SHARED ELECTRIC BICYCLES: WHO ARE THE POTENTIAL USERS?

AN EXAMINATION OF SURVEY RESULTS FROM URBAN AND SUBURBAN NEIGHBOURHOODS IN THE GREATER GOLDEN HORSESHOE AREA

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Abstract

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Bicycle sharing systems based on electric bicycles (e-bikes) have the potential to provide users with unique benefits compared to conventional bike sharing systems and privately owned e-bikes. It follows that their use-patterns and motivations would also be unique. Through an online transportation survey, this research examines the socio-demographic, attitudinal, and environmental factors that influence a respondent's propensity to consider using a shared e-bike. It was revealed that a similar proportion of people living in urban and suburban areas are willing to consider this micro-mobility option. Additionally, it appears that in urban environments, shared e-bike systems are more likely to replace transit and walking trips, while in suburban environments, they are more likely to replace car trips. The results of the analysis indicate that all respondents with income less than $50,000 (OR=1.08), suburban respondents who already own a bicycle (OR=1.06), suburban respondents who valued active, environmentally friendly, cost effective, and flexible transportation modes (OR=1.07), urban respondents who felt they had connective cycling infrastructure near them (OR=1.09), urban respondents who felt the streets were not too congested (OR=1.08), and suburban respondents who felt walking and cycling were practical ways of getting to their destinations (OR=1.11) were more likely to consider use of shared e-bikes. All respondents who do not travel for work or school (OR=0.89) and urban respondents whose primary commute modes were active (walking or cycling) (OR=0.93) were less likely to consider shared use of shared e-bikes. The findings reported in this study can be useful for transportation planners in evaluating the feasibility of implementation, and optimizing the strategic placements of shared e-bike schemes in urban and suburban areas.

Key Words: Active Transportation, Electric Bicycle, Bike Share, Greater Golden Horseshoe Area, Micro mobility

Acknowledgements

I would like to acknowledge and thank Professor Raktim Mitra for sharing his vast wealth of knowledge in the field of transportation planning with me. I would also like to thank Professor Matthias Sweet for his help in reviewing this study.

Transportation planning, particularly within Toronto and the GTA, has always been a topic of interest for me. As Toronto continues to grow, we, as a city, need to find ways of relieving traffic and transit congestion – I strongly believe that cycling has the potential to play a large role in this. Based on many anecdotes I've heard throughout the years, I believe the issues with cycling in Toronto are vast – from lack of political will in constructing adequate infrastructure, to a culture strongly rooted in private automobile use, to concerns about safety and theft. Having used a shared e-bike system in San Francisco several years ago, I believe in the potential of these systems in helping to address some of these barriers.

Cycling is something I am passionate about – my daily cycle trips to school and other destinations are a time for me to shut off my brain to the stresses and anxieties surrounding me. The involvement of physical exercise in my daily routine helps to keep my mind clear and my body healthy – something that I feel uplifts my spirits. This is especially apparent as I am writing the bulk of this paper in the height of the COVID-19 virus; with the majority of the province in quarantine, I've noticed an increase in cycling within the downtown area of Toronto, which has started me thinking about the resiliency of cycling as a form of transportation, giving users the independence to travel wherever and however they want. My hope is that this study may help, if even in the slightest, to inform decision makers, and improve the overall landscape for both current and potential cyclists.

Despite not having the option of taking a transportation elective during my two years of this master’s program, the opportunity to work with Professor Mitra has been of great value to me in further learning about this area within planning. His patience and guidance along every step of the way has been much appreciated.

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Chapter 1 Introduction

Cycling as a mode of transportation has been a much discussed topic within modern transportation planning discourse due to its low cost, zero carbon emissions, and benefits on human health (DeMaio, 2019; Dill, 2009; Fishman, Washington, & Haworth, 2013; Oja, Titze, Bauman, De Geus, Krenn, Reger-Nash, & Kohlberger, 2011; Shaheen, 2019; Shaheen, Guzman, & Zhang, 2010). The 21st century has seen rapid innovations in urban cycling; in particular, the arrival of electric bicycles, or e-bikes, has the potential to transform the mobility of people within cities worldwide, as within the Chinese market which has constituted the majority of growth in e-bikes to date. From 1998 to 2012, nearly 200 million e-bikes were sold in China, with the annual sales continually increasing (Ling, Cherry, Yang, & Jones, 2015). In the Province of Ontario, Canada, e-bikes are broadly defined as “motorized bicycles that can look like conventional bicycles, scooters, or limited-speed motorcycles” (Ministry of Transportation Ontario, n.d.). This definition captures both “electric moped scooters” and “pedal-assist” options, but this paper will be focusing on the latter, which looks and operates much like a traditional bicycle, and is similarly powered by human muscle but is equipped with a battery that enables the option of electric propulsion to assist the cyclist (Edge & Goodfield, 2017).

While the use of e-bikes has proliferated (particularly in China), bike sharing systems have also rapidly grown in popularity worldwide, as cities make investments in alternative transportation schemes to help improve mobility and reduce car dependency (Shaheen, Martin, Chan, Cohen, & Pogodzinski, 2014; Dill & Rose, 2012). It has been noted that bicycle sharing systems based on electric bicycles (e-bikes) have the potential to provide users with unique benefits compared to conventional bike sharing systems, while maintaining low environmental impacts (Langford, Chen, & Cherry, 2015). North America's first electric bike share scheme was introduced in Birmingham, Alabama, in 2015 (Willerton, 2015), and have since proliferated into other cities in the US, including Columbus, OH; New York City, NY; San Diego, CA; and San Francisco, CA.

It has been noted that e-bikes may help reduce barriers to cycling: a user is able to bike faster, for longer distances, carry more cargo, and overcome hills with much less effort than when using a conventional bicycle. This reduction of barriers increases mobility for people who would otherwise not be able to bike because of physical limitations or proximity to destinations (Macarthur, Dill, Person, 2014; Johnson & Rose, 2015). Despite the transformative potential of e-bikes, few studies have investigated how they could be integrated into a shared municipal system that best suits a city's unique transportation, weather, environmental, and demographic conditions (Campbell, Cherry, Ryerson, & Yang, 2016; Azad & Cherry, 2017).

