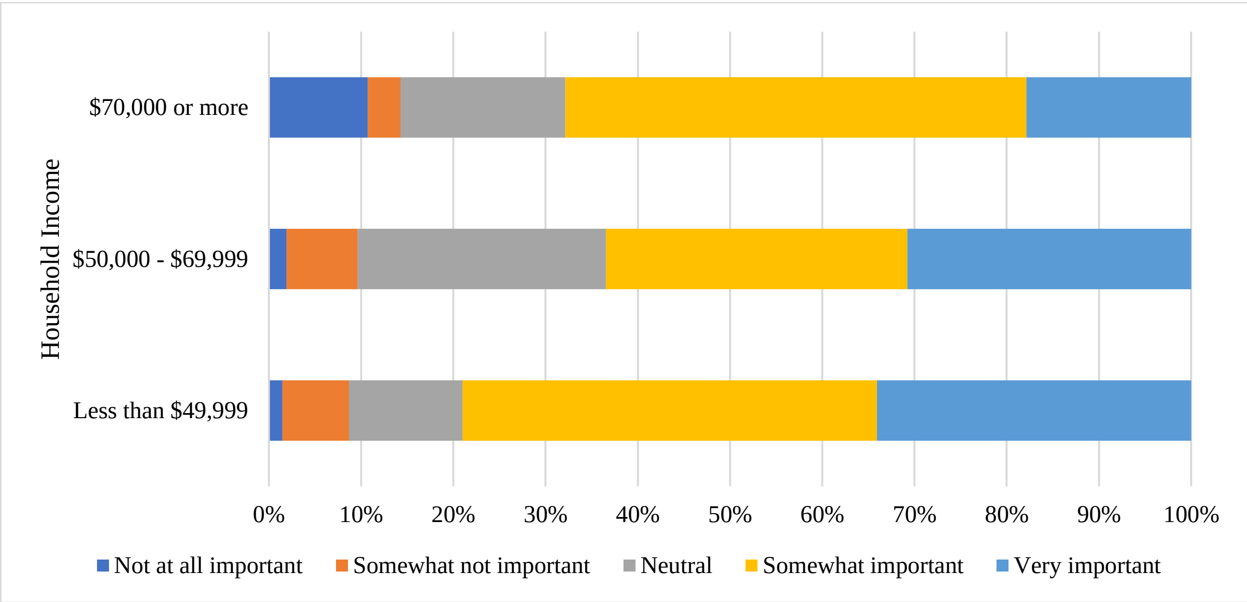


Figure 4.4 depicts a cross-tabulation between participants' household incomes and attitudes toward different bicycle infrastructures in ($p < 0.05$). Participants with low household incomes (less than $49,999 per year) reflected a higher proportion of *somewhat important* and *very important* ratings for designated bicycle signage and dedicated traffic signals compared to the other participant groups. However, the high-income group ($70,000 or more per year) included a higher proportion of the participants who valued bicycle infrastructure as *not at all important* or *somewhat not important*. Similar results were also found in participants' attitudes towards bicycle repair stations, bike-share availability, and secure bicycle parking (see the figures in Appendix A). Although the high-income group has a higher bicycle ownership, the participants in the group valued the bicycle infrastructure less. On contrary, the result showed that low-income group that has lower bicycle ownership valued bicycle infrastructure more, this result leads to bicycle affordability, and bicycle and bicycle infrastructure accessibility issues.

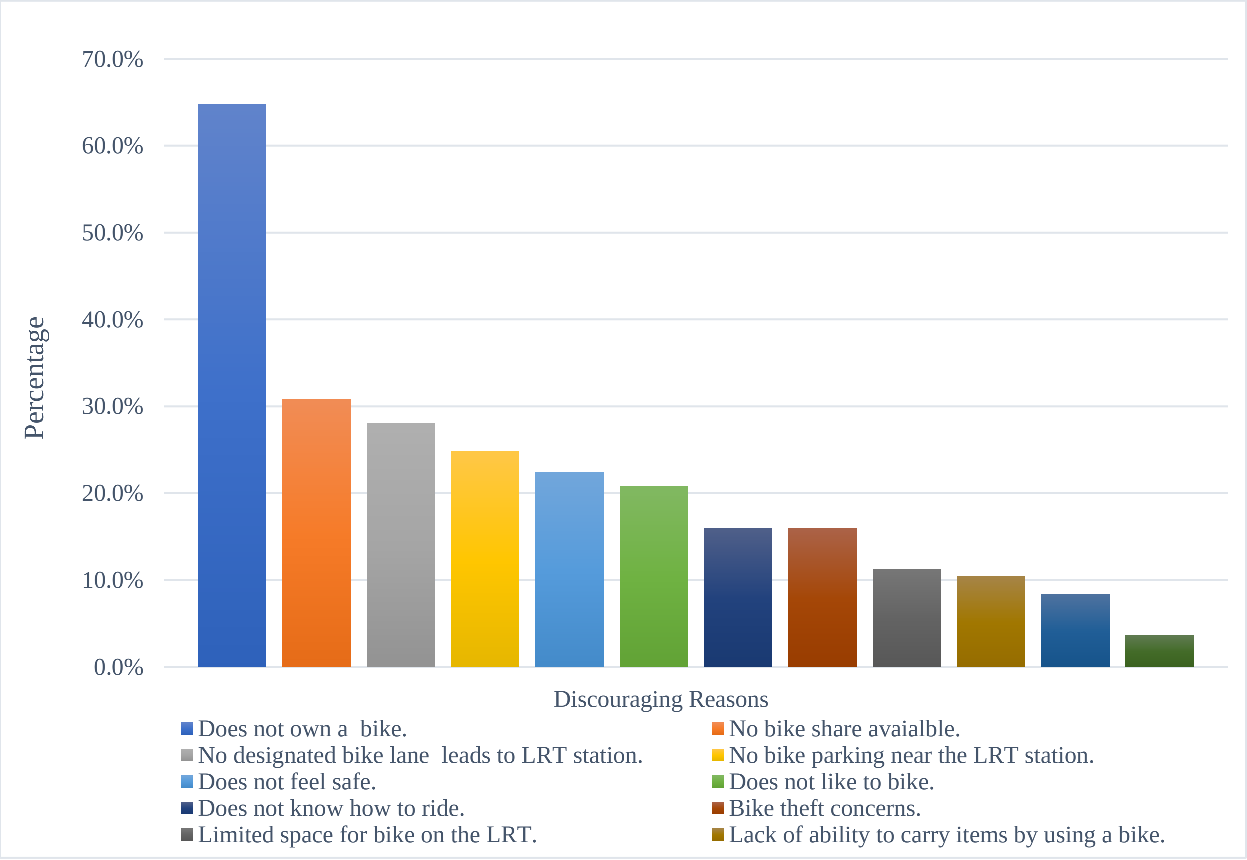
4.2 Potential Future Use of Bicycles as a Feeder Mode of Transportation to Access Light Rail Transit Stations

Question 14 in this study's survey used a multiple response format to ask participants why they felt discouraged from using bicycles as a feeder mode of transportation to access LRT stations. Figure 4.5 below shows the frequency of reasons that participants identified in response to this question. Of the study's 250 participants, 64.8% selected "*I do not own a bicycle*" as one discouraging factor.

Besides not owning a bicycle, participants also stated that they had no bike shares available near their home (30.8%), no nearby designated bicycle lanes leading to LRT stations (28%), no bicycle parking near LRT stations (24.8%), and not feeling safe cycling on the road (22.4%) as some factors that discouraged them from using bicycles as a feeder mode of transportation to access LRT stations. All of these reasons were related to a lack of bicycle infrastructure that would provide a safe, reliable cycling environment.

Participants also indicated road conditions and limited space on LRT vehicles as reasons that discouraged them from using bicycles as a feeder mode of transportation to access LRT stations. The LRT vehicle currently used by the ION LRT includes four areas featuring bicycle decals (one bicycle per person per area) designated for people who carry their bicycles onto LRT vehicles (Grand River Transit, 2020). These designated areas also serve as priority seating areas for people with disabilities, older adults and people with mobility difficulties. Most participants used LRT for work or school purposes, which may have discouraged them from using bicycles or carrying bicycles onto trains during rush hours because of crowding.

Figure 4.5 Reasons for participants' discouragement from using bicycles to access light rail transit stations



Question 15 in this study's survey used a multiple-response format to ask participants to provide different potential reasons for their encouragement to use bicycles as a feeder mode of transportation to access LRT stations. This question asked them to select one or more reasons that would encourage them to use bicycles as a feeder mode for this purpose in the future. Figure 4.6 below illustrates the responses to this question. Of the survey's 250 validated participants, nearly half (49.2%) selected "*more protected bicycle lanes or painted bicycle lanes that lead to LRT stations*" as a potential factor that could encourage them to use a bicycle for this purpose. Many participants also stated that a better cycling network around LRT stations (41.6%), additional bicycle parking at LRT stations (36%), and bike-share services' expansion (30.8%)

would encourage them to use bicycles as a feeder mode of transportation to access LRT stations. Notably, 27.1% of participants stated that they would like to take bicycle learning and cycling safety programs provided by the municipal governments. Only 13.6% of participants reported thinking that programs that helped increase automobile drivers' awareness of sharing the road with cyclists would encourage them to use bicycles.

Figure 4.6 Reasons for participants' encouragement to use bicycles to access light rail transit stations

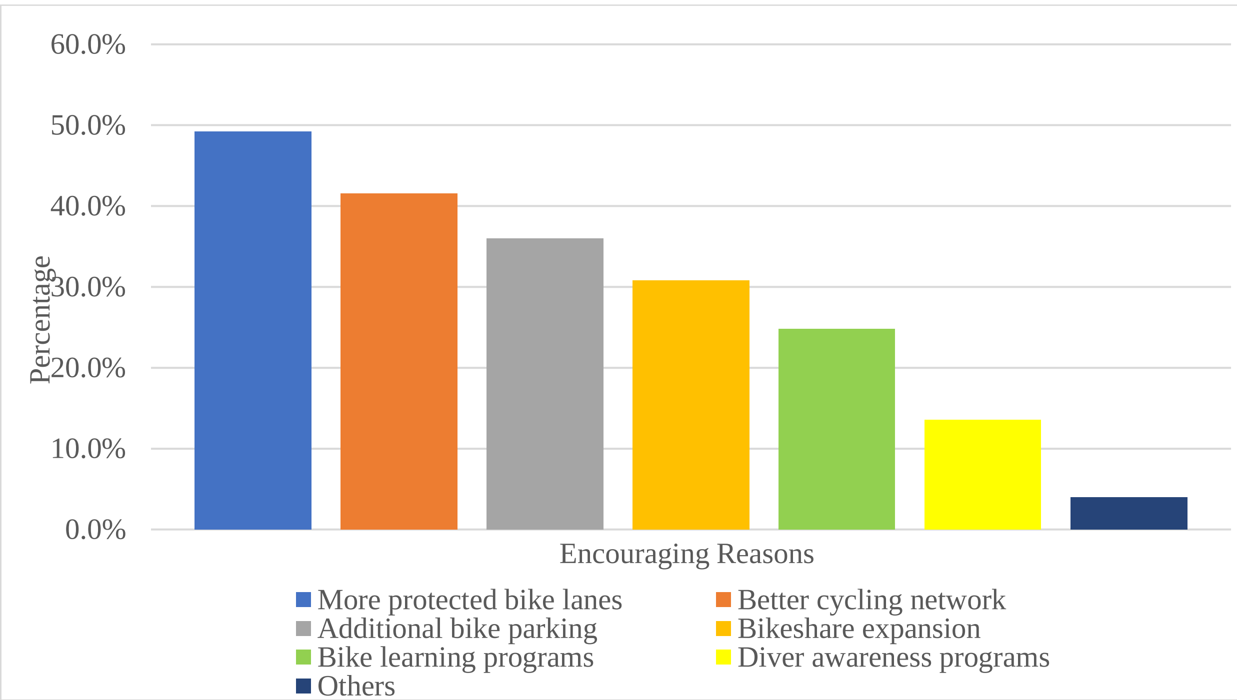


Table 4.8 ($p < 0.01$) compares the reasons cited as discouraging by bicycle owners and non-bicycle owners. This comparison clearly illustrates the difference between these two groups. Participating bicycle owners were more likely discouraged for practical reasons after they began owning a bicycle, such as bicycle theft concerns, limited space on LRT vehicles, and road conditions. Besides not owning a bicycle, non-bicycle owners tended to cite discouraging factors, such as a lack of bike shares available around their homes. Many non-bicycle owners

also stated that no nearby designated bicycle lane was connected to LRT stations and that they worried about not having enough bicycle parking at LRT stations. Some participating non-bicycle owners stated that they did not like to bicycle; however, some stated that they did not know how to bicycle. Both groups included similar numbers of participants who felt unsafe bicycling on roads.

Table 4.8 Cross-tabulation: participants' bicycle ownership and reasons discouraging bicycle use to access light rail transit stations

	Discouraging Reasons				
	Don't know how to ride	Don't like to bike	No bikeshare available	No designated bike lane to LRT	No bike parking at LRT
Bicycle Owners (*n* = 88)	12.5%	11.4%	26.1%	33.0%	29.5%
Non-bicycle owners (*n* = 162)	17.9%	25.9%	33.3%	25.3%	22.2%
	Discouraging Reasons				
	Don't feel safe bike on the road	Lack of ability to carry items by bikes	Bike theft concerns	Limit space on LRT	Road Condition
Bicycle Owners (*n* = 88)	30.7%	17.0%	30.7%	25.0%	14.8%
Non-bicycle owners (*n* = 162)	17.9%	6.8%	8.0%	3.7%	4.9%

Table 4.9 ($p < 0.01$) shows that, among the elements noted in this study's survey that would encourage bicycle owners to use bicycles as a feeder mode of transportation to access or egress

LRT stations, more protected bicycle lanes and a better cycling network were the two most-chosen elements. Non-bicycle owners chose more protected bicycle lanes the most among the available encouraging reasons. Besides additional bicycle parking, this group also chose bike-share expansions and a better cycling network. Lastly, local-government bicycle learning programs were also chosen as a potential encouraging reason.

Table 4.9 Cross-tabulation: participants' reasons encouraging bicycle use to access light rail transit stations by bicycle ownership status

	Encouraging reasons					
	Bike share expansi on	More protected bicycle lanes	Additional bicycle parking	Better cycling network	Bicycling learning program	Driver awareness program
Bicycle owners (*n* = 88)	22.7%	45.5%	31.8%	47.7%	22.7%	14.8%
Non-bicycle owners (*n* = 162)	35.2%	51.2%	38.3%	38.3%	25.9%	13.0%

Question 17 of this study's survey asked participants whether they were willing to use bicycles as a feeder mode of transportation in the future as the local government continued to implement additional bicycle infrastructure in the region, providing a better cycling environment. Figure 4.8 illustrated the survey's results about such future potential bicycle use. Of participants, 85.3% (*n* = 225) stated that they were willing to try using bicycles for this purpose, and 14.7% stated that they would continue to use the same feeder mode they were currently using for this purpose.

Figure 4.7 Participants' willingness to use bicycles as a feeder mode of transportation in the future

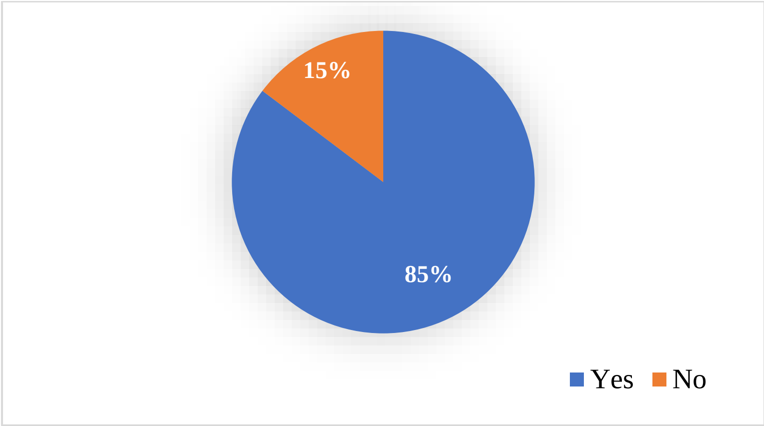


Table 4.9 presents a cross-tabulation between participants' potential use of bicycles as a feeder mode of transportation to access or egress LRT stations and the encouraging reasons cited for this use. The participants who expressed an intention toward such use chose more protected bicycle lanes, a better cycling network, and additional parking near LRT stations as their top-three encouraging factors among the survey's six options.

Table 4.10 Participants' potential future use of bicycles as a feeder mode of transportation to access or egress LRT stations and the reasons encouraging this use.

		Encouraging reasons					
		Bike share expansion	More protected bicycle lane	Additional bicycle parking	Better cycling network	Bicycling learning program	Driver awareness program
Future potential use	No	4	11	6	13	4	6
	Yes	67	99	75	81	51	27

Table 4.9 presents selected results of a cross-tabulation analysis between participants' future use of bicycles as a feeder mode of transportation to access LRT stations, their current travel

behaviours, and their frequency bicycle use for different purposes. As the table shows, no strong association was observed between this potential future use and the distance between participants' homes and LRT stations ($p = 0.072$).

The survey's Question 18 asked participants to provide feedback about their reasons for their response to Question 17. A total 53 participants provided comments in response to this question. Participants who expressed wanting to try using bicycles as a feeder mode of transportation to access or egress LRT stations in the future provided the following quotations:

- "Would try if the weather is nice."
- "If there are more protected bicycle lanes."
- "If there are programs teaching adult biking."
- "If bike prices go down after the pandemic or bike shares expand to the nearby location."
- "Better cycling infrastructure near Fairway Road."
- "Environmentally friendly and good for health."
- "The new bike lane around my neighbourhood can let me bike to more places now."

Some participants who stated that they would continue using the same feeder mode of transportation to access or egress LRT stations in the future stated:

- "I live a close distance from ION."
- "I live in Cambridge, which is too far to bike to ION."
- "It is uncomfortable to hold bikes on ION."
- "I don't like cycling."
- "I do not use bike shares."

4.3 Binary Logit Regression Analysis

4.3.1 Binary Logistic Modelling Calibration

Before conducting a modelling calibration, the researcher conducted a correlation analysis between Q17 and the other survey questions to simplify the modelling process. Table 4.10 shows the results of this correlation analysis. Questions that correlated with Q17 at a 0.1 significance level or a 0.05 significance level were used in the binary regression.