Furthermore, it is clear from the literature that the use-patterns and motivations of shared e-bike schemes are distinct from both conventional bike sharing systems and individually-owned e-bikes (Shaheen & Cohen, 2019). These unique characteristics might yield unique challenges that are not currently well-understood; this may be particularly true of suburban areas that have not yet been introduced to shared e-bike schemes, given that the limited work that does exist on shared e-bike schemes primarily focuses on urban contexts. It is important to examine how potential users of shared e-bike schemes might differ in urban and suburban settings in order to better inform transportation planners and policymakers and optimize their future implementation strategies. For example, it may be observed that those living in suburban neighbourhoods in close proximity to regional transit (e.g. GO Transit) are more likely to use shared e-bikes as a first- and last-mile connector. This may be because they are less amenable towards human-powered mobility options, but more receptive towards e-bikes, which are quicker and requires less effort – this information would be vital for city planners in deciding the setup of the e-bike share scheme. Further, the potential role in which the public sector plays in the future of shared electronic micro-mobility is unclear, given that shared mobility schemes commonly require a unified effort involving private, public, and nonprofit providers of service. It could be the case that a private corporation takes over as the provider of the service, and the public sector's subsequent role would be as a regulator, setting out policies to oversee the shared e-bike scheme. In this case, the results of the study presented here may be key for municipal and provincial governments looking to create policies in order to regulate future potential shared e-bike schemes.

The research presented in this major research paper (MRP) is novel in that the majority of existing literature focuses on socio-demographic characteristics of users of the few existing pilot e-bikeshare programs, with limited knowledge on current and potential users' travel attitudes, and built-form and environmental factors, a gap that this study aims to fill. Additionally, the majority of existing research has some self-selection bias, as many of these studies are focused on current qualities and characteristics of a single group of current users of these systems. By contrast, the work I am presenting looks at potential users from both urban and suburban neighbourhoods. By collecting information from potential users, rather than current users, this study can identify the factors that influence an individual's intention to use shared e-bikes. It is important to study both current and potential users of shared e-bike systems: the factors that influence use of shared e-bike systems, such as perceived usefulness, are expected to affect the groups differently.

This paper presents the unique perspective of socio-demographic and attitudinal characteristics in the specific context of the Greater Golden Horseshoe (GGH) region, including numerous environmental variables, most notably the distinction of responses from urban and suburban neighbourhoods. Based on the online survey of 1,640 adults living in 17 neighbourhoods in Toronto and surrounding municipalities in Ontario, Canada, this study examines the above-mentioned factors that potentially influence an individual's self-reported intention to consider replacing some of their current trips with shared e-bikes if they were to become available on a pay-per-use basis in their neighbourhood.

Research Questions:

1) To what extent are the neighbourhood residents willing to replace some of their current trips with shared e-bike trips if they were to become available in their neighbourhood on a pay-per-use basis? What current modes of transportation would these trips replace?
2) What socio-demographic, attitudinal, and environmental factors are related to the intent to use a shared e-bike?
3) Do intentions to replace current trips with shared e-bike trips vary between residents of urban and suburban neighbourhoods?

1.1 Paper Direction

In this Masters Research Paper (MRP), I analyzed survey results from residents of the

GGH region who reside in the vicinity of a bicycle facility (such as a cycle track, painted bicycle lane, or off-street cycle path) and examine socio-demographic, attitudinal, and environmental factors that may influence their intention to consider adopting shared e-bikes. Factors explored include socio-demographic characteristics, such as age, gender, education, and income; travel behaviours and attitudes, such as current primary transportation mode(s) and length of commute; and built environmental factors, such as the distinction between urban and suburban neighbourhoods, perception of safety, congestion, and connections to important destinations.

This paper begins with a Literature Review in Chapter 2. I start by discussing the history of bike share systems and the current literature on both bike share and e-bikes. I then discuss existing literature on shared e-bikes, and highlight all gaps in current knowledge. Chapter 3 will discuss the methods used – including the study design, the area examined, the data retrieved, and the conceptual framework of specific variables explored. The Results & Discussion section (Chapter 4) first provides a high level summary of the data collected, such as age, gender, and income distribution amongst the 1,640 survey respondents. Then, results from both bivariate and multivariate logistic regression models will be presented to illustrate the difference between those willing and unwilling to adopt e-bikeshare in regards to socio-demographic, attitudinal, and environmental characteristics. The results from the two models are then discussed to outline significant correlations between specific variables and the propensity and willingness to adopt e-bikeshare as a practical and realistic mode of transportation. Chapter 4 ends with some discussion about the specific challenges and limitations of this study. Chapter 5 will conclude this paper with a discussion on the implications of the findings from the analysis, and make recommendations that aim to advance our current knowledge and inform future policy.

The ultimate goal of this paper is to inform transportation planners and government bodies of the factors that may influence the adoption of shared e-bikes. Using this analysis, planners can make more informed decisions regarding the implementation of future shared e-bike systems.

Chapter 2 Literature Review

In this section, I start by discussing the history of bike share systems, from the 1st generation launched in 1965 to the current 4th generation, which is currently in development. I will then discuss the current literature on both bike share and e-bikes, highlighting the benefits, demographic characteristics of users, user motivations and preferences, effect on modal shifts, and safety concerns of each. Last, I will discuss existing literature on shared e-bikes, and highlight gaps in current knowledge.

<u>2.1 History of Bike Share</u>

Bike share systems provide users with on-demand access to bicycles at a variety of pick-up and drop-off points for one-way (point-to-point) or round-trip travel. There are various service models for bike share systems, including station-based bike sharing schemes, offering users access to bicycles through unattended stations offering one-way station-based service, and dockless bikesharing, where bicycles can be picked up anywhere and left in any location (Shaheen & Cohen, 2019). The growth of bike share systems was slow before the development of several new technologies and better tracking systems. The history of bike sharing can be broken up into four generations, according to DeMaio (2009). The 1st generation began in 1965, when Amsterdam launched its *White Bikes* program, providing ordinary, white bicycles for public use. The program collapsed within days as the bikes were thrown into canals or stolen for private use. The 2nd generation was born in Denmark and Copenhagen in the 1990s, with bikes designed specifically for intense utilitarian use, which could be picked up and returned at specific locations throughout the central city. Despite a coin deposit system, the system still experienced high theft rates due to user anonymity. These issues gave rise to the 3rd generation of bike share systems, which began in 1996 in England, and were characterized by technological improvements such as electronically-locking racks, telecommunication systems, smart cards and fobs, mobile phone access, and on-board computers. By 2009, there were more than 120 3rd generation programs active globally (DeMaio, 2009), and as of 2019, there were 572 bike sharing schemes operating in 474 cities worldwide (Meddin, 2019)

The features of 4th generation systems are currently under development, and will be characterized by improved efficiency, sustainability, and usability. These goals will be accomplished by improved distribution of bikes, installation, powering of stations, tracking, the potential of offering dockless systems, and of e-bikes within the systems (Demaio, 2009; Fishman, 2016).

2.2 Bike Share: User Impacts & Demographics, Mode Substitution, & Travel Preferences

Station-based bike sharing provides users with on-demand access to bicycles via unattended stations offering one-way travel. It has been suggested that by addressing the storage, maintenance, and parking aspects of bicycle ownership, bike sharing encourages cycling among users who might not otherwise use bicycles (Shaheen, 2019).

There are various potential user impacts of bike share, including increased mobility and flexibility, reduced greenhouse gas emissions, decreased automobile use, economic development, and public health benefits. Bike sharing can also be used to help bridge first- and last-mile gaps within transportation systems to encourage multimodal trips (DeMaio, 2009; Fishman, Washington, Haworth, 2013; Shaheen, 2019)

Demographics: several studies based in North America have determined that users of shared bicycle schemes were often Caucasian, younger and upper-to-middle income, with higher levels of education (Shaheen & Cohen, 2019; Shaheen, Martin, Chan, Cohen, & Pogodzinski, 2014; Shaheen, Martin, Cohen, & Finson, 2012). Fishman et al. (2013) explored Washington, DC's bike share system and found that compared to the general population, bike share members had significantly higher employment rates and education levels, lower average age, and were more likely to be male and Caucasian living within the inner urban area (with only 2% of users being African American). Another study, also focused on Washington DC's bike share system, found bike share users were more likely to be female and younger, to have lower household incomes, and to own fewer cars and bicycles and were more likely to cycle for utilitarian purposes compared to regular cyclists (Buck, Buehler, Happ, Rawls, Chung, Borecki, 2013).

Where most studies have concluded that men are more likely than women to use bike share, research on Montreal's BIXI scheme found that men and women have roughly the same likelihood of using bike share (Fuller, Gauvin, Lestens, Daniel, Fournier, Morency, & Drouin, 2011). Other significant correlates of use included having a docking station within 250m of home, being aged 18-24 and university educated, and using cycling as a primary mode of transportation to work (Fuller et al., 2011). It appears that, on average, bike share users are more likely to have disproportionately higher education and income, and are more likely to be male and white.

Mode substitution/shift: Bike sharing has generally been found to decrease private automobile use while increasing cycling. A study by Shaheen et al. (2012) found that half of all bike sharing members reported reducing automobile use. However, other studies have warned about the over-exaggeration of users transferring from private automobile use to public bicycles, given that it is quite common for the majority of bike share trips to be substituting other sustainable modes of transportation such as walking and transit (Fishman et al., 2013; Shaheen, Zhang, Martin, & Guzman, 2011; Shaheen, Martin, Cohen, & Finson, 2012)

In a 2015 study, Shaheen & Martin surveyed bike sharing members of four metropolitan regions (Montreal, Toronto, Washington, and Minneapolis-Saint Paul) and found that modal shifts away from public transit due to bike sharing were most prominent in urban environments with high-density urban cores. On the other hand, shifts toward public transit in response to bike sharing were more prevalent in the lower-density regions of urban peripheries. The implication is that bike sharing may serve as a first-and-last-mile connector in smaller cities and/or cities with lower densities and less robust transit networks, whereas in larger metropolitan regions with high densities and more robust transit networks, bike sharing offers quicker, cheaper, and more direct connections compared to short-distance transit trips. The main finding from Shaheen et al. (2015) is that public bike sharing tends to be more complementary to public transit in small and medium cities, and more substitutive in larger cities, helping to provide relief to over-crowded transit lines. These findings are in line with the results of a study of bike sharing in New York City, which linked notable decreases in bus ridership with the increase of bike sharing docks along a bus route (Campbell & Brakewood, 2017)

Travel Preferences, Motivation, Purpose: Members of North American bike sharing schemes often use bike share for commuting purposes (Shaheen et al., 2012; Fishman et al., 2013). Members also commonly integrate bike share as part of a trip chain, combining their bike share trips with other modes such as public transportation. Additionally, walking was found to be the most common linking mode, with many indicating they walked in combination with their bike share use (Fishman et al., 2013). Shaheen et al. (2012) also found that non-members (or daily pass holders) tended to use the system more for recreational trips. Additionally, a Montreal survey found that proximity of residences to docking stations (within 250m) to have a strong positive influence on the tendency to use bike sharing (Bachand-Marleau, Lee, El-Geneidy, 2012; Fishman et al., 2013; Fuller, Gauvin, Lestens, Daniel, Fournier, Morency, & Drouin, 2011).

Weather conditions, including temperature, rainfall, snow, wind, fog, and humidity may influence usage rates of bike share. In a study of the Washington, DC bike share system, cold temperatures, rain, and high humidity levels were found to reduce the rate of bike share usage and trip duration (Gebhart & Noland, 2014; Pucher & Buehler, 2006). Trips taken from bike share docking stations near metro stations are greater affected by rain than trips further from metro stations (Gebhart & Noland, 2014).

2.3 E-Bikes: User Impacts & Demographics, Mode Substitution, & Travel Preferences

The majority of literature on e-bikes has examined the context within China, where the e-bike market has boomed over the past two decades, and there are now more e-bikes in use than conventional bicycles (Cherry, Yang, Jones, He, 2016). There is little known about North American use patterns of e-bikes, where barriers to adoption include a lack of widespread acceptance of cycling as a viable alternative to motorized transportation modes, slow growth of cycling infrastructure, and cold winters with poor road conditions.