As Table 3.2 in Chapter 3 shows, the first step in this process was performing a binary logit regression with all identified independent variables and dependent variables, using SPSS. A correlation analysis was then completed, which provided individual significance levels between the independent variables and dependent variables. Then, once the correlation analysis was completed, only questions with a significance level of $p < 0.1$ were chosen for a second run. The same procedures were conducted for the third and fourth runs of this analysis, with different significance levels. In the fifth run, the researcher used only sociodemographic variables to conduct a regression analysis. The sixth run only used travel behaviour variables to conduct a regression analysis model. Lastly, the seventh run was based on the fourth run (all variables had a significant association with dependent variable Y and $p < 0.01$) to further eliminate variables from the variable set until all the regression variables stood at $p < 0.1$.

During the different runs, Hosmer and Lemeshow tests were used to determine whether the model was correctly specified. In general, if a $p < 0.05$ after running a test, the model is biased and should be rejected (Glen, 2020). All the testing models for these tests had higher p-values, which meant that the model was less likely to be biased. The values of the 2-log likelihood and Nagelkerke R-squared tests were noted under the model summary in Table 4.10 and were compared to determine which model best fit the data. The Nagelkerke R-squared test indicates approximately how well the model fit the logistic regression analysis dataset—unlike the R-squared test in the linear regression analysis—which could explain the proportion of variance in the dependent variables explained by the predictors. A higher value for the Nagelkerke R-squared test indicates a better model, while the 2-log likelihood would be smaller (UCLA, 2011; Long, 1997). Among the logit models, the first benchmark model had the lowest 2 log likelihood and the highest Nagelkerke R-squared values. This result was unsurprising, since it suggests that all the identified factors influenced participants' future decisions to use bicycles as a feeder mode of transportation to access or egress LRT stations.

Table 4.11 Binary logit model calibration

Model number	Number of independent variables included	Included independent variables	Model summary		Hosmer and Lemeshow Test		
			2 Log Likelihood	Nagelkerke R-Squared	Chi-Square	df	*p*-value
1	23	All	75.719	0.603	2.121	8	0.977
2	11	Q1, Q6, Q7, Q8, Q11, Q12, Q13-1, Q13-3, Q16-5, Q16-7, Q16-8	97.136	0.466	2.796	8	0.947
3	10	Q1, Q6, Q7, Q8, Q11, Q13-1, Q13-3, Q16-5, Q16-7, Q16-8	97.235	0.465	2.721	8	0.951
4	9	Q1, Q6, Q7, Q8, Q13-1, Q13-3, Q16-5, Q16-7, Q16-8	97.252	0.465	3.557	8	0.895
5	7	Q1–Q6, Q11	155.039	0.216	3.659	8	0.887
6	4	Q7–Q10	165.986	0.162	11.474	8	0.176
7	5	Q1, Q8, Q13-1, Q16-5, Q16-7	115.734	0.352	4.453	8	0.816

4.3.2 Results of the First Binary Logit Model

As discussed in Section 3.6, when dependent variables have only two outcomes, binary logistic regression analysis may be used in regression analysis (Tranmer & Elliot, 2008). Table 4.11 shows the binary logistic regression analysis results between the dependent variable and all the independent variables. Some influencing factors affected LRT riders' decisions to potentially use bicycles as a feeder mode of transportation to access LRT stations. At a significance level of

0.01, the frequency of using LRT services positively affected the participants' potential to use bicycles for this purpose. Participants were 5.2 times more likely to use bicycles for this purpose if they increased their frequency of LRT use by one level; the more frequently riders used LRT services, the greater their likelihood of using bicycles as their feeder mode of transportation to access LRT stations. Based on the participant' opinions on on-street bicycle lanes, separated bicycle lanes, bicycle signage, cycling network connectivity, and designated bicycle traffic signals and the relationship associated with the likelihood of future usage. The more important participants thought such bicycle infrastructure was, the more likely they would use bicycles as their feeder mode of transportation to access or egress the LRT stations. For example, participants who thought bicycle parking at LRT stations was *very important* were 6.4 times more likely to use bicycles as their feeder mode of transportation to access or egress LRT stations, compared to participants who chose *somewhat important* for this element. Surprisingly, separate bicycle lanes and on-street painted bicycle lanes were not the most influential bicycle infrastructure elements. Other significant factors ($p < 0.05$) included location. Unsurprisingly, compared to participants who lived outside of KW, the participants who lived in the City of Kitchener were more likely to use bicycles as their feeder mode of transportation to LRT. Participants who lived outside of the KW had to rely on automobile or bus services to be able to access LRT stations from home due to the long distance of travel compared to the participants who lived in the City of Kitchener. Further, the current cycling network connection between KW and the surrounding areas is limited. Lastly, some independent variables may have affected participating riders' decisions ($p < 0.1$), such as household income, bicycle ownership, and bicycle usage frequency for recreational or exercise purposes.

Table 4.12 Results of the First Binary Logit Model

Variables	B	S.E.	Wald	df	Sig.	Exp(B)
X_1			6.750	2	**0.034****	
X_1(1)	-1.727	1.114	2.401	1	**0.013****	0.178
X_1(2)	-4.207	1.647	6.526	1	**0.011****	0.015
X_2	0.188	0.660	0.081	1	0.776	1.207
X_3			1.630	2	0.443	
X_3(1)	0.890	0.757	1.383	1	0.240	2.434
X_3(2)	1.205	1.641	0.539	1	0.463	3.336
X_4			2.557	2	0.278	
X_4(1)	0.843	1.115	0.572	1	0.450	2.324
X_4(2)	-1.475	1.693	0.759	1	0.384	0.229
X_5			0.912	2	0.634	
X_5(1)	-0.626	1.402	0.199	1	0.655	0.535
X_5(2)	0.323	1.691	0.036	1	0.849	1.381
X_6	-0.978	0.573	2.919	1	**0.088***	0.376
X_7			2.567	2	0.277	
X_7(1)	-1.320	0.950	1.932	1	0.165	0.267
X_7(2)	-1.435	1.427	1.011	1	0.315	0.238
X_8	1.646	0.547	9.065	1	**0.003*****	5.184
X_9			1.862	2	0.394	
X_9(1)	-0.270	1.148	0.055	1	0.814	0.763
X_9(2)	-1.431	1.193	1.439	1	0.230	0.239
X_{10}			0.040	2	0.980	
X_{10}(1)	-0.057	1.187	0.002	1	0.962	0.944
X_{10}(2)	0.121	1.092	0.012	1	0.911	1.129
X_{11}	0.117	0.737	0.025	1	0.874	1.124
X_{12}(1)	1.504	0.893	2.839	1	**0.092***	4.502
X_{13}	-0.805	0.972	0.686	1	0.407	0.447
X_{14}	1.646	0.996	2.732	1	**0.098***	5.186
X_{15}	-0.272	0.874	0.097	1	0.756	0.762

X_{16}	0.016	0.414	0.002	1	**0.009*** **	1.016
X_{17}	0.011	0.481	0.001	1	**0.001*** **	0.989
X_{18}	0.048	0.450	0.012	1	0.914	1.050
X_{19}	1.572	0.565	7.745	1	**0.005*** **	0.208
X_{20}	1.857	0.619	8.999	1	**0.003*** **	6.407
X_{21}	0.280	0.368	0.579	1	0.447	1.323
X_{22}	1.477	0.557	7.016	1	**0.008*** **	4.378
X_{23}	-0.201	0.374	0.289	1	0.591	0.818
Constant	-2.991	3.239	0.853	1	0.356	0.050

*** Significance level less than 1%.

** Significance level less than 5%.

* Significance level less than 10%.

Y is the dependent variable.

Model's percentage estimated correctly: 89.1%.

4.3.3 Backward Method Implications

Although the first binary logit model had the best fit among all the tested models, notably, the seventh model used a backward method to eliminate one least significant variable at a time until all variables were significant after running the model. Table 4.12 shows that the model included only X_1 (location), X_8 (frequency of using LRT), X_{13} (frequency of using bicycles for work or school), X_{20} (opinion on bicycle signage), and X_{22} (opinion on bike share availability). The results of the regression were all significant at $p < 0.1$. These five variables can, therefore, be understood to have a stronger impact compared to other variables on participants' decisions for whether to use bicycles as a feeder mode of transportation to access or egress LRT stations in the future.

This model's results showed that current LRT riders who used LRT more frequently were more likely to try using bicycles as a feeder mode of transportation to access or egress LRT stations in the future, while riders who used bicycles frequently for work or school purposes were less likely to consider switching their current mode choices. Moreover, LRT riders who considered bicycle signage and availability of bike shares to be essential were more likely to try using bicycles as a feeder mode to access or egress LRT stations in the future.

Table 4.12 Binary logit model results using backward method

	B	S.E.	Wald	df	Sig.	Exp(B)
X_1			10.215	2	0.006	
$X_1(1)$	-0.862	0.586	2.167	1	0.014	0.422
$X_1(2)$	-2.615	0.822	10.128	1	0.001	0.073
X_8	0.889	0.268	10.964	1	0.001	2.432
X_{13}	-0.894	0.515	3.008	1	0.083	0.409
X_{20}	0.396	0.233	2.886	1	0.089	1.487
X_{22}	0.655	0.242	7.298	1	0.007	1.925
Constant	-1.213	0.821	2.179	1	0.140	0.297

Chapter 5: Discussion

This chapter comprises two sections, beginning with a discussion of the quantitative analysis findings from Chapter 4 and how they align with the academic literature reviewed in Chapter 2. This first section is followed by a discussion of the extraneous findings of the current research, this study's limitations, and future research opportunities.

5.1 Findings

5.1.1 Key Findings on Participating Current Riders' Sociodemographic Characteristics

This study's survey participants were mostly between 18 and 39 years of age. Male riders slightly outnumbered female riders among the study's participants. Most of the participating riders had obtained a post-secondary diploma or degree, and more than half of the participants lived with a parent (or parents) or roommate (or roommates) and had household gross incomes lower than $69,999 per year. Moreover, most of the survey's participants used LRT services for work or school purposes. More than half of the participants had used LRT more than three times a week before the pandemic. A large proportion of participants lived within a 3-kilometre range of LRT stations. The current LRT riders who participated in this study were less likely to use automobiles and most likely to use buses as a feeder mode of transportation to access and egress LRT stations. Male LRT riders were shown to be more likely to use bicycles to access LRT stations than female riders, but male riders were less likely to walk to LRT stations than their female counterparts. Only a minor gender difference was observed in the participants' use of buses or automobiles.

Survey participants were also asked to state the distances between their homes and LRT stations. A majority of 98.4% of participants stated that they lived within a 5-kilometre catchment area, which has been noted as suitable for bicycle use as an access mode to transit stations (Griffin & Sener, 2016; Djurhuus et al., 2014; Zuo & Wei, 2019; Wu et al., 2019; Bracher, 2000; Rietveld, 2000; Hochmair, 2015). This finding is also consistent with the corresponding 3.8-kilometre results from surveys in the City of Kitchener's "Cycling and Trails Master Plan" (2020). Therefore, this study indicates great potential for bicycle use as a feeder mode to access LRT stations and replace other modes of transportation in the KW region.

5.1.2 Bicycle Ownership and Frequency

Among this study's survey participants, only 35% had bicycles in their household, and average weekly bicycle usage remained low. Most participants used bicycles once a week or less. Both bicycle owners and non-bicycle owners in this study indicated that bicycle infrastructure was important. Female respondents were more likely to own bicycles in their households and to cycle for recreational, exercise, or other purposes once or more every week. Younger adults, between 18 and 39 years of age were shown to be more likely to own a bicycle in their household and to cycle once a week or more for all kinds of surveyed activities, compared to adults over 40 years old. The results can serve as an opportunity to promote the flexibility of the bicycle as a feeder mode to access or egress LRT stations for younger adults who already own a bicycle in the household. The overall ownership and usages of bicycle is low, the convenience of using automobile and the car culture is still dominating in KW and many participants are still using bicycle for recreational purposes. The overall bicycle infrastructure implementations in KW are still not effectively encourage participants to use bicycle more frequent.

5.1.3 Attitudes and Preferences for Bicycle Infrastructure

Among the many reasons that discouraged survey participants from using bicycles in KW in general, more than 60% of survey participants mentioned “not owning a bicycle,” followed by “no bike shares available,” showing the importance of bike share in promoting the use of bicycles as a mode of transportation, among other options. Further, “bike-share expansion” also received a higher vote compared to other bike infrastructures from respondents as a reason encouraging future bicycle use. Bike shares provide an alternative for people who do not own a bicycle themselves. The results actively demonstrate the demand for more bike share from the participants. Moreover, bike shares can benefit urban areas, where they can serve as a feeder mode for commuters’ first and last trip miles (DeMaio & Gifford, 2004; DeMaio, 2009).

Survey participants identified a lack of designated bicycle lanes leading to LRT stations and not feeling safe cycling on roads due to a lack of bicycle infrastructure. However, survey participants also stated that building more protected bicycle lanes and a better cycling network would encourage them to use bicycles. These findings align with the academic literature on attitudes toward bicycle infrastructure. Researchers have found that a higher level of on-street cycling infrastructure, such as protected or separate bicycle lanes, is preferred specifically for accessing transit stations (Dill et al., 2015; Taylor & Hahmassani, 1996; Griffin & Sener, 2016), and have suggested that bicycle lanes should be designed for people with different experiences of cycling. Providing safe and exclusive bicycle parking sites at transit stations would also contribute to a higher rate of bicycle–transit trips (La Paix & Geurs, 2015; Krizek & Stonebraker, 2010). Additionally, continuous bicycle paths connecting bike-share stations with various destinations and transit stops are essential in promoting bicycle–transit integration (Zuo & Wei, 2019).

The study also found that participants with lower income ($49,999 or less) valued bicycle infrastructure more compared to participants with higher income where social inequity issues can be one of the factors. The result is similar to the study that was conducted by Braun et al. (2017) in 22 cities in the United States where lower income group has less access to bicycle infrastructure.

5.1.4 Future Use of Bicycles as a Feeder Mode of Transportation

This study also aimed to understand the impact of bicycle infrastructure's impact on LRT riders' decisions about using bicycles as a feeder mode of transportation. Regarding this research objective, an integration of the survey results revealed that improving bicycle infrastructure in KW would increase riders' likelihood of using bicycles as a feeder mode of transportation to access or egress LRT stations.

Survey participants stated that they would use bicycles as a feeder mode of transportation more than the local governments continued implementing additional bicycle infrastructure, which would positively influence people to consider using bicycles as a transportation mode. These findings align with the academic literature on bicycle infrastructure's impact on people's higher probability of cycling (Griffin & Sener, 2016; Akar & Cliford, 2009; Duthie et al., 2010; Iseki & Tingstorm, 2014). Dill et al. (2015) stated that respondents of both genders preferred higher levels of on-street cycling infrastructure—such as protected or separate bicycle lanes—for general transportation, specifically for accessing transit stations (Taylor & Hahmassani, 1996; Griffin & Sener, 2016). La Paix & Geurs (2015) suggested that providing safe and exclusive bicycle parking sites at transit stations would also contribute to higher bicycle–transit trip rates (Krizek & Stonebraker, 2010).

This study's first binary logit regression analysis showed that riders who were frequent LRT riders were more likely to use bicycles as a feeder mode to access or egress LRT stations in the future. Participants' opinions on on-street bicycle lanes, separated bicycle lanes, bicycle signage, cycling network connectivity, bicycle parking, and designated bicycle traffic signals would affect their likelihood of using bicycles as a feeder mode of transportation in the future. The more important they thought these bicycle infrastructure elements were in affecting their decisions to use bicycles for this purpose, the more likely they were to use bicycles if these bicycle infrastructures satisfied their needs.

The study's second binary logit regression analysis using a backward method showed slightly different results compared to the first analysis results. The regression analysis revealed that the frequency of bicycle use for work or school purposes negatively affected the likelihood of using bicycles as a feeder mode of transportation in the future. The likelihood of using bicycles as a feeder mode of transportation also increased according to participants' assigned importance to bicycle traffic signage and bike share availability, while the significance of other bicycle infrastructures in the first binomial regression analysis was not found. Surprisingly, the regression analysis results did not show that separate bicycle lanes and on-street painted bicycle lanes were the most often chosen by participants in their frequency results, since they were identified in the literature review and the City of Kitchener's "Cycling and Trails Master Plan" (2020). This result is due to the different methods of inputting the data into the regression analysis, since the second regression analysis used the backward method. The backward method can over-simplification the real models of the data, where some significant results could be eliminated due to the stepwise elimination in the regression (Roecker, 1991). The Waterloo Region implemented many temporally separate bicycle lanes on high-traffic volume arterial roads in summer 2020 to provide social-distancing options for cyclists (CTV News, 2020). This project's pilot studies aimed to gather feedback from cyclists and motorists to discuss the potential of permanent separate bicycle lanes on these roads.

These findings show that besides implementing more separate bicycle lanes and on-street painted bicycle lanes, other bicycle infrastructure elements—such as bicycle traffic signage, bike share availability, and better bicycle route network connectivity—would also play an essential role in affecting current LRT riders' future likelihood of considering bicycle use as a feeder mode of transportation.

5.2 Additional Implications

5.2.1 Limitations

While the researcher attempted to obtain data that could represent the whole population of KW's LRT riders, some limitations affected this study's data collection process. These limitations may have resulted in sampling bias and affected the precision of the results.

First, due to the COVID-19 pandemic, the project's original plan to recruit participants randomly on the street near LRT stations was cancelled due to social-distancing measures and new rules prohibiting face-to-face recruitment during the pandemic posted by the University of Waterloo Research Ethics Committee (University of Waterloo, 2020). The researcher had to move the study's recruitment process online, using social media through a Facebook group. Because of this recruitment via social media, many LRT riders who did not use Facebook or did not join the Facebook group may not have been reached, such as older adult riders. Inclusion of older adult participants in the study may result in a lower overall percentage of willingness to use bikes as a feeder mode in the future than the study result. Also, many students may not have been reached due to closures of universities and colleges during the pandemic and the transition to online classes (University of Waterloo, 2020; Wilfred Laurier University, 2020). In this research, due to the COVID-19 restriction where participants were not able to be recruited randomly on the street but was recruited online through the Facebook group "I support light rail transit in Waterloo Region" where the group's members already have an interest in public transit discussion, and they are more likely to use public transit for their commutes. This may result a selections bias for the total sampling population and the results of the study since people who do not use Facebook, who did not join the group or has limited access to the internet were not reached. Therefore, this study's results may not completely accurately reflect all KW LRT riders' travel behaviours and attitudes toward bicycle infrastructure.

Second, the study's survey was sent out at the end of August, asking about respondents' travel behaviour before late March, when various public health measures to curb the pandemic took effect (Government of Canada, 2020; Government of Ontario, 2020). For this reason, participants may have experienced difficulty remembering all the details of their previous travel behaviour accurately. Therefore, discrepancies may have arisen in the participants' responses.

Third, an ideal survey sample size should have a 5% margin of error and a 95% confidence level (Survey Monkey, 2020). The total number of LRT riders was 1,281,000 between July and September, as CBC News (2019) indicated; therefore, given a sample size requirement of 5%, this study's sample size should have exceeded 348. The survey's sample size was 250 due to data collection difficulties during the COVID-19 pandemic; however, the sample size of 250 represented about 10% of the members of the Facebook group "I Support Light Rail Transit in the Region of Waterloo". The overall result may contain a greater margin of error and the potential for a larger random sampling error.

Finally, Question 8 of the survey asked about participants' frequency of LRT service use, but this question should have been specified further and asked about a single trip or a round trip, since respondents may have only used LRT in just one of these ways and used a different mode of transportation for the other. Moreover, the survey only asked respondents whether they were willing to cycle under "fair weather conditions," which respondents may have understood differently. In the study's regression analysis stage, the researcher removed some responses, such as "prefer not to answer" and "others," treating them as missing data due to extremely low responses. These excluded responses may not have accurately reflected the respondents' actual situations.

5.3 Future Studies

Based on the limitations discussed in Section 5.2.2, this study could be improved in future research. A new study could be conducted after the COVID-19 pandemic ends to examine post-pandemic travel behaviour in KW. During the data collection process, such a future study could also reach out to recruit older adults' participation or promote the study via different channels besides social media. During this data collection process, the survey questionnaire could also be refined to investigate more details about participants, such as their time spent on trips and which LRT stations they start and end their trips at, which would allow for a wider range of location analyses, such as bike-share availability, current bicycle infrastructure near chosen stations, and potential GIS mapping analysis. Such a future study's range of survey questions could also extend to cover additional trip characteristics among respondents, such as satisfaction levels and how they occupy their time while using LRT. Further, a refined survey questionnaire could also investigate participants' willingness to cycle under different weather conditions, since weather, as an uncontrollable factor, can significantly affect people's decisions to use bikes as a transportation mode or promote cycling. To better understand respondents' attitudes toward bicycle infrastructure, the survey could include more stated-choice questions under different hypothetical scenarios, and the questions could feature pictures of different infrastructure designs. To obtain a larger sample size, future research could collaborate with GRT or the Waterloo Region to disseminate the survey to potential participants. A future study could also focus on analyzing bicycle–LRT integration programs' economics or feasibility. Such research could determine whether revenue from additional bicycle transit riders would exceed the expense of providing or expanding bike share services. Although this suggested topic focuses more heavily on economics than the current research, such consideration will be important in future cycling infrastructure planning.

Chapter 6: Conclusion and Recommendations

"Chapter 1: Introduction" outlined this study's purpose of understanding current LRT riders' future potential use of bicycles as feeder mode to access or egress LRT stations and the determinants of encouraging such actions by using Kitchener-Waterloo as a case study. The results of the study showed great potential to promote bicycle–LRT integration in KW, and bicycle infrastructure is proven to be one of the major determinants of encouraging such action. This final chapter concludes this thesis, and based on the findings and conclusions, the policy recommendations related to bicycle infrastructure planning, as well as recommendations for municipal planners, are presented.

6.1 Conclusion

Transit accessibility in cities is a topical and urgent issue. This research has filled the gap in the literature surrounding socioeconomic groups and purposes related to LRT use in mid-sized Canadian cities by using Kitchener-Waterloo as a case study. This thesis further contributes to the literature by identifying future research opportunities focusing on bicycle–LRT integration. A web-based survey was distributed via the Facebook group "I Support Light Rail Transit in the Region of Waterloo." This project's descriptive statistical analysis revealed current LRT riders' feeder transportation mode choices, travel behaviour, primary purposes, and different sociodemographic background in KW. Among the bicycle infrastructures discussed, separate bicycle lanes and on-street painted bicycle lanes were the two elements of bicycle infrastructure that received higher mean scores.

Furthermore, the study's binary logit model quantified the identified factors' significance levels. Besides separate bicycle lanes and on-street painted bicycle lanes, other bicycle infrastructure elements—such as bicycle traffic signage and bike shares—were also shown to encourage people to use bicycles as a feeder transportation mode. This study has also shown that the more often people use LRT, the more likely they are to try using bicycles as a feeder mode if bicycle infrastructure satisfies their needs. Moreover, the study’s descriptive statistical analysis results indicated that current LRT riders in KW have an overall positive attitude towards bicycle infrastructure. Based on these research findings, several recommendations were proposed in this chapter, focusing on increasing current LRT riders’ willingness to use bicycles as a feeder mode to access and egress LRT stations in the future.

Overall, this thesis research’s findings were consistent with previous studies examining bicycle infrastructure’s importance in encouraging people to cycle (Wang & Wen, 2017; Schoner & Levinson, 2014; Basch et al., 2018). The lack of bicycle infrastructure, such as bike share, separated bicycle lanes, designated signage, and parking at the current stage, were the reasons that discourage people to use bicycle. People in KW demonstrated a willingness to use bicycles if bicycle infrastructure is implemented and safe environments are provided for travel. As a result, this study identified great potential for current LRT riders and future riders to use bicycles as a feeder mode of transportation to access or egress LRT stations if local governments continue to implement more bicycle infrastructures.

Bicycle–transit integration is an upcoming urban travel mode used in cities across the North America. With proper bicycle infrastructure, the flexibility of bicycle use, and support and promotion from local governments, the future of bicycle and urban rail transportation can create a more efficient and resilient transportation network with less dependency on automobiles and fuel. However, there is a need for an adaptation of policies to the specific circumstances faced by the mid-sized cities.

6.2 Policy and Practice Recommendations

"Chapter 2: Literature Review" showed that, without local government support, implementing bicycle infrastructure would be slow and ineffective. Urban growth, with higher job and population densities and mixed land use, will support more cycling, greater transit ridership, and bicycle access at transit stations (Wang & Wen, 2017; Zuo & Wei, 2019). Municipal planners should fully embrace denser, mixed-use growth that will support more active and public transportation and transit-oriented developments along the LRT corridor. A comprehensive transportation and planning policy would therefore benefit growing cities and regions, such as Kitchener-Waterloo. Planners should play multiple roles in such projects by fulfilling professional duties, providing advice, and advocating for projects that support bicycle–LRT integration.

6.2.1 Bicycle Infrastructure Implementation

This study's survey analysis has shown that bicycle infrastructure is essential in promoting bicycle–LRT integration. Such infrastructure benefits growing regions like KW, and the implementation of infrastructure should follow comprehensive transportation plans and policies. The City of Waterloo is currently seeking public input to update its active transportation plan, which would benefit the city in developing a similar plan to support cycling activities in the city and integrate such initiatives with the "Cycling and Trail Master Plan" from the City of Kitchener (2020), which provides convenient policy support between the two cities.

When considering building a new bicycle infrastructure, local governments should provide more separate bicycle lanes on busy arterial roads or roads has higher speed limits (50km/h or higher), such as Downtown Kitchener, Uptown Waterloo, and University Avenue, where density is high, to create a safe environment for riders. Separate bicycle lanes should be built for people of all ages and abilities to encourage more people to try cycling. Painted bicycle lanes should be used on secondary arterial roads with slower speed limit (40km/h) that currently have low bicycle volumes, and these lanes should be upgraded to separate bicycle lanes once bicycle traffic volume increases, if future budgets permit. Collector roads in the community that can lead people to ride bicycles to the major transit stations should considered to reallocate into shared street which has low speed limit (30km/h), visible shared street painting on the road, signs for directions and traffic calming implementations. Moreover, high-capacity bicycle parking or full-service, staffed bicycle parking should be provided at high-volume LRT stations. Both Kitchener and Waterloo should implement a system across multiple locations to measure performance, such as a bicycle traffic counting board in Uptown Waterloo, to better understand traffic volume and prioritize infrastructure implementation.

In addition, government should integrate equity recommendations from researchers specifically towards the lower income or visible minority community into policy and planning can lead to a greater equity in representation, distribution of resources, and decision-making in promoting cycling. City of Victoria provides a good example that provides more separated bike-lanes in the lower income area so people in those neighbourhoods have a better and safe cycling trip.

6.2.2 Transit Map Integration and Bike Share Expansion

Bicycle infrastructures, such as bicycle parking and bicycle lanes or trail signage, are major factors for encouraging people to use bicycles and must be integrated with not only local landmarks but also local transit systems. The current GRT map only shows bus routes and LRT routes in the Waterloo Region (Grand River Transit, 2021). However, a bicycle-friendly map should be made available online and at stations or stops, showing how the area's cycling network integrates with iExpress Bus stops and ION LRT stations to provide a clear wayfinding solution for riders who choose to use bicycles as feeder mode.

The study's survey analysis has shown that demand exists in the Region for bike share expansion from the previous service area into areas other than KW's central transit corridor. Such expansion would benefit the bike-share system's integration with local transit, such as transit maps' showing where major bike-share parking lots are available and offering an integrated payment system.

6.2.3 Weather and Bicycle Infrastructure Maintenance

Weather is an uncontrollable factor that affects people's decisions to use a bicycle, which was not considered in this research. However, bicycle infrastructure, such as secure bicycle parking with overhead covers, change rooms, or showers for people who bike to LRT stations, can help to ease unattractiveness during rainy days. During the summer months, bicycle use as a feeder mode of transportation offers competitive advantages compared to bus use. Bus services are reduced during the summer due to the summer break from schools and universities. The promotion of bicycle–LRT integration should be encouraged during this time for LRT riders to try to experience the convenience bicycle brings to them. The use of bicycles as a feeder mode of transportation provides more flexibility for people using LRT, who typically use buses instead. In the long run, bicycle use will help reduce overall carbon emissions.

Winter maintenance is a key aspect that encourages people to cycle during the season. In 2019, the Waterloo Region conducted separate bicycle lane projects along University Avenue and Columbia Avenue and hired contractors to remove snow from these bicycle lanes during the winter months (Region of Waterloo, 2020). However, removing snow only partially from the network does not sufficiently provide a safe environment for bicycle use. Local government should be consistent with winter maintenance among all cycling infrastructure while prioritizing high-volume bicycle lanes.

6.2.4 Implementations for other Mid-size Cities

Most Canadian cities are mid-sized defined by Winters et al. (2018) as cities with populations of 50,000 to 500,000 people. The common issues among Canadian mid-sized cities are having fewer resources for active transportation and less complete infrastructure (Flatt & Sotomayor, 2016) compared to large cities such as Toronto, Vancouver, and Montreal. However, in recent years, many mid-sized cities have been making bold investment into active transportation (Winters, et al., 2018). Different cities have its own unique situation such as typography, weather pattern, active transportation culture, and finance where the recommendation for KW in this research does not fit all. Kitchener-Waterloo is unique since there are three major post-secondary institutions locate in the cities. The University of Waterloo and Wilfred Laurier University locate in the City of Waterloo and Conestoga College locates in the City of Kitchener which created a higher proportion of young adults that are living in the area compared to other mid-sized Canadian cities. In the survey data, there are 30% of the participants are in the age group of 18 to 24 where young adults are more willing to adapt changes towards a more sustainable living and transportation modes such as using bicycles and public transit. The overall representation of student populations also affects the municipal policies and plan to provides better and more sustainable access to the campus. On the other hands, the other mid-sized Canadian cities that do not have a major post-secondary institution are typically having a higher proportion for older age groups where cities must adapt different strategies when they promote cycling and public transit integration. Local municipal governments must base on their own situation to decide what kind of bicycle infrastructure will fit the best to their communities. For example, if the local municipal government only have a small amount of budget to implement bicycle infrastructure in part of the community. The local planners should consult with local community members from different social backgrounds to make the appropriate decisions. If the budget is not able to support a permanent bicycle lane and future maintenance, a pilot-study could be implemented to see how local community members react to the project and make necessary changes after. Local municipality should also apply for federal funding and leverage funding with the provincial government.

Many mid-sized cities have higher automobile ownership where planners will encounter some push back from the automobile communities about lower speed, narrow lanes and inconvenient turns or access to buildings. Planners needs to find the right balance or an alternative solution between motorized and non motorized transportation modes sharing the road. Planners should also consider the socio-demographic background of the local community members that low-income group and visible minority group have a chance to provide their opinions since many lower income community members relies on public transportation and active transportation to access their workplace.

From the studies of Fischer and Winters (2021) study of three different mid-sized Canadian cities on street reallocation implementation during the COVID-19 pandemic, Halifax reallocate the most of its streets into shared streets to support mobility, recreation, and help local business to survive through the pandemic. Victoria on the other hand already has a more completed cycling network compared to Halifax where it reallocated less street in length and focus on reallocation in downtown core area. Both cities have a more successful results compare to Kelowna. Many mid-sized Canadian cities that do not have many bicycles infrastructure exists can learn from the strategies Halifax used during COVID-19 pandemic and implement those into local context during the summer season as a pilot study.

6.2.5 COVID-19 Impacts

Notably, COVID-19 has changed mobility patterns in cities around the world, including Kitchener and Waterloo (City of Kitchener, 2020). During the summer of 2020, bicycles had sold out due to social-distancing measures and gym closures that were recommended by health authorities (CTV News, 2020; Government of Canada, 2020; Government of Ontario, 2020), and cycling had become a safer transportation mode that also satisfied people's physical activity needs. The pandemic has, therefore, created opportunities for the rapid implementation of cycling and trail infrastructure projects for Kitchener-Waterloo.

References

Andersson, D.E., Shyr, O.F. & Lee, A. (2012). The successes and failures of a key transportation link: accessibility effects of Taiwan's high-speed rail. *Ann Reg Sci 48*, 203–223. https://doi.org/10.1007/s00168-010-0405-5

Andrey, J., Mills, B., Leahy, M., & Suggett, J. (2003). Weather as a chronic hazard for road transportation in Canadian cities. Natural Hazards, 28(2–3), 319–343. https://doi.org/10.1023/A:1022934225431

Ahmed, F., Rose, G., & Jakob, C. (2013). Commuter cyclist travel behavior. *Transportation Research Record*, *2387*, 76–82. https://doi.org/10.3141/2387-09

Ajzen, I. (2012). The theory of planned behavior. *Handbook of Theories of Social Psychology: Volume 1* (pp. 438–459). https://doi.org/10.4135/9781446249215.n22

Aldred, R., & Jungnickel, K. (2014). Why culture matters for transport policy: The case of cycling in the UK. *Journal of Transport Geography, 34,* 78–87.

Alvanides, S. (2014). Active transport: Why and where do people (not) walk or cycle? *Journal of Transport and Health*, *1*(4), 211–213. https://doi.org/10.1016/j.jth.2014.11.002

APTA. (2009). Bicycle and transit integration: A practical transit agency guide to bicycle integration and equitable mobility. https://www.apta.com/wp-content/uploads/Standards_Documents/APTA-SUDS-UD-RP-009-18.pdf

Asensio, J. (2002). Transport mode choice by commuters to Barcelona's CBD. *Urban Studies*, *39*(10), 1881–1895. https://doi.org/10.1080/0042098022000003000

Assunçao-Denis, M. È., & Tomalty, R. (2019). Increasing cycling for transportation in Canadian communities: Understanding what works. *Transportation Research Part A: Policy and Practice*, *123*(xxxx), 288–304. https://doi.org/10.1016/j.tra.2018.11.010

Bachand-Marleau, J., Larsen, J., & El-Geneidy, A. M. (2011). Much-anticipated marriage of cycling and transit: How will it work? *Transportation Research Record*, *2247*, 109–117. https://doi.org/10.3141/2247-13

Badoe, D. A., & Miller, E. J. (2000). Transportation-land-use interaction: Empirical findings in North America, and their implications for modeling. *Transportation Research Part D: Transport and Environment*, *5*(4), 235–263. https://doi.org/10.1016/S1361-9209(99)00036-X

Bagloee, S. A., Sarvi, M., & Wallace, M. (2016). Bicycle lane priority: Promoting bicycle as a green mode even in congested urban area. *Transportation Research Part A: Policy and Practice*, *87*, 102–121. https://doi.org/10.1016/j.tra.2016.03.004

Basch, C. H., Ethan, D., & Basch, C. E. (2019). Bike lane obstructions in Manhattan, New York City: Implications for bicyclist safety. *Journal of Community Health*, *44*(2), 396–399. https://doi.org/10.1007/s10900-018-00596-4

Ben-Elia, E., & Ettema, D. (2011). Rewarding rush-hour avoidance: A study of commuters' travel behavior. *Transportation Research Part A: Policy and Practice*, *45*(7), 567–582. https://doi.org/10.1016/j.tra.2011.03.003

Berridge, G. (2012). The promotion of cycling in London: The impact of the 2007 Tour de France Grand Depart on the image and provision of cycling in the capital. *Journal of Sport and Tourism*, *17*(1), 43–61. https://doi.org/10.1080/14775085.2011.635018

Biernat, E., Buchholtz, S., & Bartkiewicz, P. (2018). Motivations and barriers to bicycle commuting: Lessons from Poland. *Transportation Research Part F: Traffic Psychology and Behaviour*, *55*, 492–502. https://doi.org/10.1016/j.trf.2018.03.024

Bike Share Toronto, (2020). *How it works*. https://bikesharetoronto.com/#

Blanchet, G., Legendre, P. & Borcard, D. (2016). Forward selection of explanatory variables *Ecology 89*(9), 2623–2632. Wiley. http://www.jstor.org/stable/27650800

Blondiau, T., Van Zeebroeck, B., & Haubold, H. (2016). Economic benefits of increased cycling. *Transportation Research Procedia*, *14*, 2306–2313. https://doi.org/10.1016/j.trpro.2016.05.247

Bopp, M., Gayah, V. V., & Campbell, M. E. (2015). Examining the link between public transit use and active commuting. *International Journal of Environmental Research and Public Health*, *12*(4), 4256–4274. https://doi.org/10.3390/ijerph120404256

Bracher, T. (2000). Demand characteristics and co-operation strategies for the bicycle and railway transport chain. *World Transportation. Policy Practice. 6*(3), 18–24 (2000)

Broach, J., Dill, J., & Gliebe, J. (2012). Where do cyclists ride? A route choice model developed with revealed preference GPS data. *Transportation Research Part A: Policy and Practice*, *46*(10), 1730–1740. https://doi.org/10.1016/j.tra.2012.07.005

Buehler, R. (2012). Determinants of bicycle commuting in the Washington, DC region: The role of bicycle parking, cyclist showers, and free car parking at work. *Transportation Research Part D: Transport and Environment*, *17*(7), 525–531. https://doi.org/10.1016/j.trd.2012.06.003

Buehler, R., & Hamre, A. (2015). The multimodal majority? Driving, walking, cycling, and public transportation use among American adults. *Transportation*, *42*(6), 1081–1101. https://doi.org/10.1007/s11116-014-9556-z

Bunting, T. E., & Filion, P. (1999). Dispersed city form in Canada: A kitchener CMA case example. *Canadian Geographer, 43(3)*, 268–287. https://doi.org/10.1111/j.1541-0064.1999.tb01385.x

Bunting, T., Filion, P., Hoernig, H., Seasons, M., & Lederer, J. (2007). Density, size, dispersion: Towards understanding the structural dynamics of mid-size cities. *Canadian Journal of Urban Research, 16(2)*, 27–52.