Demographics: A 2007 survey of two large Chinese cities, Kunming, and Shanghai, found that the greatest difference between conventional cyclists and those using e-bikes comes from household income and education level, which are both significantly higher for e-bike users. In these two cities, there is roughly a 50% gender split among both e-bikes and bicycles. Older respondents generally indicated they were more likely to take the bus than walk or ride a bicycle in the absence of e-bikes (Cherry & Cervero, 2007).

User Impacts: Dill & Rose (2012) interviewed 28 e-bike owners in Portland provided insight into the potential market and use of e-bikes in North America. Owners of e-bikes noted their ability to travel longer distances and over hills with relative ease and to arrive at a destination less sweaty and tired than a regular bicycle would allow. These features and insights revealed that e-bikes could expand the bicycling population to include more women, older adults, and people with physical limitations by reducing the above-mentioned barriers to cycling (Dill & Rose, 2012).

Another survey of e-bike owners in Australia focused on responses from participants aged 65 and older. The majority of these respondents rode their e-bike weekly and replaced trips taken with private automobile. The respondents felt safer on e-bikes compared to conventional bicycles, and indicated that it helped to increase regular physical activity. Motivations for purchasing an e-bike included riding with less effort, replacing car trips, maintaining or increasing health, overcoming hills, riding with a medical condition, or keeping up with family and friends. The study concluded that initiatives and policies to support e-bike use may increase uptake by older people in Australia (Johnson & Rose, 2015).

Travel Preferences, Motivation, Purpose: The WeBike project, in which 30 e-bikes were given to members of the University of Waterloo, Canada, for personal use, found that the primary trip purpose of e-bikes was for commuting, with most trips lasting less than 20 minutes and taking place in the summer months (though it was also found that e-bike use continues throughout the winter months). When asked their opinions on the various transportation options, participants rated regular bicycles higher than e-bikes, even after using e-bikes through the field trial (Gorenflo, Rios, Golab, Keeshav, 2017)

Cherry and Cervero (2007) found that in the Chinese context, e-bike users travel considerably more than conventional bicycle users, and speed was the primary reason for adoption. The higher the travel time of other modes, the higher the likelihood of choosing an e-bike. The authors also noted that user attitudes affect an individual's choice in using e-bikes, with users primarily citing speed, effort, safety, and crowded transit as factors that influence their choice to use e-bikes (Cherry & Cervero, 2007).

Johnson and Rose (2015) reported that older adults felt safer on e-bikes compared to conventional bicycles. Most also indicated that it helped to increase regular physical activity. Motivations for purchasing an e-bike included riding with less effort, replacing car trips, maintaining or increasing health, overcoming hills, riding with a medical condition, or keeping up with family and friends. The study concluded that initiatives and policies to support e-bike use may increase uptake by older people in Australia (Johnson & Rose, 2015).

Mode substitution/shift: Dill & Rose (2012) found that in Portland, most e-bike owners used their e-bikes to substitute for either conventional bicycle or private automobile vehicles. Johnson & Rose's (2015) study of e-bike owners (aged 65 and older) supports these findings, with the majority of e-bike trips replacing trips taken with private automobiles. In China, Cherry & Cervero (2007) found that since travel time of a trip significantly influences alternative mode choice, most e-bike users would travel by bus if their e-bikes were unavailable. The same study found that e-bikes displace only a small amount of car trips (Cherry & Cervero, 2007). However, in a later study, it was found that e-bikes are replacing many urban car trips in Kunming, China (Cherry, Yang, Jones, He, 2016). At the same time, many who transition into e-bikes from non-motorized modes (waking, cycling) would transition out of e-bikes for a more motorized mode (bus, taxi, car). The authors observed a general decrease in popularity of bicycle and bus modes, and an increased popularity of car and taxi modes, which could imply that e-bikes are enabling more personal mobility and increases the probability of shifting towards personal modes of transit (Cherry et al., 2016)

2.4 E-Bike Share

There have been some small e-bikeshare pilots (in Europe and the US), with about 4000 total e-bikes across bikeshare systems in 2014 (Campbell, Cherry, Ryerson, & Yang, 2016; Langford, Cherry, Yoon, Worley, & Smith, 2013). Langford et al (2013) studied the experiences from North America's first e-bikesharing scheme (cycleUshare) at the University of Tennessee, Knoxville. The system launched with two stations as a small pilot project and was open to students, faculty, and staff from the University. With 93 enrolled users, the study found that only 22% of the users accounted for 81% of all trips taken. Speed and convenience were major deciding factors in the participants' decisions to use the system, and speed and comfort were the most cited factors for selecting an e-bike over a regular bicycle. They found that e-bike users could travel greater distances within a shorter time frame than conventional cyclists, which facilitated additional stops. Though the majority of trips were for utilitarian purposes (travelling to campus and classes), trips by e-bike were still shown to have been taken for a wider variety of purposes than regular bicycle trips. Walking was the mode most displaced by the e-bikeshare system, indicating that e-bikeshare expanded user mobility. Of interest was the fact that a larger number of female users agreed that regular bicycles were more attractive than e-bikes because they were more maneuverable and provided better exercise opportunities.

A similar study was conducted by Ioakimidis et al. (2016) at the University of Mons (UMONS), Belgium, in order to identify the key factors that influence the use of an e-bike sharing system among students. The majority of respondents indicated they would rent an e-bike for its practicality, comfort, and ecological benefits. Other reasons included its ease of use, being able to avoid traffic congestion, and saving on transportation costs. As for trip purpose, the majority of respondents indicated they would use it for commuting purposes, while a smaller group cited sightseeing and entertainment as a motivation for e-bikeshare adoption. Reasons why a user would not use shared e-bikes included weather conditions (the most cited reason), lack of bicycle lanes in Mons, perceptions of e-bikes as unsafe, preference for conventional bicycles, and preference for public transportation (Ioakimidis, Koutra, Rycerski, & Genikomsakis, 2016).