Burke, C. M., & Scott, D. M. (2018). Identifying “sensible locations” for separated bike lanes on a congested urban road network: A Toronto case study. *Professional Geographer*, *70*(4), 541–551. https://doi.org/10.1080/00330124.2018.1455518

Bussière, Y. D., Torres, I. E., Collomb, J. L., & Ravalet, E. (2010). Cycling in the city, reduction of greenhouse gas emissions and economic impact on tourism: Case study of Puebla, Mexico. *WIT Transactions on Ecology and the Environment*, *142*, 779–790. https://doi.org/10.2495/SW100701

Cai, W., Li, Y., & Shao, X. (2008). A variable selection method based on uninformative variable elimination for multivariate calibration of near-infrared spectra. *Chemometrics and Intelligent Laboratory Systems*, *90*(2), 188–194. https://doi.org/10.1016/j.chemolab.2007.10.001

Calgary Transit. (2005). Calgary’s CTrain–Effective capital utilization. http://www.calgarytransit.com/pdf/calgary_ctrain_effective_capital_utilization_TRB_paper.pdf

Cao, J., & Cao, X. (2014). The impacts of LRT, neighbourhood characteristics, and self-selection on auto ownership: Evidence from Minneapolis-St. Paul. *Urban Studies*, *51*(10), 2068–2087. https://doi.org/10.1177/0042098013505887

Cao, J., & Ermagun, A. (2017). Influences of LRT on travel behaviour: A retrospective study on movers in Minneapolis. *Urban Studies*, *54*(11), 2504–2520. https://doi.org/10.1177/0042098016651569

Caulfield, B. (2014). Re-cycling a city - Examining the growth of cycling in Dublin. *Transportation Research Part A: Policy and Practice, 61*, 216–226. https://doi.org/10.1016/j.tra.2014.02.010

Caulfield, B., Brick, E., & McCarthy, O. T. (2012). Determining bicycle infrastructure preferences - A case study of Dublin. *Transportation Research Part D: Transport and Environment*, *17*(5), 413–417. https://doi.org/10.1016/j.trd.2012.04.001

CBC News, (2019). More than 1 million boardings on ION trains since launch: Report. https://www.cbc.ca/news/canada/kitchener-waterloo/ion-train-boarding-numbers-report-1.5324341

Cervero, R. (1984). Journal report: Light rail transit and urban development. *Journal of the American Planning Association*, *50*(2), 133-147.

Cervero, R. (2002). Built environments and mode choice: Toward a normative framework. *Transportation Research Part D: Transport and Environment*, *7*(4), 265–284. https://doi.org/10.1016/S1361-9209(01)00024-4

Cervero, R. (2004). *Transit-oriented development in the United States: experiences, challenges, and prospects* . Transportation Research Board.

Cervero, R., Sarmiento, O. L., Jacoby, E., Gomez, L. F., & Neiman, A. (2009). Influences of built environments on walking and cycling: Lessons from Bogotá. *International Journal of Sustainable Transportation*, *3*(4), 203–226. https://doi.org/10.1080/15568310802178314

Chan, K., & Farber, S. (2020). Factors underlying the connections between active transportation and public transit at commuter rail in the Greater Toronto and Hamilton Area. *Transportation*, *47*(5), 2157–2178. https://doi.org/10.1007/s11116-019-10006-w

Chen, C. F., & Chen, P. C. (2013). Estimating recreational cyclists' preferences for bicycle routes - Evidence from Taiwan. *Transport Policy*, *26*, 23–30. https://doi.org/10.1016/j.tranpol.2012.01.001

Chen, J., Li, Z., Wang, W., & Jiang, H. (2018). Evaluating bicycle–vehicle conflicts and delays on urban streets with bike lane and on-street parking. *Transportation Letters*, *10*(1), 1–11. https://doi.org/10.1080/19427867.2016.1207365

Chen, L., Pel, A., Chen, X., Sparing, D., & Hansen, I. (2012). Determinants of bicycle transfer demand at metro stations analysis of stations in Nanjing, China. *Transportation Research Record*, *2276*(2276), 131–137. https://doi.org/10.3141/2276-16

Cheng, Y. H., & Liu, K. C. (2012). Evaluating bicycle-transit users' perceptions of intermodal inconvenience. *Transportation Research Part A: Policy and Practice*, *46*(10), 1690–1706. https://doi.org/10.1016/j.tra.2012.10.013

Chiu, W., & Leng, H. K. (2017). Let's go cycling: an analysis of tourists' experience on online user-generated content. *International Journal of Tourism Cities*, *3*(1), 30–42. https://doi.org/10.1108/IJTC-10-2016-0045

Christiansen, L. B., Madsen, T., Schipperijn, J., Ersbøll, A. K., & Troelsen, J. (2014). Variations in active transport behavior among different neighborhoods and across adult life stages. *Journal of Transport and Health*, *1*(4), 316–325. https://doi.org/10.1016/j.jth.2014.10.002

Ciesla, K., Krukowicz, T., & Firlag, K. (2018). Analysis of cyclists' behaviour on different infrastructure elements. *MATEC Web of Conferences, 231*, 1–8. https://doi.org/10.1051/matecconf/201823103001

City of Kitchener, (2014). *City of Kitchener official plan*. https://www.kitchener.ca/en/building-and-development/official-plan.aspx#City-of-Kitchener-Official-Plan-A-Complete--Healthy-Kitchener-2014

City of Kitchener, (2020). *Bikeway types*. https://www.kitchener.ca/en/getting-around/bikeway-types.aspx#Bike-Boxes

City of Kitchener (2020). *Secure bike parking*. https://www.kitchener.ca/en/getting-around/secure-bike-parking.aspx#Current-locations-of-secure-bicycle-parking

City of Kitchener, (2020). *Bike fix-it stations*. https://www.kitchener.ca/en/getting-around/bike-fix-it-stations.aspx

City of Kitchener, (2020). *Cycling and trails master plan*. https://www.kitchener.ca/en/resourcesGeneral/Documents/DSD_TRANSPORT_CTMP_Draft_Plan_Summary_Report.pdf

City of Toronto (2020). Bloor street bike lanes. https://www.toronto.ca/services-payments/streets-parking-transportation/cycling-in-toronto/cycle-track-projects/bloor-street-bike-lanes/

City of Vancouver (2017). *Transportation Design guidelines: all ages and abilities cycling routes*. https://vancouver.ca/files/cov/design-guidelines-for-all-ages-and-abilities-cycling-routes.pdf

City of Waterloo, (2011). *Transportation master plan*. https://www.waterloo.ca/en/government/resources/Documents/Cityadministration/TransportationMasterPlan/Transportation-Master-Plan---PDF-Version.pdf

City of Waterloo, (2012). *City of Waterloo official plan*. https://www.waterloo.ca/en/government/resources/Documents/Cityadministration/Official-plan/2020/City-of-Waterloo-Official-Plan-Office-Consolidation.pdf

City of Waterloo, (2019). *City of Waterloo 2019-2022 Strategic Plan*. https://www.waterloo.ca/en/government/resources/Documents/Cityadministration/Strategic-plans/City-of-Waterloo-2019-2022-Strategic-Plan-Report-CAO2019-004.pdf

City of Waterloo, (2020). *Cycling*. https://www.waterloo.ca/en/living/cycling.aspx#

Cole-Hunter, T., Donaire-Gonzalez, D., Curto, A., Ambros, A., Valentin, A., Garcia-Aymerich, J., Martínez, D., Braun, L. M., Mendez, M., Jerrett, M., Rodriguez, D., de Nazelle, A., & Nieuwenhuijsen, M. (2015). Objective correlates and determinants of bicycle commuting propensity in an urban environment. *Transportation Research Part D: Transport and Environment*, *40*(2), 132–143. https://doi.org/10.1016/j.trd.2015.07.004

Collins, S. E., Witkiewitz, K., & Larimer, M. E. (2011). The theory of planned behavior as a predictor of growth in risky college drinking. *Journal of Studies on Alcohol and Drugs*, *72*(2), 322–332. https://doi.org/10.15288/jsad.2011.72.322

Conn, K. M., Mo, C. H., & Sellers, L. M. (2019). When less is more in boosting survey response rates*. *Social Science Quarterly*, *100*(4), 1445–1458. https://doi.org/10.1111/ssqu.12625

Creemers, L., Cools, M., Tormans, H., Lateur, P. J., Janssens, D., & Wets, G. (2012). Identifying the determinants of light rail mode choice for medium-and long-distance trips. *Transportation Research Record*, *2275*, 30–38. https://doi.org/10.3141/2275-04

CTV News, (2020). ‘There is nothing left to sell’: Canada faces bike shortage amid COVID-19 pandemic. https://toronto.ctvnews.ca/there-is-nothing-left-to-sell-canada-faces-bike-shortage-amid-covid-19-pandemic-1.5060304

CTV News, (2020). Temporary bike lines installed during COVID-19 pandemic is coming to an end. https://kitchener.ctvnews.ca/temporary-bike-lines-installed-during-covid-19-pandemic-coming-to-an-end-1.5129046

Cui, B., Boisjoly, G., Miranda-Moreno, L., & El-Geneidy, A. (2020). Accessibility matters: Exploring the determinants of public transport mode share across income groups in Canadian cities. *Transportation Research Part D: Transport and Environment, 80*(July 2019), 102276. https://doi.org/10.1016/j.trd.2020.102276

Cui, Y., Mishra, S., & Welch, T. F. (2014). Land use effects on bicycle ridership: A framework for state planning agencies. *Journal of Transport Geography*, *41*, 220–228. https://doi.org/10.1016/j.jtrangeo.2014.10.004

Currie, G., Ahern, A., & Delbosc, A. (2011). Exploring the drivers of light rail ridership: An empirical route level analysis of selected Australian, North American and European systems. *Transportation*, *38*(3), 545–560. https://doi.org/10.1007/s11116-010-9314-9

Daley, M., & Rissel, C. (2011). Perspectives and images of cycling as a barrier or facilitator of cycling. *Transport Policy*, *18*(1), 211–216. https://doi.org/10.1016/j.tranpol.2010.08.004

Daisy, N. S., Liu, L., & Millward, H. (2020). Trip chaining propensity and tour mode choice of out-of-home workers: evidence from a mid-sized Canadian city. *Transportation, 47(2),* 763–792. https://doi.org/10.1007/s11116-018-9915-2

Dayton RTA Link (2020). *Pricing*. https://www.linkdayton.org/

de Sousa, A. A., Sanches, S. P., & Ferreira, M. A. G. (2014). Perception of barriers for the use of bicycles. *Procedia - Social and Behavioral Sciences*, *160*(Cit), 304–313. https://doi.org/10.1016/j.sbspro.2014.12.142

Deenihan, G., & Caulfield, B. (2015). Do tourists value different levels of cycling infrastructure? *Tourism Management*, *46*(April 2010), 92–101. https://doi.org/10.1016/j.tourman.2014.06.012

Deenihan, G., & Caulfield, B. (2014). Estimating the health economic benefits of cycling. *Journal of Transport and Health*, *1*(2), 141–149. https://doi.org/10.1016/j.jth.2014.02.001

Delbosc, A., McDonald, N., Stokes, G., Lucas, K., Circella, G., & Lee, Y. (2019). Millennials in cities: Comparing travel behaviour trends across six case study regions. *Cities*, *90*(January), 1–14. https://doi.org/10.1016/j.cities.2019.01.023

Delmelle, D. (2012). Exploring spatio-temporal commuting patterns in a university environment. *Transport Policy, 21*, 1–9. https://doi.org/10.1016/j.tranpol.2011.12.007

Deschaintres, E., Morency, C., & Trépanier, M. (2019). Analyzing transit user behavior with 51 weeks of smart card data. *Transportation Research Record*, *2673*(6), 33–45. https://doi.org/10.1177/0361198119834917

DeShazo, J. R., & Fermo, G. (2002). Designing choice sets for stated preference methods: The effects of complexity on choice consistency. *Journal of Environmental Economics and Management*, *44*(1), 123–143. https://doi.org/10.1006/jeem.2001.1199

DiGioia, J., Watkins, K. E., Xu, Y., Rodgers, M., & Guensler, R. (2017). Safety impacts of bicycle infrastructure: A critical review. *Journal of Safety Research*, *61*, 105–119. https://doi.org/10.1016/j.jsr.2017.02.015

Dijst, M., Böcker, L., & Kwan, M. P. (2013). Exposure to weather and implications for travel behaviour: introducing empirical evidence from Europe and Canada. *Journal of Transport Geography, 28*, 164–166. https://doi.org/10.1016/j.jtrangeo.2013.01.004

Dill, J., Monsere, C. M., & McNeil, N. (2012). Evaluation of bike boxes at signalized intersections. *Accident Analysis and Prevention*, *44*(1), 126–134. https://doi.org/10.1016/j.aap.2010.10.030

Djurhuus, S., Hansen, H. S., Aadahl, M., & Glümer, C. (2014). The association between access to public transportation and self-reported active commuting. *International Journal of Environmental Research and Public Health*, *11*(12), 12632–12651. https://doi.org/10.3390/ijerph111212632

Domencich, T., & McFadden, D. (1975). *Urban travel demand: A behavioral analysis: A Charles River Associates research study*. North-Holland Pub. Co.

Donald, I. J., Cooper, S. R., & Conchie, S. M. (2014). An extended theory of planned behaviour model of the psychological factors affecting commuters' transport mode use. *Journal of Environmental Psychology*, *40*, 39–48. https://doi.org/10.1016/j.jenvp.2014.03.003

Downward, P., & Lumsdon, L. (2001). The development of recreational cycle routes: An evaluation of user needs. *Managing Leisure*, *6*(1), 50–60. https://doi.org/10.1080/13606710010026368

Drop Mobility, (2019). Drop mobility partners with Region of Waterloo and Cities of Kitchener, Cambridge, and Waterloo to launch a new bike share program. https://www.dropmobility.com/press/2019/5/10/drop-mobility-partners-with-the-region-of-waterloo-and-cities-of-kitchener-cambridge-and-waterloo-to-launch-a-new-bike-share-program

Duany, A., Speck, J., & Lydon, M. (2010). *The smart growth manual*. New York, NY: McGraw-Hill.

Ellison, R. B., & Greaves, S. (2011). Travel time competitiveness of cycling in Sydney, Australia. *Transportation Research Record*, *2247*, 99–108. https://doi.org/10.3141/2247-12

Farthing, S. (2016). *Research Design in Urban Planning: A Student's Guide*. SAGE Publications.

Félix, R., Moura, F., & Clifton, K. J. (2019). Maturing urban cycling: Comparing barriers and motivators to bicycle of cyclists and non-cyclists in Lisbon, Portugal. *Journal of Transport and Health*, *15*(September), 100628. https://doi.org/10.1016/j.jth.2019.100628

Fernández Pierna, J. A., Abbas, O., Baeten, V., & Dardenne, P. (2009). A backward variable selection method for PLS regression (BVSPLS). *Analytica Chimica Acta*, *642*(1–2), 89–93. https://doi.org/10.1016/j.aca.2008.12.002

Fernández-Heredia, Á., Monzón, A., & Jara-Díaz, S. (2014). Understanding cyclists' perceptions, keys for a successful bicycle promotion. *Transportation Research Part A: Policy and Practice*, *63*, 1–11. https://doi.org/10.1016/j.tra.2014.02.013

Filion, P., & Bunting, T. (2004). Distinctions between middle-size and large cities: Growth level, urban form and transportation. Plan Canada, 44(3), 18–21.

Firth, C. L., Hosford, K., & Winters, M. (2021). Who were these bike lanes built for? Social-spatial inequities in Vancouver's bikeways, 2001–2016. *Journal of Transport Geography, 94*(April), 103122. https://doi.org/10.1016/j.jtrangeo.2021.103122

Fischer, J., & Winters, M. (2021). COVID-19 street reallocation in mid-sized Canadian cities: socio-spatial equity patterns. Canadian Journal of Public Health, 112(3), 376–390. https://doi.org/10.17269/s41997-020-00467-3

Fishman, E. (2016). Bikeshare: A review of recent literature. *Transport Reviews*, *36*(1), 92–113. https://doi.org/10.1080/01441647.2015.1033036

Fishman, E., Washington, S., & Haworth, N. (2012). Barriers and facilitators to public bicycle scheme use: A qualitative approach. *Transportation Research Part F: Traffic Psychology and Behaviour*, *15*(6), 686–698. https://doi.org/10.1016/j.trf.2012.08.002

Fishman, E., Washington, S., & Haworth, N. (2013). Bike Share: A Synthesis of the Literature. *Transport Reviews*, *33*(2), 148–165. https://doi.org/10.1080/01441647.2013.775612

Flynn, B. S., Dana, G. S., Sears, J., & Aultman-Hall, L. (2012). Weather factor impacts on commuting to work by bicycle. *Preventive Medicine, 54*(2), 122–124. https://doi.org/10.1016/j.ypmed.2011.11.002

Fu, X., & Juan, Z. (2017). Understanding public transit use behavior: integration of the theory of planned behavior and the customer satisfaction theory. *Transportation*, *44*(5), 1021–1042. https://doi.org/10.1007/s11116-016-9692-8

Gajic, A., Cameron, D., & Hurley, J. (2012). The cost-effectiveness of cash versus lottery incentives for a web-based, stated-preference community survey. *European Journal of Health Economics*, *13*(6), 789–799. https://doi.org/10.1007/s10198-011-0332-0

Gao, J., Helbich, M., Dijst, M., & Kamphuis, C. B. M. (2017). Socioeconomic and demographic differences in walking and cycling in the Netherlands: How do these translate into differences in health benefits? *Journal of Transport and Health*, *6*(May), 358–365. https://doi.org/10.1016/j.jth.2017.06.001

Gatersleben, A. (2007). Contemplating cycling to work: Attitudes and perceptions in different stages of change. *Transportation Research. Part A, Policy and Practice, 41*(4), 302–312. https://doi.org/10.1016/j.tra.2006.09.002

Gideon, L. (2012). Handbook of survey methodology for the social sciences. *Handbook of Survey Methodology for the Social Sciences*, 1–520. https://doi.org/10.1007/978-1-4614-3876-2

Givoni, M., & Banister, D. (2010). *Integrated transport: from policy to practice*. Routledge.

Givoni, R. (2007). The access journey to the railway station and its role in passengers' satisfaction with rail travel. *Transport Policy, 14*(5), 357–365. https://doi.org/10.1016/j.tranpol.2007.04.004

Glen, S. (2020). *Chi-Square Statistic: How to Calculate It/Distribution*. https://www.statisticshowto.com/probability-and-statistics/chi-square/

Glen, S. (2020). *Cronbach's Alpha: Simple Definition, Use and Interpretation*. https://www.statisticshowto.com/probability-and-statistics/statistics-definitions/cronbachs-alpha-spss/

Gonzaga, F. B., Braga, L. R., Sampaio, A. P., Martins, T. S., de Oliveira, C. G., & Pacheco, R. M. S. (2017). A simple method for forward variable selection and calibration: evaluation for compact and low-cost laser-induced breakdown spectroscopy system. *Analytical and Bioanalytical Chemistry*, *409*(11), 3017–3024. https://doi.org/10.1007/s00216-017-0247-4

González, R. M., Román, C., & Marrero, Á. S. (2018). Visitors' attitudes towards bicycle use in the Teide National Park. *Sustainability (Switzerland)*, *10*(9), 1–18. https://doi.org/10.3390/su10093283

Goritz, A. (2006). Incentives in web studies: Methodological issues and a review. *International Journal of Internet Science*, *1*(1).

Government of Canada (2020). *Coronavirus Disease (COVID-19): Prevention and Risks*. https://www.canada.ca/en/public-health/services/diseases/2019-novel-coronavirus-infection/prevention-risks.html#

Government of Ontario (2020). *COVID-19 public health measures and restrictions*. https://covid-19.ontario.ca/zones-and-restrictions

Government of Ontario (2020). *A place to grow: growth plan for the Greater Golden Horseshoe*. https://www.ontario.ca/document/place-grow-growth-plan-greater-golden-horseshoe

Gössling, S. (2013). Urban transport transitions: Copenhagen, city of cyclists. *Journal of Transport Geography*, *33*, 196-206.

Grand River Transit (2019). *Bus Service Changes for ION Launch*. https://www.grt.ca/en/about-grt/bus-service-changes-ion.aspx#:~:text=Big%20changes%20are%20coming%20to,bus%20stops%20will%20be%20removed.

Grand River Transit, (2020). *Flexible Transit*. https://www.grt.ca/en/schedules-maps/flexible-transit.aspx

Grand River Transit, (2020). *Bikes, e-bikes, e-scooters, and other personal vehicles*. https://www.grt.ca/en/rider-information/cycling.aspx

Grand River Transit, (2021). *System maps*. https://www.grt.ca/en/schedules-maps/system-map.aspx

Gray, B. (2019). *Richmond Street and Adelaide Street Cycle Tracks*. 32. http://app.toronto.ca/tmmis/viewAgendaItemHistory.do?item=2015.PW6.12

Grid (2020). *Find a bike*. http://gridbikes.com/

Griffin, G. P., & Sener, I. N. (2016). Planning for bike share connectivity to rail transit. *Journal of Public Transportation*, *19*(2), 1–22. https://doi.org/10.5038/2375-0901.19.2.1

Guo, Y., Yang, L., Huang, W., & Guo, Y. (2020). Traffic safety perception, attitude, and feeder mode choice of metro commute: Evidence from Shenzhen. *International Journal of Environmental Research and Public Health*, *17*(24), 1–20. https://doi.org/10.3390/ijerph17249402

Ha, J., Lee, S., & Ko, J. (2020). Unraveling the impact of travel time, cost, and transit burdens on commute mode choice for different income and age groups. *Transportation Research Part A: Policy and Practice*, *141*(July), 147–166. https://doi.org/10.1016/j.tra.2020.07.020

Habib, K. N., Mann, J., Mahmoud, M., & Weiss, A. (2014). Synopsis of bicycle demand in the City of Toronto: Investigating the effects of perception, consciousness and comfortability on the purpose of biking and bike ownership. *Transportation Research Part A: Policy and Practice*, *70*, 67–80. https://doi.org/10.1016/j.tra.2014.09.012

Han, H., Meng, B., & Kim, W. (2017). Bike-traveling as a growing phenomenon: Role of attributes, value, satisfaction, desire, and gender in developing loyalty. *Tourism Management*, *59*, 91–103. https://doi.org/10.1016/j.tourman.2016.07.013

Han, H., Meng, B., & Kim, W. (2017). Emerging bicycle tourism and the theory of planned behavior. *Journal of Sustainable Tourism 25*(2), 292–309. https://doi.org/10.1080/09669582.2016.1202955

Hatfield, J., Poulos, R. G., Rissel, C., Flack, L. K., Grzebieta, R., McIntosh, A. S., & Murphy, S. (2018). Factors associated with cyclists' self-reported choice of lane position. *Transportation Research Part F: Traffic Psychology and Behaviour*, *55*, 403–414. https://doi.org/10.1016/j.trf.2018.03.016

Haworth, N., & Schramm, A. (2011). How do level of experience, purpose for riding, and preference for facilities affect location of riding? Study of adult bicycle riders in Queensland, Australia. *Transportation Research Record*, *2247*, 17–23. https://doi.org/10.3141/2247-03

Heerwegh, D. (2006). An Investigation of the Effect of Lotteries on Web Survey Response Rates. *Field Methods*, *18*(2), 205–220. https://doi.org/10.1177/1525822X05285781

Heesch, K. C., Giles-Corti, B., & Turrell, G. (2015). Cycling for transport and recreation: Associations with the socio-economic, natural and built environment. *Health and Place*, *36*, 152–161. https://doi.org/10.1016/j.healthplace.2015.10.004

Heesch, K. C., Giles-Corti, B., & Turrell, G. (2014). Cycling for transport and recreation: Associations with socio-economic position, environmental perceptions, and psychological disposition. *Preventive Medicine*, *63*, 29–35. https://doi.org/10.1016/j.ypmed.2014.03.003

Heinen, E. (2011). *Bicycle commuting*. IOS Press/Delft University Press.

Heinen, E., Maat, K., & Van Wee, B. (2011). The role of attitudes toward characteristics of bicycle commuting on the choice to cycle to work over various distances. *Transportation*

Research Part D: Transport and Environment, *16*(2), 102–109. https://doi.org/10.1016/j.trd.2010.08.010

Hensher, D., & Stopher, P. (1978). Behavioural travel modelling. Croom Helm.

Hensher, D. (1999). A bus-based transitway or light rail? Continuing the saga on choice versus blind commitment. *Road & Transport Research, 8*(3), 3–.

Hernandez, M., Eldridge, R., & Lukacs, K. (2018). Public transit and bikesharing. In *Public Transit and Bikesharing*. https://doi.org/10.17226/25088

Ho, C.Q., Mulley, C., Hensher, D.A., (2020). Public preferences for mobility as a service: Insights from stated preference surveys. *Transportation Research. Part A, Policy and Practice, 131*, 70–90. https://doi.org/10.1016/j.tra.2019.09.031

Hochmair, H. (2015). Assessment of bicycle service areas around transit stations. *International Journal of Sustainable Transportation, 9*(1), 15–29. https://doi.org/10.1080/15568318.2012.719998

Hong, J., Philip McArthur, D., & Stewart, J. L. (2020). Can providing safe cycling infrastructure encourage people to cycle more when it rains? The use of crowdsourced cycling data (Strava). *Transportation Research Part A: Policy and Practice*, *133*(August 2019), 109–121. https://doi.org/10.1016/j.tra.2020.01.008

Hough, G., & Hassanien, A. (2010). Transport choice behaviour of Chinese and Australian tourists in Scotland. *Research in Transportation Economics*, *26*(1), 54–65. https://doi.org/10.1016/j.retrec.2009.10.008

Hunt, J. D., & Abraham, J. E. (2007). Influences on bicycle use. *Transportation*, *34*(4), 453–470. https://doi.org/10.1007/s11116-006-9109-1

Hunter, W., Srinivasan, R., Thomas, L., Martell, C., & Seiderman, C. (2011). Evaluation of shared lane markings in Cambridge, Massachusetts. *Transportation Research Record*, *2247*, 72–80. https://doi.org/10.3141/2247-09

JALION (2003), “TALVIPYÖRÄILY LAAJUUS MOTIIVIT JA ESTEET TERVEYSVAIKUTUKSET” (In Suomi/Finnish). *JALION*. https://docplayer.fi/7216725-Talvipyoraily-laajuus-motiivit-ja-esteet-terveysvaikutukset.html

Ji, Y., Fan, Y., Ermagun, A., Cao, X., Wang, W., & Das, K. (2017). Public bicycle as a feeder mode to rail transit in China: The role of gender, age, income, trip purpose, and bicycle theft experience. *International Journal of Sustainable Transportation*, *11*(4), 308–317. https://doi.org/10.1080/15568318.2016.1253802

Johnson, T. P., & Wislar, J. S. (2012). Response rates and nonresponse errors in surveys. *JAMA - Journal of the American Medical Association*, *307*(17), 1805–1806. https://doi.org/10.1001/jama.2012.3532

Kager, R., Bertolini, L., & Te Brömmelstroet, M. (2016). Characterisation of and reflections on the synergy of bicycles and public transport. *Transportation Research Part A: Policy and Practice*, *85*, 208–219. https://doi.org/10.1016/j.tra.2016.01.015

KALAŠOVÁ, A., & KRCHOVÁ, Z. (2011). The possibility of solving cycling transport in central urban areas. *Transport Problems: An International Scientific Journal*, *6*(2), 21–26. http://eds.a.ebscohost.com/eds/results?sid=738d6cc9-0491-46d6-8754-9d5d1fedfbc4@sessionmgr4003&vid=1&hid=4111&bquery=transport+rowerowy&bdata=JmNsaTA9RlQxJmNsdjA9WSZsYW5nPXBsJnR5cGU9MCZzaXRlPWVkcy1saXZlJnNjb3BlPXNpdGU=

Kamruzzaman, M., Shatu, F. M., Hine, J., & Turrell, G. (2015). Commuting mode choice in transit-oriented development: Disentangling the effects of competitive neighbourhoods, travel attitudes, and self-selection. *Transport Policy*, *42*, 187–196. https://doi.org/10.1016/j.tranpol.2015.06.003

Kaplan, S., Manca, F., Nielsen, T. A. S., & Prato, C. G. (2015). Intentions to use bike-sharing for holiday cycling: An application of the theory of planned behavior. *Tourism Management*, *47*, 34–46. https://doi.org/10.1016/j.tourman.2014.08.017

Kerr, J., Emond, J. A., Badland, H., Reis, R., Sarmiento, O., Carlson, J., Sallis, J. F., Cerin, E., Cain, K., Conway, T., Schofield, G., Macfarlane, D. J., Christiansen, L. B., Van Dyck, D., Davey, R., Aguinaga-Ontoso, I., Salvo, D., Sugiyama, T., Owen, N., Mitáš, J., … Natarajan, L. (2016). Perceived neighborhood environmental attributes associated with walking and cycling for transport among adult residents of 17 cities in 12 countries: The IPEN study. Environmental health perspectives, 124(3), 290–298. https://doi.org/10.1289/ehp.1409466

Kendrick, C., Moore, A., Haire, A., Bigazzi, A., Figliozzi, M., Monsere, C., & George, L. (2011). Impact of bicycle lane characteristics on exposure of bicyclists to traffic-related particulate matter. *Transportation Research Record*, *2247*, 24–32. https://doi.org/10.3141/2247-04

Kim, K. (2020). Effects of weather and calendar events on mode-choice behaviors for public transportation. *Journal of Transportation Engineering, Part A: Systems*, *146*(7), 04020056. https://doi.org/10.1061/jtepbs.0000371

Kim, M., & Cho, G. H. (2021). Analysis on bike-share ridership for origin-destination pairs: Effects of public transit route characteristics and land-use patterns. *Journal of Transport Geography*, *93*(May 2020), 103047. https://doi.org/10.1016/j.jtrangeo.2021.103047

Kim, U. (2008). Curbing automobile use for sustainable transportation: analysis of mode choice on short home-based trips. *Transportation (Dordrecht)*, *35*(6), 723–737. https://doi.org/10.1007/s11116-008-9177-5

Kim, S., Ulfarsson, G. F., & Todd Hennessy, J. (2007). Analysis of light rail rider travel behavior: Impacts of individual, built environment, and crime characteristics on transit access. *Transportation Research Part A: Policy and Practice*, *41*(6), 511–522. https://doi.org/10.1016/j.tra.2006.11.001

Klicnik, I., & Dogra, S. (2019). Perspectives on active transportation in a mid-sized age-friendly city: "you stay home*." International Journal of Environmental Research and Public Health*, *16*(24). https://doi.org/10.3390/ijerph16244916

Ko, J., Lee, S., & Byun, M. (2019). Exploring factors associated with commute mode choice: An application of city-level general social survey data. *Transport Policy*, *75*(May 2017), 36–46. https://doi.org/10.1016/j.tranpol.2018.12.007

Koglin, T. (2015). Organisation does matter - planning for cycling in Stockholm and Copenhagen. *Transport Policy*, *39*, 55–62. https://doi.org/10.1016/j.tranpol.2015.02.003

Koglin, T., & Rye, T. (2014). The marginalisation of bicycling in Modernist urban transport planning. *Journal of Transport and Health*, *1*(4), 214–222. https://doi.org/10.1016/j.jth.2014.09.006

Koh, P. P., & Wong, Y. D. (2013). Influence of infrastructural compatibility factors on walking and cycling route choices. *Journal of Environmental Psychology*, *36*, 202–213. https://doi.org/10.1016/j.jenvp.2013.08.001

Kovačic, N. (2015). Profiling bicycle tourists: A case of Croatia. *Tourism and Hospitality Management*, *21*(2), 159–177. https://doi.org/10.20867/thm.21.2.4

Krizek, K. J., & Stonebraker, E. W. (2010). Bicycling and transit: A marriage unrealized. *Transportation Research Record*, *2144*, 161–167. https://doi.org/10.3141/2144-18

Krizek, K., Stonebraker, E., & Tribbey, S. (2011). Bicycling access and egress to transit: informing the possibilities. *Mineta Transportation Institute Publications*. http://scholarworks.sjsu.edu/mti_publications/78

Krizek, K. J., (2005). Household lifestyles and their relationship to land-use and transportation planning. Minneapolis: *Humphrey Institute of Public Affairs*. http://www.cura.umn.edu/sites/cura.advantagelabs.com/files/publications/35-4- Krizek.pdf.

Kulczycki, C., & Halpenny, E. A. (2014). Sport cycling tourists' setting preferences, appraisals and attachments. *Journal of Sport and Tourism*, *19*(2), 169–197. https://doi.org/10.1080/14775085.2015.1070741

LA Metro (2020). *Metro Bike Share*. https://bikeshare.metro.net/how-it-works/classic/

Lamont, M. (2009). Reinventing the wheel: A definitional discussion of bicycle tourism. *Journal of Sport and Tourism*, *14*(1), 5–23. https://doi.org/10.1080/14775080902847363

Larsen, J., & El-Geneidy, A. (2011). A travel behavior analysis of urban cycling facilities in Montréal, Canada. *Transportation Research Part D: Transport and Environment*, *16*(2), 172–177. https://doi.org/10.1016/j.trd.2010.07.011

Li, Z., Wang, W., Liu, P., & Ragland, D. R. (2012). Physical environments influencing bicyclists' perception of comfort on separated and on-street bicycle facilities. *Transportation Research Part D: Transport and Environment*, *17*(3), 256–261. https://doi.org/10.1016/j.trd.2011.12.001

Liang, Q., Weng, J., Zhou, W., Santamaria, S. B., Ma, J., & Rong, J. (2018). Individual travel behavior modeling of public transport passenger based on graph construction. *Journal of Advanced Transportation*, *2018*. https://doi.org/10.1155/2018/3859830

Liu, C., Susilo, Y. O., & Karlström, A. (2015). The influence of weather characteristics variability on individual's travel mode choice in different seasons and regions in Sweden. *Transport Policy*, *41*, 147–158. https://doi.org/10.1016/j.tranpol.2015.01.001

Liu, Y., Ji, Y., Feng, T., & Timmermans, H. (2020). Understanding the determinants of young commuters' metro-bikeshare usage frequency using big data. *Travel Behaviour and Society*, *21*(December 2019), 121–130. https://doi.org/10.1016/j.tbs.2020.06.007

Lois, D., Moriano, J. A., & Rondinella, G. (2015). Cycle commuting intention: A model based on theory of planned behaviour and social identity. *Transportation Research Part F: Traffic Psychology and Behaviour*, *32*(2015), 101–113. https://doi.org/10.1016/j.trf.2015.05.003

Long, J. S. (1997). *Regression Models for Categorical and Limited Dependent Variables.* Sage Publications.

Loo, B. P. Y. (2002). Role of stated preference methods in planning for sustainable urban transportation: State of practice and future prospects. *Journal of Urban Planning and*

Development, *128*(4), 210–224. https://doi.org/10.1061/(ASCE)0733-9488(2002)128:4(210)

Loukopoulos, P., Jakobsson, C., G€arling, T., Schneider, C. M., & Fujii, S. (2005). Public attitudes towards policy measures for reducing private car use: Evidence from a study in Sweden. *Environmental Science & Policy*, *8*(1), 57–66.