In another study, Campbell et al. (2016) explored factors influencing the choice of both shared bicycles and shared electric bikes in Beijing. The authors found that the demand for e-bike share was strongly negatively impacted by "heavy rain". However, where classic bikeshare demand was negatively impacted by poor air quality days and high/uncomfortable temperatures, e-bikeshare demand was not as sensitive to this. The authors also found that in Beijing, unlike bikeshare, e-bikeshare appealed to a distinct social demographic: young to middle age males who tend to have low income and education levels. The results indicated that e-bikeshare can be deployed with more targeted purposes than classic bikeshare in Beijing. Campbell et al. (2016) outlines several potential use scenarios for e-bike share in Beijing, including to provide relief to over-subscribed bus routes, as they provide superior mobility and speed in urban locations.

Finally, there has been some research into the more technical components of deploying an e-bikeshare scheme, which is out of the scope of this particular study. This includes research looking into the optimal design of an e-bike sharing system, in terms of system requirements to successfully develop and deploy an e-bike sharing system (e.g. system architecture, operational concepts, and battery management) (Thomas, Vallee, Klonari, & Ioakimidis, 2015; Ji, Cherry, Han, Jordan, 2014; Cherry, 2010).

2.5 Gaps in current literature

The majority of existing knowledge focuses on user surveys and system-use data analysis of conventional bike share schemes, as in the literature described above (Ji, Cherry, Han, & Jordan, 2014; DeMaio, 2009; Fishman et al., 2013; Shaheen et al., 2011). These investigations have identified common factors that influence conventional bikeshare adoption, such as location, user benefits, demographics, environmental conditions, and safety, but few studies describe methods for investigating the viability of new technologies such as e-bikeshare. Further, much of the research is based on surveys among current users. (Buck et al., 2013; Gebhart & Noland, 2014; Martin & Shaheen, 2014). The research presented in this paper addresses this gap, as the 1,640 respondents of the survey were recruited based on their proximity to a major bicycle facility as opposed to the self-selected sample of current bikeshare, e-bike, and e-bikeshare users in which most existing analysis is based on. Additionally, the influence of an individual's travel behaviours and attitudes in propensity to consider e-bikes and shared e-bikes is an understudied area in existing literature; the few studies that do exist on this topic focus on privately owned e-bikes (Cherry & Cervero, 2007), and do not explore statistical correlation between these attitudinal factors and likelihood of using a shared e-bike.

Current trends suggest that e-bikes will proliferate in the 4th generation of bike share schemes. However, there is no known research into how a large-scale e-bikeshare system would be used, and how cities can implement them in a way that best suits their unique transportation, weather, and demographics. The few studies that do exist on e-bike share systems have focused on either small-scale pilots on university campuses, factors influencing use in Chinese cities, or the technical system requirements for e-bike share deployment.

Chapter 3 Methods

This chapter describes the methodological approaches adopted to explore this study's key research question focusing on socio-demographic, attitudinal, and environmental factors that potentially influence the adoption of shared e-bike systems. First, the study area, survey design, and data retrieved are described. Next, the conceptual framework of the study is discussed, highlighting the specific socio-demographic, attitudinal, and environmental variables that were selected for analysis. Finally, a discussion of the statistical methods used to analyze the data set is presented.

3.1 Study Area

This study is set in the Greater Golden Horseshoe (GGH) region of Ontario, representing the largest urban region and economic centre in Canada, supporting a population of approximately 8.8 million in 2016 (Statistics Canada). None of the municipalities within the GGH has piloted shared e-bike systems – though Waterloo's WeBike Project provided 30 e-bikes (private, not shared) to members of the University to identify and study trip preference and attitudinal factors.

While the use of e-bikes is currently legal under legislation from the Ontario Ministry of Transportation (given certain stipulations, such as mandatory pedals, a maximum speed of 32km/h, a maximum weight of 120kg, etc.), there are no shared e-bike systems that exist in Ontario as of the beginning of 2020. However, as part of a major expansion planned for 2020, the Toronto Parking Authority (TPA), which oversees Bike Share Toronto, has announced plans for the addition of 300 e-bikes to the system, as well as an expansion in the number of docking stations and to the fleet of existing bicycles (Smee, 2020).

3.2 Study Design & Data

Data for this study was collected from an online transportation survey conducted in 17 urban and suburban neighbourhoods located in major cities within the GGH region (6 in Toronto, 4 in Hamilton, 3 in Kitchener-Waterloo, 2 in Ajax, and 2 in Markham/Richmond Hill). The data was gathered in June and September of 2019 from 1,640 residents aged 18 or above residing in these 17 neighbourhoods. Participants were found based on their postal code and proximity to several pre-identified major streets, some of which have bicycle facilities on them (such as a cycle track, painted bicycle lanes, or off-street cycle paths), accessed through Campaign Research, a private polling company that was hired to carry out this survey. Participants were compensated with consumer points that can be redeemed through different programs (e.g. air miles, grocery store points). The survey was primarily focused on understanding bicycling behaviour, but also included questions related to shared micro-mobility (specifically, e-bikes and e-scooters).

Questions in the survey covered socio-demographic characteristics, travel behaviours and attitudes, residential location and typology, and neighbourhood environmental characteristics and perceptions. Additionally, the residential location of each respondent was identified as being either “urban” or “suburban” based on postal code information and a my subjective understanding of the built environment conditions within these locations. Since the sample included the distinction between urban and suburban neighbourhoods, the dataset provided the additional dimension of environmental built form that deepens the novelty and importance of this study.

Summary results from the survey which focus on key characteristics of participants are presented in Table 1. Of the sample, 57% of respondents were from urban locations, whereas 43% were from suburban locations. From a socio-demographic perspective, 26% of the overall sample were over 65 years of age compared to 17% for the overall GGH region, 52% were men compared to 48% for the GGH region, 66% earned more than $50,000 per year before taxes compared to the Ontario median income of $74,287, and 6% were unemployed compared to Ontario's rate of 5.5%. A limitation of this study is the existence of sampling bias in regards to the response rates among genders and for respondents older than 65. This further discussed in section 4.5. As such, the conclusions drawn from this study are based on unweighted data – the weights were unavailable during the time of my analysis.

From a travel behaviour perspective, 53% of the sample already owned a bicycle, with no difference in rate between urban and suburban. Private automobiles were the most common mode of transportation for overall sample, with 49% of respondents citing either a car, car share, ride share, or taxi as their primary commute mode. Public transportation (local public transit & GO regional transit) was the second most common form of transportation at 24%, and active transportation (walking or cycling) followed closely behind at 23%. As one may expect, the primary mode is dramatically different across locations: in suburban communities, automobiles are much more dominant as the primary mode, with 72% of suburban respondents indicating cars as their primary mode, compared to a much smaller 32% for urban respondents; by contrast, only 5% of suburban respondents used public transit as their primary mode, compared to a much larger 31% for urban respondents.

Table 1: Summary Statistics of the Survey Participants (n=1640)

	Urban		Suburban		Overall	
Respondent Characteristic	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**
Location						
Urban	-	-	-	-	934	57%
Suburban	-	-	-	-	706	43%
Age						
18-24	39	4%	27	4%	66	4%
25-65	670	72%	480	68%	1150	70%
Over 65	225	24%	199	28%	424	26%
Gender						
Male	419	45%	363	51%	782	48%
Female (or third gender)	515	55%	343	49%	858	52%
Education						
Bachelor Degree or Higher	553	59%	386	55%	939	57%
Diploma/Certificate/College Degree	233	25%	197	28%	430	26%
High School	137	15%	115	16%	252	15%
Other	11	1%	8	1%	19	1%
Family Structure						
Live with Parents	36	4%	56	8%	92	6%
Live with Partner & Children	151	16%	190	27%	341	21%
Live with Partner no Children	322	34%	252	36%	574	35%
Single-parent with Children	28	3%	42	6%	70	4%
Other	41	4%	36	5%	77	5%
Single	356	38%	130	18%	486	30%
Employment						
Retired	226	24%	237	34%	463	28%
Student	32	3%	11	2%	43	3%
Unemployed (or unable to work)	75	8%	29	4%	104	6%
Working (full & part time)	601	64%	429	61%	1030	63%
Income						
$100,000 or more	297	32%	244	35%	541	33%
$50,000 - $100,000	312	33%	235	33%	547	33%
Less than $50,000	225	24%	106	15%	331	20%
Prefer not to answer	100	11%	121	17%	221	13%

Bicycle Ownership						
Yes	495	53%	375	53%	870	53%
No	439	47%	331	47%	770	47%
Primary Commute Mode						
Active Transportation (Walk or Bicycle)	311	33%	60	8%	371	23%
Automobile (Car, Car Share, Ride Share, Taxi)	295	32%	507	72%	802	49%
Public Transit (Local or GO)	290	31%	107	5%	397	24%
Other	38	4%	32	15%	70	4%
Commute Length(To Work/School)						
Less than 30 Minutes	397	43%	294	42%	691	42%
30-60 Minutes	264	28%	154	22%	418	25%
60 Minutes and over	37	4%	46	7%	83	5%
I do not travel to school/work	236	25%	212	30%	448	27%

3.3 Variables

The main outcome variable for the analysis was whether the respondent would consider replacing current trips with shared e-bikes, data on which was collected in the online survey. The survey first provided a brief definition of e-bikes, and mentioned that “many service providers have become interested in these new means of transportation, and some municipalities are piloting these services as ride-share options”. Following this, propensity to replace current trips with an e-bike share system was identified by the key question: “If an e-bike was available in your neighbourhood on a pay-per-use basis (similar to a bike-share service), would you consider replacing some of your current trips with an e-bike?”, with responses grouped as either “Yes” or “No/Unsure”. A subsequent question also asked respondents to identify the type(s) of trips that they would consider replacing with an e-bike had they responded “Yes” to considering replacing current trips with a shared e-bike.

With regard to explanatory variables, I explored socio-demographic characteristics of the respondents and their typical travel behaviour, as well as an individual’s travel attitudes and motivations. As such, the survey included eight statements focusing on a respondent's attitudes and motivations toward their everyday travel behaviour, and asked the respondent to rank each statement on a 5-point scale ranging from "strongly disagree" to "strongly agree". These statements are listed in Table 2 and are grouped based on a Principle Component Analysis (PCA) that reduced the dimensionality of the eight variables in order to create 3 attitudinal "factors" that are much more meaningful when analyzed. The three factors represent the discrete dimensions of travel-behaviours and motivations observed among participants, including 1) weather and climate-related attitudes, 2) efficiency-related attitudes, and 3) preference towards active, environmentally friendly and cost-effective-transportation options. The PCA process used is discussed more elaborately in a 2020 research paper that used the same survey data to examine potential users of shared e-scooters (Mitra & Hess, 2020).

Finally, perceptions of the built environment within the neighbourhoods surveyed were captured through seven statements, which were also ranked on a scale ranging from "strongly disagree" to "strongly agree". For ease of interpretation, these responses were grouped into "Agree" (combining "strongly agree" and "agree"), and "Disagree" (combining "neutral", "disagree", and "strongly disagree"). These statements included: "The bicycle facility connects me to my typical/important destinations", "There are different options to conveniently get to and from my usual destinations", "I see people in my neighbourhood walking & cycling to various places", "Walking & cycling are a practical way to get to my usual destinations", "Many people I know walk or cycle", "The roads are not too congested", and "My neighbourhood streets are safe for all road users". Under this framework, the assumption is that respondents residing in walkable or bike-able neighbourhoods would be more amenable to adopting shared e-bikes. It is also anticipated, based on existing research, that the propensity to consider shared e-bikes may differ among urban and suburban neighbourhoods, and the relationships between the abovementioned factors and e-bike preference can also vary across different urban and suburban neighbourhoods. Shaheen and Cohen (2019) emphasize that in general, people residing in urban areas are more amenable to micro-mobility, though there is no research that has looked into differentiations for e-bikes or shared e-bikes.