Loutzenheiser, D., (2005) Bicycles on Transit Policies for all US Rail Systems [Online]. http:// www.massbike.org/info/biketran.htm

Lowry, M. B., Furth, P., & Hadden-Loh, T. (2016). Prioritizing new bicycle facilities to improve low-stress network connectivity. *Transportation Research Part A: Policy and Practice*, *86*, 124–140. https://doi.org/10.1016/j.tra.2016.02.003

LRTA, (2019). *World systems list index.* https://web.archive.org/web/20191101165010/http://lrta.org/world/worldind.html

Lubitow, A., Tompkins, K., & Feldman, M. (2019). Sustainable Cycling For All? Race and Gender-Based Bicycling Inequalities in Portland, Oregon. *City and Community*, *18*(4), 1181–1202. https://doi.org/10.1111/cico.12470

Lumsdon, L. (2000). Transport and tourism: Cycle tourism–a model for sustainable development? *Journal of Sustainable Tourism*, *8*(5), 361–377. https://doi.org/10.1080/09669580008667373

Ma, L., & Dill, J. (2015). Associations between the objective and perceived built environment and bicycling for transportation. *Journal of Transport and Health*, *2*(2), 248–255. https://doi.org/10.1016/j.jth.2015.03.002

Ma, T., & Knaap, G. J. (2019). Estimating the impacts of capital bikeshare on metrorail ridership in the Washington Metropolitan Area. *Transportation Research Record*, *2673*(7), 371–379. https://doi.org/10.1177/0361198119849407

Ma, T., Liu, C., & Erdoğan, S. (2015). Bicycle sharing and public transit: Does capital bikeshare affect metrorail ridership in Washington, D.C.? *Transportation Research Record*, *2534*(2534), 1–9. https://doi.org/10.3141/2534-01

Ma, T., & Knaap, G. J. (2019). Estimating the Impacts of Capital Bikeshare on Metrorail Ridership in the Washington Metropolitan Area. *Transportation Research Record*, *2673*(7), 371–379. https://doi.org/10.1177/0361198119849407

Ma, X., Ji, Y., Yang, M., Jin, Y., & Tan, X. (2018). Understanding bikeshare mode as a feeder to metro by isolating metro-bikeshare transfers from smart card data. *Transport Policy*, *71*(April), 57–69. https://doi.org/10.1016/j.tranpol.2018.07.008

Malucelli, F., Giovannini, A., & Nonato, M. (2015). Designing single origin-destination itineraries for several classes of cycle-tourists. *Transportation Research Procedia*, *10*(July), 413–422. https://doi.org/10.1016/j.trpro.2015.09.091

Mamrayeva, D., & Tashenova, L. (2017). Prospects of bicycle-sharing in urban tourism in the republic of Kazakhstan: Myth or reality? *Transport Problems*, *12*(2), 65–76. https://doi.org/10.20858/tp.2017.12.2.7

Manzo A.N., Burke J.M. (2012) Increasing Response Rate in Web-Based/Internet Surveys. In: Gideon L. (eds) *Handbook of Survey Methodology for the Social Sciences.* Springer. https://doi-org.proxy.lib.uwaterloo.ca/10.1007/978-1-4614-3876-2_19

Martens, K. (2004). The bicycle as a feedering mode: Experiences from three European countries. *Transportation Research. Part D, Transport and Environment*, *9*(4), 281–294. https://doi.org/10.1016/j.trd.2004.02.005

Marqués, R., Hernández-Herrador, V., Calvo-Salazar, M., & García-Cebrián, J. A. (2015). How infrastructure can promote cycling in cities: Lessons from Seville. *Research in Transportation Economics*, *53*, 31–44. https://doi.org/10.1016/j.retrec.2015.10.017

Martens, K. (2007). Promoting bike-and-ride: The Dutch experience. *Transportation Research Part A: Policy and Practice*, *41*(4), 326–338. https://doi.org/10.1016/j.tra.2006.09.010

Martens, K. (2004). The bicycle as a feedering mode: Experiences from three European countries. *Transportation Research Part D: Transport and Environment*, *9*(4), 281–294. https://doi.org/10.1016/j.trd.2004.02.005

Martin, E. W., & Shaheen, S. A. (2014). Evaluating public transit modal shift dynamics in response to bikesharing: A tale of two U.S. cities. *Journal of Transport Geography*, *41*, 315–324. https://doi.org/10.1016/j.jtrangeo.2014.06.026

McCullough, S. R., Lugo, A., van Stokkum, R., University of California, D., University, A., UTC, P. S. R. 9, Technology, O. of the A. S. for R. and, & Sarah, R. (2019). *Making Bicycling Equitable: Lessons from Sociocultural Research. 51p*. https://doi.org/10.7922/G22R3PWK

McGovern, M. E., Canning, D., & Bärnighausen, T. (2018). Accounting for non-response bias using participation incentives and survey design: An application using gift vouchers. *Economics Letters*, *171*, 239–244. https://doi.org/10.1016/j.econlet.2018.07.040

McNeil, N. (2011). Bikeability and the 20-min neighborhood: How infrastructure and destinations influence bicycle accessibility. *Transportation Research Record*, *2247*, 53–63. https://doi.org/10.3141/2247-07

Menai, M., Charreire, H., Feuillet, T., Salze, P., Weber, C., Enaux, C., Andreeva, V. A., Hercberg, S., Nazare, J. A., Perchoux, C., Simon, C., & Oppert, J. M. (2015). Walking and cycling for commuting, leisure and errands: Relations with individual characteristics and leisure-time physical activity in a cross-sectional survey (the ACTI-Cités project). *International Journal of Behavioral Nutrition and Physical Activity*, *12*(1), 1–10. https://doi.org/10.1186/s12966-015-0310-5

Metrolinx. (2016). *GO Rail Station Access Plan*. https://doi.org/10.1093/nar/gku985

Metrolinx, (2020a). *Eglinton Crosstown LRT*. http://www.metrolinx.com/en/greaterregion/projects/crosstown.aspx

Metrolinx, (2020b). *Finch West LRT*. http://www.metrolinx.com/en/greaterregion/projects/finchwest-lrt.aspx

Metrolinx, (2020c). *Hurontario LRT*. http://www.metrolinx.com/en/greaterregion/projects/hurontario-lrt.aspx

Mississauga Transit (2020). *Travelling with a bike*. https://www.mississauga.ca/miway-transit/travelling-with-us/travelling-with-a-bike/

Moniruzzaman, M., & Páez, A. (2012). Accessibility to transit, by transit, and mode share: Application of a logistic model with spatial filters. *Journal of Transport Geography, 24*, 198–205. https://doi.org/10.1016/j.jtrangeo.2012.02.006

Moskovitz, D., & Wheeler, N. (2011). Bicycle parking analysis with time series photography. *Transportation Research Record*, *2247*, 64–71. https://doi.org/10.3141/2247-08

Mouratidis, K., Ettema, D., & Næss, P. (2019). Urban form, travel behavior, and travel satisfaction. *Transportation Research Part A: Policy and Practice*, *129*(June), 306–320. https://doi.org/10.1016/j.tra.2019.09.002

Muñoz, B., Monzon, A., & López, E. (2016). Transition to a cyclable city: Latent variables affecting bicycle commuting. *Transportation Research Part A: Policy and Practice*, *84*, 4–17. https://doi.org/10.1016/j.tra.2015.10.006

Mayers, R. F., & Glover, T. D. (2020). Whose Lane Is It Anyway? The Experience of Cycling in a Mid-Sized City. *Leisure Sciences*, *42*(5–6), 515–532. https://doi.org/10.1080/01490400.2018.1518174

Mayers, R., & Glover, T. (2021). Safe cycling space: How it is produced and experienced by cyclists. *Journal of Leisure Research*, *52*(3), 370–391. https://doi.org/10.1080/00222216.2020.1864685

Nairne, J.S., (2003). Psychology: *The adaptive mind* (3rd ed), Thomson Learning Inc.

National Academies of Sciences, Engineering, and Medicine (2018). *Public transit and bikesharing.* The National Academies Press. https://doi.org/10.17226/25088.

National Academy of Sciences, Engineering and Medicine. (2005). *Integration of bicycles and transit*. The National Academies Press. https://doi.org/10.17226/13554

Nello-Deakin, S., & Nikolaeva, A. (2020). The human infrastructure of a cycling city: Amsterdam through the eyes of international newcomers. *Urban Geography*, 1-23.

Neuman, W., & Robson, K. (2017). *Basics of Social Research: Qualitative and Quantitative Approaches* (Fourth Canadian edition.). Pearson Canada.

Nielsen, T. A. S., Olafsson, A. S., Carstensen, T. A., & Skov-Petersen, H. (2013). Environmental correlates of cycling: Evaluating urban form and location effects based on Danish micro-data. *Transportation Research Part D: Transport and Environment*, *22*, 40. https://doi.org/10.1016/j.trd.2013.02.017

Nkurunziza, A., Zuidgeest, M., Brussel, M., & Van Maarseveen, M. (2012). Examining the potential for modal change: Motivators and barriers for bicycle commuting in Dar-es-salaam. *Transport Policy*, *24*, 249–259. https://doi.org/10.1016/j.tranpol.2012.09.002

Nosal, T., & Miranda-Moreno, L. F. (2014). The effect of weather on the use of North American bicycle facilities: A multi-city analysis using automatic counts. *Transportation Research Part A: Policy and Practice*, *66*(1), 213–225. https://doi.org/10.1016/j.tra.2014.04.012

OC Transpo (2020). *Welcome to your future O-Train Network.* https://www.octranspo.com/en/news/article/welcome-to-your-future-otrain-network/

OC Transpo (2020). *Bikes on our network*. https://www.octranspo.com/en/plan-your-trip/how-to-ride/bikes-on-our-network/

Olafsson, A. S., Nielsen, T. S., & Carstensen, T. A. (2016). Cycling in multimodal transport behaviours: Exploring modality styles in the Danish population. *Journal of Transport Geography*, *52*, 123–130. https://doi.org/10.1016/j.jtrangeo.2016.03.010

O’Sullivan, S., & Morrall, J., (1996). Walking distances to and from light-rail transit stations. *Transportation Research Record 1538*, 19–26.

Ortúzar S., J., & Willumsen, L. (2012). Modelling transport (Fourth edition.). John Wiley & Sons.

Pace, L. E., Lee, Y. S., Tung, N., Hamilton, J. G., Gabriel, C., Raja, S. C., Jenkins, C., Braswell, A., Domchek, S. M., Symecko, H., Spielman, K., Karlan, B. Y., Lester, J., Kamara, D., Levin, J., Morgan, K., Offit, K., Garber, J., & Keating, N. L. (2020). Comparison of up-front cash cards and checks as incentives for participation in a clinician survey: A study within a trial. *BMC Medical Research Methodology*, *20*(1), 1–7. https://doi.org/10.1186/s12874-020-01086-9

Pan, S. (2010). Intermodal transfer between bicycles and rail transit in Shanghai, China. *Transportation Research Record*, *2144*(1), 181–188. https://doi.org/10.3141/2144-20

Park, S., Kang, J., & Choi, K. (2014). Finding determinants of transit users' walking and biking access trips to the station: A pilot case study. *KSCE Journal of Civil Engineering*, *18*(2), 651–658. https://doi.org/10.1007/s12205-014-0073-6

Parkany,E., Gallagher, R., & Viveiros, P. (2005). Are attitudes important in travel choices? *Transportation Research Board Annual Meeting*.

Parkinson, T., & Fisher, I., (1996). Rail transit capacity. TCRP Report 13, *Transportation Research Board*, National Academy Press.

Patel, S. J., & Patel, C. R. (2019). *An Infrastructure Review of Public Bicycle Sharing System (PBSS): Global and Indian Scenario*. https://doi.org/10.1007/978-981-13-2032-3_11

Pikora, T., Giles-Corti, B., Bull, F., Jamrozik, K., & Donovan, R. (2003). Developing a framework for assessment of the environmental determinants of walking and cycling. *Social Science and Medicine*, *56*(8), 1693–1703. https://doi.org/10.1016/S0277-9536(02)00163-6

Pritchard, R. (2018). Revealed preference methods for studying bicycle route choice—a systematic review. In *International Journal of Environmental Research and Public Health* *15*(3). https://doi.org/10.3390/ijerph15030470

Pruetz, R. (2013). Comes in Cycles. *Planning*, *79*(9), 10,12-15.

Puan, O. C., Hassan, Y. A. H., Mashros, N., Idham, M. K., Hassan, N. A., Warid, M. N. M., & Hainin, M. R. (2019). Transportation mode choice binary logit model: A case study for Johor Bahru city. *IOP Conference Series: Materials Science and Engineering*, *527*(1). https://doi.org/10.1088/1757-899X/527/1/012066

Pucher, J., & Buehler, R. (2009). Integrating bicycling and public transport in North America. *Journal of Public Transportation*, *12*(3), 79–104. https://doi.org/10.5038/2375-0901.12.3.5

Pucher, J., Buehler, R., Bassett, D. R., & Dannenberg, A. L. (2010). Walking and cycling to health: A comparative analysis of city, state, and international data. *American Journal of Public Health*, *100*(10), 1986–1992. https://doi.org/10.2105/AJPH.2009.189324

Pucher, J., Buehler, R., & Seinen, M. (2011). Bicycling renaissance in North America? An update and re-appraisal of cycling trends and policies. *Transportation Research Part A: Policy and Practice*, *45*(6), 451–475. https://doi.org/10.1016/j.tra.2011.03.001

Pucher, J., Dill, J., & Handy, S. (2010). Infrastructure, programs, and policies to increase bicycling: An international review. *Preventive Medicine*, *50*(SUPPL.), S106–S125. https://doi.org/10.1016/j.ypmed.2009.07.028

Pucher, J., Garrard, J., & Greaves, S. (2011). Cycling down under: A comparative analysis of bicycling trends and policies in Sydney and Melbourne. *Journal of Transport Geography*, *19*(2), 332–345. https://doi.org/10.1016/j.jtrangeo.2010.02.007

Region of Waterloo, (2019). Moving forward - 2018 Transportation master plan. https://www.regionofwaterloo.ca/en/living-here/resources/Transportation-Master-Plan/DOCS_ADMIN-3030800-v3-TMP_Report_Moving_Forward_Main_Report_FINAL_2019-06-12.pdf

Region of Waterloo, (2019). Separated Cycling Lanes. https://www.regionofwaterloo.ca/en/exploring-the-region/separated-cycling-lanes.aspx#

Region of Waterloo, (2020). *Construction and Road Closures–Current Construction Projects*. Retrieved from https://www.regionofwaterloo.ca/en/living-here/construction-and-road-closures.aspx

Region of Waterloo. (2020). Micromobility update. Staff report: TES-TRS-20-14. https://ehq-production-canada.s3.ca-central-1.amazonaws.com/6d9502fa823407dfb50d8d2c24c0feb63093f1e2/original/1607553172/Staff_Report_-_2020_Micromobility_Update_and_Next_Steps_%28Bikeshare_and_Escooters%29_-_TES-TRS-20-14_%282%29.pdf_29806552118093ead71e92a3ea8cd43e?X-Amz-Algorithm=AWS4-HMAC-SHA256&X-Amz-Credential=AKIAIBJCUKKD4ZO4WUUA%2F20210408%2Fca-central-1%2Fs3%2Faws4_request&X-Amz-Date=20210408T195809Z&X-Amz-Expires=300&X-Amz-SignedHeaders=host&X-Amz-Signature=4208bca87aebb4ef5c6b950603dca7d819da1c7f07124ec0d871cd9b239bf669

Reilly, J., Williams, P., & Haider, W. (2010). Moving towards more eco-efficient tourist transportation to a resort destination: The case of Whistler, British Columbia. *Research in Transportation Economics*, *26*(1), 66–73. https://doi.org/10.1016/j.retrec.2009.10.009

Replogle, M. (1982). Role of Bicyles in Public Transportation. *Transportation Research Record*, *11*(2), 55–62.

Replogle, M. A. (1984). Role of bicycles in public transportation Access. *Transportation Research Record*, *11*, 55–62.

Rietveld, P. (2000). The accessibility of railway stations: The role of the bicycle in the Netherlands. *Transportation Research. Part D, Transport and Environment*, *5*(1), 71–75. https://doi.org/10.1016/S1361-9209(99)00019-X

Ritchie, B. W., & Hall, C. M. (1999). Bicycle tourism and regional development: A New Zealand case study. *Anatolia*, *10*(2), 89–112. https://doi.org/10.1080/13032917.1999.9686974

Ritchie, B. W., Tkaczynski, A., & Faulks, P. (2010). Understanding the motivation and travel behavior of cycle tourists using involvement profiles. *Journal of Travel and Tourism Marketing*, *27*(4), 409–425. https://doi.org/10.1080/10548408.2010.481582

Roecker, E. (1991). Prediction error and its estimation for subset-selected models. *Technometrics*, *33*(4), 459–468. https://doi.org/10.1080/00401706.1991.10484873

Roman, M., & Roman, M. (2014). Bicycle transport as an opportunity to develop urban tourism–Warsaw example. *Procedia - Social and Behavioral Sciences*, *151*, 295–301. https://doi.org/10.1016/j.sbspro.2014.10.027

Sabir, M., (2011). Weather and travel behaviour. PhD thesis. Vrije Universiteit Amsterdam, http://edepot.wur.nl/304943.