Table 2: Factor Analysis of Transportation Attitudes and Motivations

	Factors		
	Factor 1: Weather and Climate	Factor 2: Quick and Predictable	Factor 3: Active, Flexible, and Cost-Effective
I would not walk or bike when it is raining or snowing outside	0.624		
I would not walk or bike when it is too hot, humid, or cold outside	0.996		
It is important for me to reach my destinations as quickly as possible		0.801	
It is important for my trip time to be predictable		0.684	
It is important for my trip to be cost-effective			0.509
It is important for me to have flexibility in time when making a trip			0.406
It is important for me to be able to make environmentally friendly transportation choices			0.751
It is important for me to be physically active			0.526

Note: Varimax Rotation

KMO measure of sampling adequacy: 0.69; Bartlett's test of sphericity: 3031.78 (df=28), P<0.001

The variables tested were a mix of categorical survey responses and attitudinal statements in which the respondent would either agree or disagree with (both of which were incorporated in the multivariate model as dummy variables). The variables examined are summarized in Table 3.

Table 3: Explanatory Variables

Variable	Description
Socio-Demographics	
Age	Age of respondent (0) Less than 18, (1) Between 18-24, (2) Between 25-65, (3) Over 65
Income	Respondent's yearly household income before tax (0) Prefer not to answer, (1) Less than \$50,000, (2) \$50,000-\$100,000, (3) More than \$100,000
Gender	Gender of respondent (0) Female & other, (1) Male
Education	Highest level of education attained by respondent (0) Highschool & other, (1) Diploma, certificate, or college degree, (2) Bachelor degree or higher
Family Structure	Description of current family structure (0) Single, (1) Live with parents, (2) Lone-parent with children, (3) Live with partner but no children, (4) Live with partner and child(ren), (5) Other
Housing Type	Type of house respondent resides in (0) Single family/semi-detached, (1) Townhouse, (2) Low-rise apartment, (3) High-rise apartment, (4) Other
Employment Status	Current employment status of respondent (0) Working (full time & part time), (1) Student, (2) Retired, (3) Unemployed or unable to work (due to disability)
Travel Characteristics & Attitudes/Motivations	
Current Ownership of Bicycle	Whether respondent owns a bicycle currently (0) No, (1) Yes
Current Primary Mode for Commute	Primary means of transport for commute under fair weather conditions (0) Active transportation (walk or cycle), (1) Public transit (local public transit or GO Transit), (2) Automobile (car, car share, taxi, ride share services), (3) Other
Length of Commute	Length of commute to primary place of work or school (0) I do not travel to school or work, (1) Less than 30 minutes, (2) 30 to 60 minutes, (3) 60 minutes and over

Factor 1: Weather & Climate	See Table 2
Factor 2: Quick & Predictable	See Table 2
Factor 3: Active, Flexible, and Cost-effective	See Table 2
Neighbourhood Characteristics & Perceptions	
Bicycle facility connects to important destinations	Whether the nearby bicycle facility connects to respondent's typical destinations (work, school, shopping, recreation, visiting friends) (0) No or Unsure, (1) Yes
Different transport options to conveniently get to my destinations	Respondent has different options to conveniently get to and from usual destinations (0) Disagree (neutral, disagree, and strongly disagree), (1) Agree (strongly agree and agree)
Walking & cycling are a practical way to get to my destinations	Practical for respondent to walk or cycle to their destinations (0) Disagree (neutral, disagree, and strongly disagree), (1) Agree (strongly agree and agree)
Many people I know walk & cycle	Respondent knows many people who walk or cycle 0) Disagree (neutral, disagree, and strongly disagree), (1) Agree (strongly agree and agree)
The roads are not too congested	Respondent believes neighbourhood roads are not too congested 0) Disagree (neutral, disagree, and strongly disagree), (1) Agree (strongly agree and agree)
My neighbourhood streets are safe for all road users	Respondent believe streets are safe for all road users 0) Disagree (neutral, disagree, and strongly disagree), (1) Agree (strongly agree and agree)

3.4 Statistical Methods Used

The self-reported intention to consider adoption of shared e-bikes if they were to become available in the neighbourhood was explored using binomial logistic regression. Another dimension of analysis was added by running separate models on the urban and suburban neighbourhoods sample subsets in addition to the overall dataset.

First, the variables selected, representing the respondents' socio-demographic characteristics, travel behaviour, travel attitudes and motivations, and neighbourhood environment perceptions, were tested for their bi-variate association with this key research question. The coefficients (β) from the bivariate logistic regression show the quantifiable impact that increasing each variable by one unit would have on propensity to adopt a shared e-bike. For each one unit change in the variable, the log odds of a respondent adopting e-bikeshare is expressed by the coefficient amount. Within the two models, variables that were statistically significant at $p \leq 0.05$ (for any of the urban, suburban, or overall models) were considered for further multivariate analysis.

Second, three multivariate logistic regression models explore the incremental effects of a respondent's socio-demographic characteristics (model 1), travel characteristics and attitudes/motivations (model 2), and neighbourhood environment and perceptions (model 3) on the likelihood of e-bike share adoption. The coefficients in these models represents the log-odds of the self-reported intent to consider an e-bike share. These results are also reported in terms of the Odds Ratio ($OR= e^{\beta}$), which represent the increase or decrease in the odds that a respondent would be willing adopt an e-bike share based on the variable in question. The results from the chi-square tests, bivariate, and multivariate logistic regression are discussed in Chapter 4. Three separate sets of logistic regression were estimated based on locational subsets of the dataset. The first set of regression was based on the overall dataset, including all respondents regardless of urban or suburban location. The two other sets of logistic regression used urban and suburban subsets of the overall dataset to take into account the distinct factors affecting potential for shared e-bike use between urban and suburban respondents.

Chapter 4 Results & Discussion

This chapter discusses the results from the data analysis that explores this study's key research question focusing on socio-demographic, attitudinal, and environmental factors that potentially influence the respondent's self-reported intention to consider replacing some of their current trips with shared e-bike systems. First, a high-level descriptive analysis of the data sample is presented, highlighting both the proportion of respondents who indicated they would consider replacing current trips with shared e-bikes if they were to become available in their neighbourhoods on a pay-per-use basis, as well as the distribution of the types of trips that these respondents indicated they would likely replace with this shared micro-mobility. Next, results from the bivariate logistic model are presented to determine which variables were significantly correlated with the likelihood of e-bike share consideration, without considering other confounding effects. Finally, three multivariate models of the correlates of the propensity for shared e-bike adoption is presented and discussed.