Saneinejad, S., Roorda, M. J., & Kennedy, C. (2012). Modelling the impact of weather conditions on active transportation travel behaviour. *Transportation Research Part D: Transport and Environment*, *17*(2), 129–137. https://doi.org/10.1016/j.trd.2011.09.005

Sagaris, L., & Arora, A. (2016). Evaluating how cycle-bus integration could contribute to “sustainable” transport. *Research in Transportation Economics*, *59*, 218–227. https://doi.org/10.1016/j.retrec.2016.05.008

Salmani, F., Taheri, S. M., & Abadi, A. (2019). A forward variable selection method for fuzzy logistic regression. *International Journal of Fuzzy Systems*, *21*(4), 1259–1269. https://doi.org/10.1007/s40815-019-00615-z

Santos, J.R.A. (2000). Getting the most out of multiple response questions. *Journal of Extension*, *38*(3). https://www.joe.org/joe/2000june/tt2.php

Saplıoğlu, M., & Aydın, M. M. (2018). Choosing safe and suitable bicycle routes to integrate cycling and public transport systems. *Journal of Transport and Health*, *10*(May), 236–252. https://doi.org/10.1016/j.jth.2018.05.011

Schoner, J. E., & Levinson, D. M. (2014). The missing link: Bicycle infrastructure networks and ridership in 74 US cities. *Transportation*, *41*(6), 1187–1204. https://doi.org/10.1007/s11116-014-9538-1

Sears, J., Flynn, B., Aultman-Hall, L., & Dana, G. (2012). To bike or not to bike. *Transportation Research Record*, *2314*, 105–111. https://doi.org/10.3141/2314-14

Sener, I. N., Eluru, N., & Bhat, C. R. (2009). An analysis of bicycle route choice preferences in Texas, US. *Transportation*, *36*(5), 511–539. https://doi.org/10.1007/s11116-009-9201-4

Shams, K., Jin, X., Fitzgerald, R., Asgari, H., Hossan, M.S., (2017). Value of reliability for road freight transportation: evidence from a stated preference survey in Florida. *Transportation Research Record*, *2610*(1), 35–43. https://doi.org/10.3141/2610-05

Shaheen, S., & Chan, N. (2016). Mobility and the sharing economy: potential to overcome first- and last-mile public transit connections. *UC Berkeley: Transportation Sustainability Research Center*, 573–588. https://doi.org/10.7922/G2862DN3

Shannon, T., Giles-Corti, B., Pikora, T., Bulsara, M., Shilton, T., & Bull, F., (2006). Active commuting in a university setting: assessing commuting habits and potential for modal change. *Transport Policy 13*, 240–253. https://doi.org/10.1016/j.tranpol.2005.11.002

Sherwin, H. (2010). *Bike-rail integration as one sustainable transport solution to reduce car dependence*. http://eprints.uwe.ac.uk/16859/

Si, H., Shi, J. gang, Wu, G., Chen, J., & Zhao, X. (2019). Mapping the bike sharing research published from 2010 to 2018: A scientometric review. *Journal of Cleaner Production*, *213*, 415–427. https://doi.org/10.1016/j.jclepro.2018.12.157

Singer, E., & Ye, C. (2013). The use and effects of incentives in surveys. *Annals of the American Academy of Political and Social Science*, *645*(1), 112–141. https://doi.org/10.1177/0002716212458082

Song, Y., & Huang, Y. (2020). Investigating Complementary and Competitive Relationships between Bikeshare Service and Public Transit: *A Spatial-Temporal Framework. Transportation Research Record, 2674*(1), 260–271. https://doi.org/10.1177/0361198119899389

Spencer, P., Watts, R., Vivanco, L., & Flynn, B. (2013). The effect of environmental factors on bicycle commuters in Vermont: Influences of a northern climate. *Journal of Transport Geography, 31*, 11–17. https://doi.org/10.1016/j.jtrangeo.2013.05.003

Sperandei, S. (2014). Understanding logistic regression analysis. *Biochemia Medica*, *24*(1), 12–18. https://doi.org/10.11613/BM.2014.003

Stanley, M., Roycroft, J., Amaya, A., Dever, J. A., & Srivastav, A. (2020). The effectiveness of incentives on completion rates, data quality, and nonresponse bias in a probability-based internet panel survey. *Field Methods, 32*(2), 159–179. https://doi.org/10.1177/1525822X20901802

Statistics Canada (2017). Kitchener, CY [Census subdivision], Ontario and Waterloo, CY [Census subdivision], Ontario (table). Census Profile. 2016 Census. Statistics Canada Catalogue no. 98-316-X2016001. Ottawa. Released November 29, 2017. https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/index.cfm?Lang=E (accessed January 26, 2020)

Steensig, S.L. (2021). Meet the bike-loving Finnish city that keeps pedalling even in the snow. *Euronews*. https://www.euronews.com/2021/01/22/meet-the-bike-loving-finnish-city-that-keeps-pedalling-even-in-the-snow?fbclid=IwAR3rz3EinFTiDR-aWmp2OLtUreKVIwU0wY4vi1ITHls9xNo71_TLDHhOl58

Stinson, M. A., & Bhat, C. R. (2003). Analysis using a stated preference survey. *Transportation Research Record: Journal of the Transportation Research Board*, *1828*(03), 107–115.

Su, J. G., Winters, M., Nunes, M., & Brauer, M. (2010). Designing a route planner to facilitate and promote cycling in Metro Vancouver, Canada. *Transportation Research Part A: Policy and Practice*, *44*(7), 495–505. https://doi.org/10.1016/j.tra.2010.03.015

Su, J., Shao, P., & Fang, J. (2008). Effect of incentives on web-based surveys. *Tsinghua Science and Technology*, *13*(3), 344–347. https://doi.org/10.1016/S1007-0214(08)70055-5

Sue, V.M, & Ritter, L.A. (2008). Conducting online surveys Los Angeles/ London/ New Delhi. *Development in Practice, 18*(3), 463-465. https://doi.org/10.1080/09614520802031274

Sun, B., Ermagun, A., & Dan, B. (2017). Built environmental impacts on commuting mode choice and distance: Evidence from Shanghai. *Transportation Research Part D: Transport and Environment*, *52*, 441–453. https://doi.org/10.1016/j.trd.2016.06.001

Suraci, D. (n.d.). *Bicycle and Transit Integration: A Practical Transit Agency Guide to Bicycle Integration and Equitable Mobility*. https://www.apta.com/resources/mobility/Documents/Bike_Transit_Integrartion_V6.compressed.pdf

Survey Monkey (2020). Sample Size Calculator. https://www.surveymonkey.com/mp/sample-size-calculator/

Tai, T., Ngah, R., & Shah, M. Z. (2018). Psycho-social attributes and quality of life: Overview and pilot study of commuters' travel behaviour. *MATEC Web of Conferences*, *181*. https://doi.org/10.1051/matecconf/201818103002

Tan, L., & Ma, C. (2020). Choice behavior of commuters' rail transit mode during the COVID-19 pandemic based on logistic model. *Journal of Traffic and Transportation Engineering (English Edition)*, *xxx*. https://doi.org/10.1016/j.jtte.2020.07.002

Tang, G., Keshav, S., Golab, L., Wu, K., (2018). Bikeshare pool sizing for bike-and-ride multimodal transit. IEEE Trans. Intell. Transp. Syst. 1–11.

Teisl, M., Roe, B., & Vayda, M., (2006). Incentive effects on response rates, data quality, and survey administration costs. *International Journal of Public Opinion Research, 18*(3), 364–373. https://doi.org/10.1093/ijpor/edh106

Teschke, K., Dennis, J., Reynolds, C. C. O., Winters, M., & Harris, M. A. (2016). Bicycling crashes on streetcar (tram) or train tracks: Mixed methods to identify prevention measures. *BMC Public Health*, *16*(1), 1–10. https://doi.org/10.1186/s12889-016-3242-3

The Centre for Active Transportation (2019). *Increasing Cycling in Canada*. https://www.tcat.ca/wp-content/uploads/2019/09/Increasing-Cycling-in-Canada-A-Guide-to-What-Works-2019-09-25.pdf

Thomas, B., & De Robertis, M. (2013). The safety of urban cycle tracks: A review of the literature. *Accident Analysis and Prevention*, *52*, 219–227. https://doi.org/10.1016/j.aap.2012.12.017

Thompson, J., Wijnands, J. S., Savino, G., Lawrence, B., & Stevenson, M. (2017). Estimating the safety benefit of separated cycling infrastructure adjusted for behavioral adaptation among drivers; an application of agent-based modelling. *Transportation Research Part F: Traffic Psychology and Behaviour*, *49*, 18–28. https://doi.org/10.1016/j.trf.2017.05.006

Tilahun, N. Y., Levinson, D. M., & Krizek, K. J. (2007). Trails, lanes, or traffic: Valuing bicycle facilities with an adaptive stated preference survey. *Transportation Research Part A: Policy and Practice*, *41*(4), 287–301. https://doi.org/10.1016/j.tra.2006.09.007

Toronto Transit Commission (2020). *Taking your bike on TTC Vehicles*. https://www.ttc.ca/Riding_the_TTC/Bikes/Bikes_on_TTC_Vehicles.jsp

Train, K.E., & McFadden, D. (1978). The goods/leisure trade-off and disaggregate work trip mode choice models. *Transportation Research 12,* 349-353.

Tranmer, M., & Elliot, M. (2008). Binary logistic regression. *Cathie Marsh for Census And Survey Research*, *Paper*, *20*.

Translink (2020). *Bikes on Transit*. https://www.translink.ca/rider-guide/bikes-on-transit

Transport Canada (2012). *Urban bicycle planning Téléchargé de Scholars Portal Books sur 2019-01-08 Urban Bicycle Planning*.

UCLA (2011). *FAQ: What are pseudo R-squareds?* https://stats.idre.ucla.edu/other/mult-pkg/faq/general/faq-what-are-pseudo-r-squareds/

Uncles, M., Ben-Akiva, M., Lerman, S., (1987). Discrete choice analysis: Theory and application to travel demand. *The Journal of the Operational Research Society, 38*(4), 370–. https://doi.org/10.2307/2582065

University of Waterloo (2020). *COVID-19 Information: Research Information*. https://uwaterloo.ca/coronavirus/research-information#return-to-research

University of Waterloo, (2020). *COVID-19 Information: Latest Updates*. https://uwaterloo.ca/coronavirus/

Vietinghoff, C. (2021). An intersectional analysis of barriers to cycling for marginalized communities in a cycling-friendly French City. *Journal of Transport Geography, 91*(January 2020), 102967. https://doi.org/10.1016/j.jtrangeo.2021.102967

Villwock-Witte, N., & Van Grol, L. (2015). Case study of transit-bicycle integration: Openbaar Vervoer-fiets (Public Transport-Bike) (OV-fiets). *Transportation Research Record*, *2534*, 10–15. https://doi.org/10.3141/2534-02

Wang, L., & Wen, C., (2017). The relationship between the neighborhood built environment and active transportation among adults: A systematic literature review. Urban Science, 1(3), 29–. https://doi.org/10.3390/urbansci1030029

Wang, R. & Liu, C. (2013). Bicycle- transit integration in the United States 2001–2009. *Journal of Public Transportation*, *16*(3), 95–119. https://doi.org/10.5038/2375-0901.16.3.6

Welch, T. F., Gehrke, S. R., & Wang, F. (2016). Long-term impact of network access to bike facilities and public transit stations on housing sales prices in Portland, Oregon. *Journal of Transport Geography*, *54*(September 2015), 264–272. https://doi.org/10.1016/j.jtrangeo.2016.06.016

Whalen, K. E., Páez, A., & Carrasco, J. A. (2013). Mode choice of university students commuting to school and the role of active travel. *Journal of Transport Geography*, *31*, 132–142. https://doi.org/10.1016/j.jtrangeo.2013.06.008

Winters, M., Branion-Calles, M., Therrien, S., Fuller, D., Gauvin, L., Whitehurst, D. G. T., & Nelson, T. (2018). Impacts of Bicycle Infrastructure in Mid-Sized Cities (IBIMS): Protocol for a natural experiment study in three Canadian cities. *BMJ Open*, *8*(1), 1–11. https://doi.org/10.1136/bmjopen-2017-019130

Wilfred Laurier University, (2020). *COVID-19: Laurier is discontinuing in-person instruction in all courses*. https://www.wlu.ca/coronavirus/news/2020/march/laurier-is-discontinuing-in-person-instruction-in-all-courses.html

Wu, X., Lu, Y., Lin, Y., & Yang, Y. (2019). Measuring the destination accessibility of cycling transfer trips in metro station areas: A big data approach. *International Journal of Environmental Research and Public Health*, *16*(15). https://doi.org/10.3390/ijerph16152641

Wulansari, D. N., & Astari, M. D. (2018). Mode choice analysis using discrete choice model from transport user (Case study: Jakarta LRT, Indonesia). *MATEC Web of Conferences*, *181*. https://doi.org/10.1051/matecconf/201818103001

Xing, Y., Volker, J., & Handy, S. (2018). Why do people like bicycling? Modeling affects toward bicycling. *Transportation Research Part F: Traffic Psychology and Behaviour*, *56*, 22–32. https://doi.org/10.1016/j.trf.2018.03.018

Yan, X., Levine, J., & Zhao, X. (2019). Integrating ridesourcing services with public transit: An evaluation of traveler responses combining revealed and stated preference data.

Transportation Research Part C: Emerging Technologies, *105*(January 2018), 683–696. https://doi.org/10.1016/j.trc.2018.07.029

Yang, M., Zhao, J., Wang, W., Liu, Z., Li, Z., (2015). Metro commuters' satisfaction in multi-type access and egress transferring groups. *Transportation Research. Part D, Transport and Environment*, *34*, 179–194. https://doi.org/10.1016/j.trd.2014.11.004

Yiannakoulias, N., Bennet, S. A., & Scott, D. M. (2012). Mapping commuter cycling risk in urban areas. *Accident Analysis and Prevention*, *45*, 164–172. https://doi.org/10.1016/j.aap.2011.12.002

Younes, H., Nasri, A., Baiocchi, G., & Zhang, L. (2019). How transit service closures influence bikesharing demand; lessons learned from SafeTrack project in Washington, D.C. metropolitan area. *Journal of Transport Geography, 76*(March), 83–92. https://doi.org/10.1016/j.jtrangeo.2019.03.004

Yu, S., Alper, H.E., Nguyen, A.M., Brackbill, R.M., Turner, L., Walker, D.J, …Zweig, K.C. (2017). The effectiveness of a monetary incentive offers on survey response rates and response completeness in a longitudinal study. BMC Medical Research Methodology, 17(1), 77–77. https://doi.org/10.1186/s12874-017-0353-1Zellner, D., Keller, F., & Zellner, G. E. (2004). Variable Selection in Logistic Regression Models. *Communications in Statistics - Simulation and Computation*, *33*(3), 787–805. https://doi.org/10.1081/SAC-200033363

Zhang, B. & Batterman, S (2013). Air pollution and health risks due to vehicle traffic. *The Science of the Total Environment*, *450-451*, 307–316. https://doi.org/10.1016/j.scitotenv.2013.01.074

Zhang, Z., Qian, C., & Bian, Y. (2019). Bicycle–metro integration for the 'last mile': Visualizing cycling in Shanghai. *Environment and Planning A*, *51*(7), 1420–1423. https://doi.org/10.1177/0308518X18816695

Zhang, Y., & Zhang, Y. (2018). Associations between public transit usage and bikesharing behaviors in the United States. *Sustainability (Switzerland), 10(6)*, 1–20. https://doi.org/10.3390/su10061868

Zhao, J., Wang, J., Xing, Z., Luan, X., & Jiang, Y. (2018). Weather and cycling: Mining big data to have an in-depth understanding of the association of weather variability with cycling on an off-road trail and an on-road bike lane. *Transportation Research Part A: Policy and Practice*, *111*(March), 119–135. https://doi.org/10.1016/j.tra.2018.03.001

Zhao, P., & Li, S. (2017). Bicycle-metro integration in a growing city: The determinants of cycling as a transfer mode in metro station areas in Beijing. *Transportation Research Part A: Policy and Practice, 99*, 46–60. https://doi.org/10.1016/j.tra.2017.03.003

Zhou, J. (2012). Sustainable commute in a car-dominant city: Factors affecting alternative mode choices among university students. *Transportation Research. Part A, Policy and Practice, 46*(7), 1013–1029. https://doi.org/10.1016/j.tra.2012.04.001

Zhou, J., Wang, Y., & Wu, J. (2018). Mode choice of commuter students in a college town: An exploratory study from the United States. *Sustainability (Switzerland), 10*(9), 1–18. https://doi.org/10.3390/su10093316

Zuo, T., & Wei, H. (2019). Bikeway prioritization to increase bicycle network connectivity and bicycle-transit connection: A multi-criteria decision analysis approach. *Transportation Research Part A: Policy and Practice, 129*(September 2018), 52–71. https://doi.org/10.1016/j.tra.2019.08.003

ZYP Bikeshare (2019). ZYP Bikeshare. http://revbirmingham.org/who-we-are/history/zyp-bikeshare/

Appendix A

Figure A.1. Participants' household income by bike-share availability (*p* < 0.01)

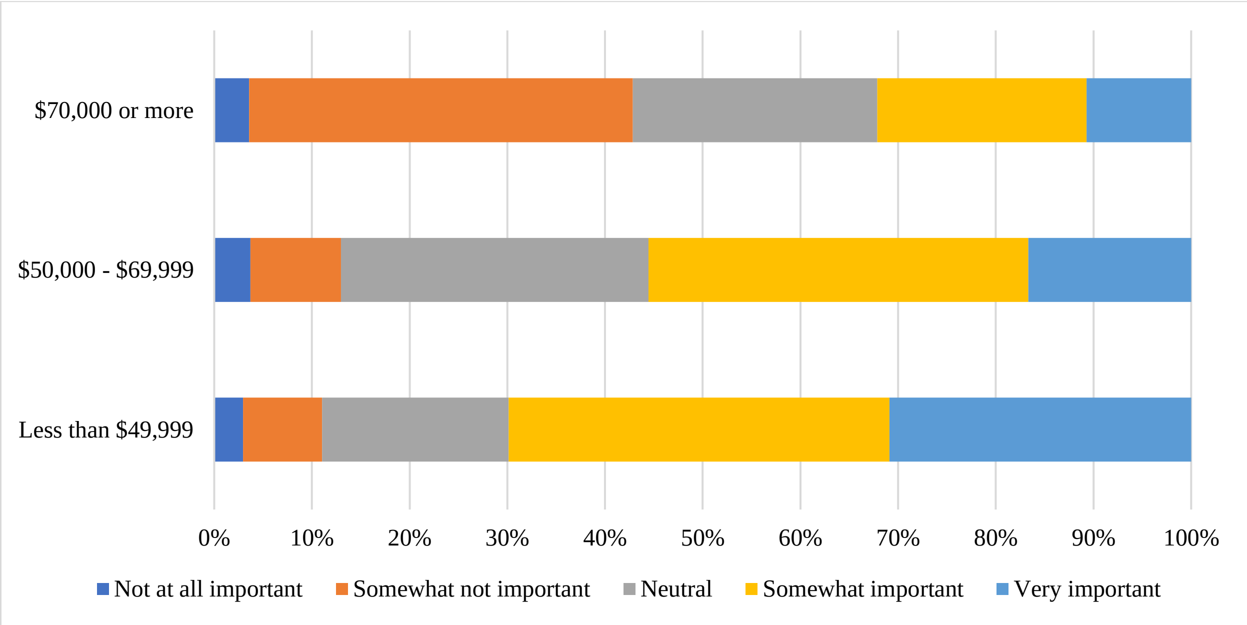


Figure A.2. Participants' household income by secure bicycle parking (*p* < 0.01)

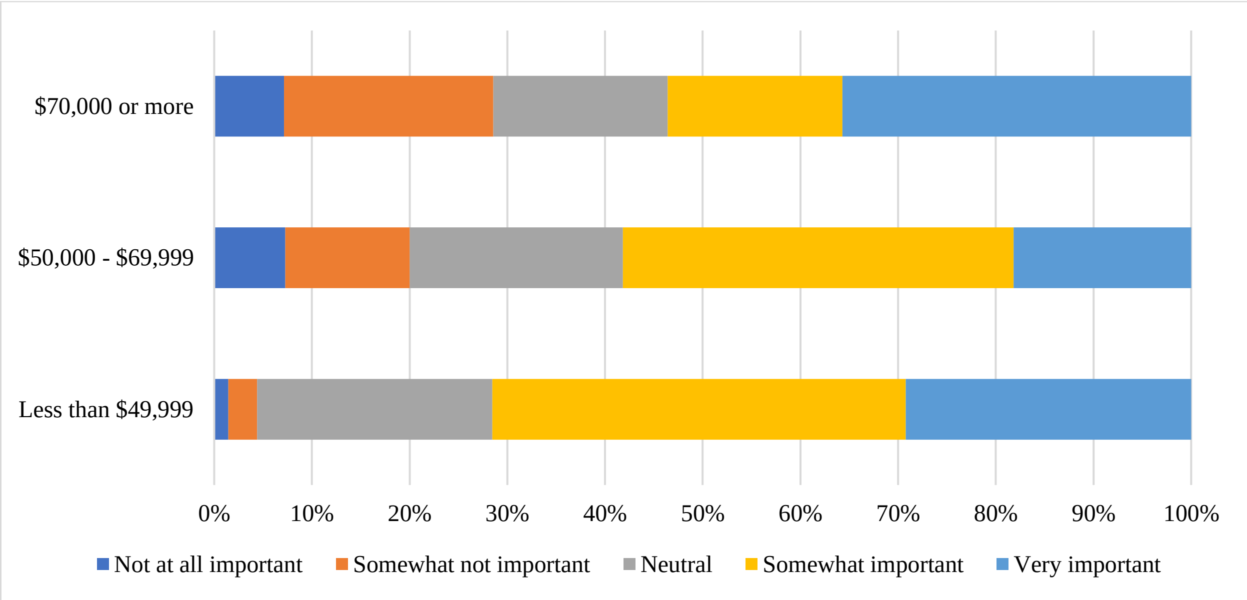
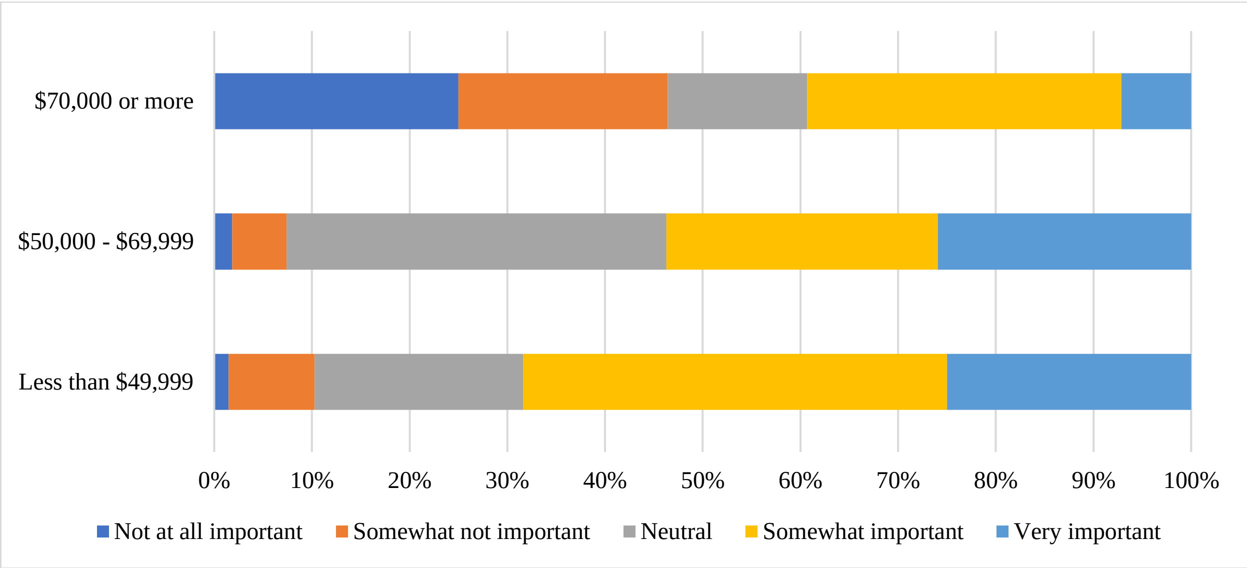


Figure A.3. Participants' household income by attitude to bicycle repair stations ($p < 0.01$)



Appendix B–Survey Questions

Survey Questions

Page 1: Questions 1 to 6 below will ask you about some demographic information about yourself.

1. Which municipality or township do you currently live in the Waterloo Region?

- ☐ Kitchener
- ☐ Cambridge
- ☐ Waterloo
- ☐ Woolwich
- ☐ Wellesley
- ☐ Wilmot
- ☐ North Dumfries
- ☐ I live outside of the Waterloo Region.

2. What age group do you belong to?

- ☐ 18–24
- ☐ 25–29
- ☐ 30–34
- ☐ 35–39
- ☐ 40–49
- ☐ 50–59

- 60 or older

3. What is your gender?

- Female
- Male
- Non-binary/third gender
- I prefer not to identify.

4. What is the highest level of education you have attained?

- Master's degree or Ph.D. or M.D.
- Bachelor's degree or similar
- College Diploma/certificate
- High School
- I prefer not to answer.

5. Which of the following best describes your current household structure?

- Single or Live alone
- Live with parent(s)
- Live with roommate(s)
- Lone parent with child(ren)
- Live with partner but no child
- Live with partner and child(ren)
- I prefer not to answer.

6. What is your yearly household income before tax?

□ Less than $29,999

□ $30,000–$49,999

□ $50,000–$69,999

□ $70,000–$99,999

□ $100,000 or more

□ I prefer not to answer.

Page 2: Questions 7–11 below will ask you about your travel behavior. If your travel behavior has changed due to the COVID-19 outbreak (e.g., working from home, taking online courses, and public space shut down), please answer the following questions based on your travel behavior prior to the COVID-19 outbreak.

7. What is the primary purpose for you to use the ION LRT service?

□ Commute for work

□ Commute for school

□ Grocery shopping

□ Visiting hospital

□ Dropping off/picking up child(ren)

□ Visiting family members

□ To access entertainment/recreation/leisure facility

□ Others, please specify: ______________________

8. How often do you use the ION LRT service?

- ☐ Daily
- ☐ More than 3 times a week
- ☐ 1 to 3 times a week
- ☐ Less than once a week

9. How do you access the ION LRT station from home?

- ☐ Walk
- ☐ Bike
- ☐ Bus (GRT, GO Transit, Greyhound or other regional transit)
- ☐ Auto mobile/ car drop-off (private vehicles, taxi, uber, carpooling etc.)

10. How do you reach your destination from the ION LRT station?

- ☐ Walk
- ☐ Bike
- ☐ Bus (GRT, GO Transit, Greyhound, or other regional transit)
- ☐ Auto mobile/ car drop-off (private vehicles, taxi, uber, carpooling etc.)

11. Please indicate roughly how far your home is to ION LRT station?

- ☐ Less than 500 meters
- ☐ 501 meters–1,000 meters
- ☐ 1,001–1,500 meters
- ☐ 1,501–3,000 meters

- 3,000–5,000 meters
- More than 5,000 meters

Page 3: Questions 12–18 will ask you questions related to bike, bike usage, bike infrastructure and your opinions towards bike.

12. Do you own a working bicycle?

- Yes
- No

13. Thinking about your day-to-day transportation over the last year, how often did you use a bicycle (including using bike share) for the following purposes?

	Three times a week or more	**Once a Week or more**	**Once a Month or more**	**Less than once a Month or Never**
Commute to work/school	☐	☐	☐	☐
Recreation/exercise	☐	☐	☐	☐
Other trips (Shopping, visiting Friends etc.)	☐	☐	☐	☐

14. What are the reasons that discourage you to use bike a feeder mode of transportation to access the ION LRT stations in fair weather condition? (select all applies to you)

- I do not own a bike.
- I do not know how to ride a bike.
- I do not like to bike.
- There is no bike-share around my home to the LRT station.
- There is no designated bike lane near me that leads to LRT station.

- ☐ There is no bike parking near the LRT station.
- ☐ I do not feel safe to bike on the road.
- ☐ Lack of ability to carry items by using a bike.
- ☐ I do not feel safe to park my bike at the LRT stations/bike theft concerns.
- ☐ Limited space on the LRT
- ☐ Road condition
- ☐ Others, please specify: ____

15. What are the following reasons will help to encourage you to use bike as a feeder mode of transportation to access the ION LRT stations in fair weather condition? (select all applies to you)

- ☐ Bike-share service expansion to my neighbourhood or my destination.
- ☐ More protected bike lanes or painted bike lanes that leads to the LRT stations.
- ☐ Additional bike parking at the LRT stations.
- ☐ Better cycling network around the LRT stations.
- ☐ Bike learning and cycling safety program(s) provided by the local government.
- ☐ Program(s) that help to increase automobile drivers' awareness of sharing road with cyclists.
- ☐ Others, please specify: ____

16. How important would the following bike infrastructure affect your decision to bike as a feeder mode to access or egress the LRT stations?

	Very Important	**Somewhat Important**	**Neutral**	**Somewhat Not Important**	**Not at All Important**
On-street painted bike lanes	☐	☐	☐	☐	☐
Separated bike lanes	☐	☐	☐	☐	☐
Off-street bike lanes (Multi-use trails)	☐	☐	☐	☐	☐
Cycling network connectivity	☐	☐	☐	☐	☐
Bike lane signage and designated signal for cyclists	☐	☐	☐	☐	☐
Secure bike parking	☐	☐	☐	☐	☐
Bike share availability	☐	☐	☐	☐	☐
Bike repair station	☐	☐	☐	☐	☐

17. Both regional and municipal governments have invested in bike infrastructures, such as implementing permanent bike lane projects, improving cycling network connections, separated bike lane pilot projects and adding bike parking on the street in the past few years and more projects are planned in the next few years.

    In 2019, many bike related projects were implemented by local government, such as separated bike lane pilot projects on University Avenue, and on Erb Street in Waterloo and separated bike lanes pilot project on Queen Boulevard, and permanent bike lane instalments in downtown in Kitchener.

    Further, the Waterloo Region partnered with Drop Mobility to provide bike share pilot program in Kitchener, Waterloo and Cambridge.

    Do you think the all the actions that were taken by the local governments will make you to consider using bike as a feeder mode to access LRT stations in fair weather condition?

    - ☐ Yes, I would like to try using the bike as a feeder mode to access LRT station.
    - ☐ No, I would stay the same by using the current transportation mode to access LRT station.

18. Please briefly explain the reason(s) for your choice on Question 17.

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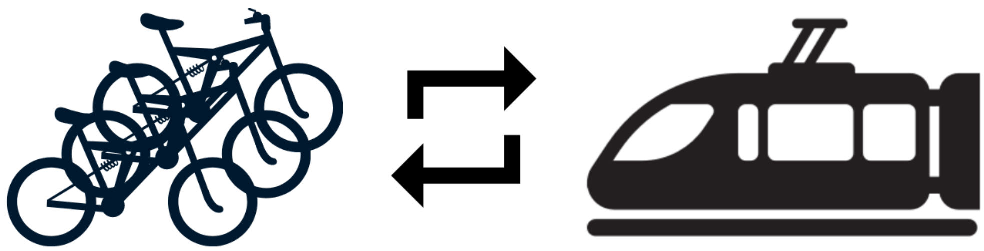
Appendix C–Recruitment Materials

Invitation to Participate

Researchers from University of Waterloo
are seeking adults LRT riders to
participate in a study regarding:
Bike-LRT Integration



If you would like to participate, please follow the link below for more information and the online survey:

https://bit.ly/2Y6XgpH

or Scan the QR code on your mobile device.

The survey will take approximately 15-20 minutes. Participants will be able to enter in a draw to win 1 of the 10
- $20 Tim Hortons Gift Cards.

Participants must be at least 18 years of age and able to provide consent to the study. This study has been reviewed by, and received ethics clearance through a University of Waterloo Research Ethics Committee. This research is not affiliated with the Region of Waterloo and is not an extension of any previous or current study by the Region of Waterloo.

UNIVERSITY OF WATERLOO

Recruitment Message on Social Media

Hello everyone! My name is Long Lin, a second-year urban planning master student from the University of Waterloo. I am currently looking for ION LRT riders who are 18 years or older to participate in my thesis research study of bike-transit integration in Kitchener-Waterloo. My study focuses on what will encourage LRT riders to use bike as a feeder mode to access the LRT stations. By participating the study, you will be able to leave your email address to enter a draw of winning 1 of the 10 - $20 Tim Horton's gift card. All the data collect from the survey will only be used towards my study and your identity will be confidential. More details about the study are available through the link in the information letter section. Please follow the link: https://bit.ly/2Y6XgpH or scan the QR code in the flyer below to access the information letter and the survey. Thank you very much! This thesis research study is supervised by Dr. Joe Qian, Associate Professor at the School of Planning of the University of Waterloo. The study has been reviewed by and received ethics clearance through a University of Waterloo Research Ethics Committee. If you any question regarding this study or would like additional information to assist you in reaching a decision about participation, please contact me at long.lin@uwaterloo.ca.

Information Letter

Title of Study: Bike-Light Rail Transit (LRT) Integration Study in Kitchener-Waterloo

Faculty Supervisor: Dr. Joe Qian, Associate Professor, Ph.D., School of Planning, University of Waterloo. Email: z3qian@uwaterloo.ca

Student Investigator: Long Lin, Master's Candidate, School of Planning, University of Waterloo Email: long.lin@uwaterloo.ca

To help you make an informed decision regarding your participation, this letter will explain what the study is about, the possible risks and benefits, and your rights as a research participant. If you do not understand something in the letter, please contact Long Lin prior to consenting to the study.

What is this study about?

You are invited to participate in a research study about the bike-light rail transit (LRT) integration in the City of Kitchener and the City of Waterloo, Ontario. The purpose of this research is to determine the factors that will encourage daily LRT riders to use bike as a feeder mode to access or egress the ION Light Rail Transit (LRT) stations from their homes to their final destinations. This research is important because studies have shown that better cycling network and bike infrastructure that integrate to the existing transit network will encourage people to bike in general. Examining the current gaps in cycling network, bike infrastructure and factors to encourage current riders to bike will provide insights and opportunities for local municipal government to identify priority in bike-related projects.

The work is being undertaken as part of my (Long Lin) Master's Thesis research. The research will be used to demonstrate the important factors that influence riders to use bike as a feeder mode to access or egress the LRT stations and possibilities to make the cities more bikeable.

I. Your responsibilities as a participant

What does participation involve?

Participation in the study will consist of one session, in which you will be asked to complete an online survey that is expected to take approximately 15 to 20 minutes. The survey will ask questions about your usage of the Light Rail Transit (LRT), the purpose of using LRT, your opinions about bike as a potential mode of transportation, and some demographic information. Surveys will be completed online though Qualtrics™, or a similar online survey platform, and hard copies can also be made available. The survey link can be found in the Consent Form. It is important to note when information is transmitted over the internet privacy cannot be guaranteed. There is always a risk your response may be intercepted by a third party (e.g., government agencies, hackers.) University of Waterloo researchers will not collect or use internet protocol (IP) addresses or other information which could link your participation on your computer or electronic device without first informing you.

Who may participate in the study?

In order to be involved in this study, you must be at least 18 years of age and be able to understand and read English.

II. Your Rights as a participant

Is participation voluntary?

Your participation in this study is voluntary. You are not required to complete the survey and may decline from answering any questions you prefer not to answer. The survey is anonymous, and you will not be asked for your name or any identifying information. Once the survey responses have been submitted, there is not possible way to withdraw your consent to participate because there will be no way to identify which survey responses are yours. However, if you wish to participate in the draw of winning one for the prizes or if you wish to receive the results of the study, your identity will not be anonymous. To ensure the confidentiality, the email address of the participants will be kept in a separate file. Only those associated with this study will have access to these records, which are secured by password protection. Records will be kept for at least 2 years. All records will be destroyed according to University of Waterloo policy.

Will you receive anything for participating in the study?

Upon completion of the survey, you will be entered into a draw, by entering your email, to win 1 of 10 - Tim Hortons gift cards valued at $20. Your email will not be linked to your survey responses. Your odds of winning one of the prizes is based on the number of individuals who participate in the study. We expect the approximately 250 individuals will take part in the study. Information collected to draw for the prizes will not linked to the study data in any way, and this identifying information will be stored separately, then destroyed after the prizes have been provided. The amount received is taxable. It is your responsibility to report this amount for income tax purposes. Should you wish to know the results of the study, you can leave your email (which will not be linked to your survey responses) and a summary of the results will be sent to you.

What are the possible benefits of the study?

Participation in this study may not provide any personal benefit to you, but it may contribute to an understanding of the factors influence of bike-transit integration in the mid-size city in urban planning and to the academic planning community.

What are the risks associated with this study?

There are no known or anticipated risks associated with this study.

Will your identity be known?

Your participation and survey responses will be confidential, and those associated with this study will not know the identity of the participants. The participants' email address will be stored separately from the survey responses, your survey responses will not be linked to your email. The email address will be only used to contact the winners of the draw and participants who wish to receive the results of the study.

Will your information be kept confidential?

Your identity will be kept confidential. All information gathered from participants will be aggregated, and only the research team will have access to study data. Data will be stored in an encrypted folder on my password protected laptop. No identifying information will be used in my thesis or any presentation or publications based on this research.

III. Questions, comments, or concerns

Who is sponsoring/funding this study?

The study is not funded by any person or organization.

How to enter the draw of winning the prizes if you wish to stop participating during the survey?

If you wish to stop participating in the study during the survey, the participants can simply click the "→" button at the bottom of each page and leave the rest of the response blank to reach the end of the online survey and leave your email address to enter the draw. Your survey response will not be linked to the email address.

Has the study received ethics clearance?

This study has been reviewed and received ethics clearance through a University of Waterloo Ethics Committee (ORE#42052). If you have questions for the Committee contact the Office of Research Ethics, at 1-519-888-4567 ext. 36005 or ore-ceo@uwaterloo.ca.

Who should I contact if I have questions regarding my participation in the study?

If you have any question regarding this study, or would like additional information to assist you in reaching a decision about participation, please contact Long Lin by email at long.lin@uwaterloo.ca

Please complete the following questions of informed consent:

I have read the Information Letter posted above.

- Yes
- No

By providing your consent, you are not waiving your legal rights or releasing the investigator(s) or involved institution(s) from their legal and professional responsibilities.

I agree of my own free will to participate in the study.

- Yes
- No

I have had the opportunity to ask questions related to the study and have received satisfactory answers to my questions and any additional details.

- Yes
- No

I was informed that participation in the study is voluntary and that I can withdraw this consent by informing the researcher.

- Yes
- No

I give permission for use of anonymous quotations on any thesis or publications that comes from this research.

- Yes
- No