4.1 Descriptive Analysis

Data from an online survey was used to investigate which individuals would consider using shared e-bikes if they were to become available on a pay-per-use basis in their neighbourhood. Of the sample (n=1,640), 21% indicated they would consider adopting e-bike share for some of their current trips, while the remainder of the sample population were either unwilling or unsure about using this service (Table 4). These responses do not change too significantly when the urban versus suburban layer are added on, with only 2% more urban respondents were willing to consider shared e-bikes compared to suburban respondents. The difference between urban and suburban respondents was not statistically significant (p=0.4217).

This is contrary to the previous hypothesis that propensity towards this shared micro-mobility option would vary significantly between urban and suburban neighbourhoods (Shaheen & Cohen, 2019). Based on this finding, it appears that the differences in demand-side economics are subtle – however, it is also worth considering the differences in supply-side economics between urban and suburban neighbourhoods. Specifically, it can be hypothesized that shared e-bikes located in a denser (e.g. urban) area will likely serve more users in the neighbourhood given the greater density of residents within a given radius. Despite the interest expressed by suburban area residents, the future geographical location of shared e-bikes will likely be heavily influenced by the supply side of this economical equation in which potential users in urban areas present much larger market scale returns.

Table 4: Respondents who would consider shared e-bikes to replace some of their current trips if available

	%		
	All (n=1,640)	Urban (n=934)	Suburban (n=706)
Yes	21%	22%	20%
No	54%	54%	54%
Unsure	24%	23%	25%

Note: no statistical difference in e-bike share preference between urban and suburban locations x^2=1.7271, p=0.4217

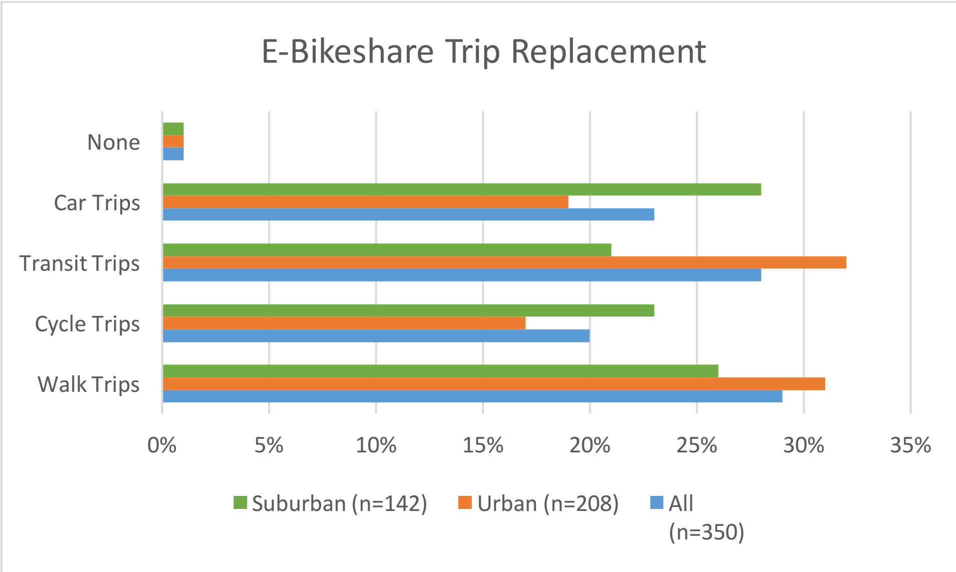
Additionally, of the individuals who responded "Yes" to considering replacing some current trips with shared e-bikes, most were willing to replace existing walk (29%) and transit (28%) trips, with car trips (23%) and cycle trips (20%) representing a sizeable portion as well (Table 5 & Figure 1). However, these figures change when the urban and suburban layer is added onto the analysis, with many more urban respondents indicating they would replace transit (32%) and walk (31%) trips compared to car trips (19%) and cycle trips (17%). For suburban respondents, most indicated they would replace car trips (28%) and walk trips (26%), with cycle (23%), and transit (21%) trips following closely behind. As such, it appears that in urban environments, shared e-bike systems are more likely to replace transit and walk trips, This is in line with Shaheen & Martin's (2015) study, which found that modal shifts away from public transit and other more active modes due to public bike sharing schemes were most prominent in urban environments with high-density urban cores, where the bike sharing scheme offers quicker, cheaper, and more direct connections compared to short-distance transit trips, and tends to be more substitutive, providing relief to over-crowded transit lines.

Table 5: Types of trips potentially to be substituted by a shared e-bike

	%		
	All (n=350)	Urban (n=208)	Suburban (n=142)
Walk Trips	29%	31%	26%
Cycle Trips	20%	17%	23%
Transit Trips	28%	32%	21%
Car Trips	23%	19%	28%
None	1%	1%	1%

Note: Multiple-response question.

Figure 1: Shared E-Bike Trip Replacement



<u>4.2 Bivariate Logistic Regression Model Results</u>

Results from the bivariate logistic regression are shown in Table 6. The dependent variable in this model was the respondent's self-reported intention to consider using shared e-bike systems if they were to become available in their neighbourhood on a pay-per-use basis ("Yes" versus "No or unsure").

Table 6: Bivariate association between intention to consider shared e-bikes and various factors (n=1640)

	Consider Shared E-Bikes if Available (Yes vs. No/Unsure)								
	OVERALL			URBAN ONLY			SUBURBAN ONLY		
Variable	**Coef**	**S.E**	**P-Value**	**Coef**	**S.E**	**P-Value**	**Coef**	**S.E**	**P-Value**
Age									
18-24	1			1			1		
25-65	-0.02	0.05	0.6959	-0.06	0.07	0.3677	0.04	0.08	0.6151
Over 65	-0.12	0.05	0.0317 *	-0.17	0.07	0.0181 *	-0.04	0.08	0.6308
Annual household income before tax									
Prefer not to answer	1			1			1		
Less than 50,000	0.11	0.04	0.00164 **	0.09	0.05	0.0719 .	0.12	0.05	0.020506 *
50,000 - 100,000	0.04	0.03	0.19912	0.03	0.05	0.5585	0.05	0.04	0.29703

100,000 +	0.04	0.03	0.19534	0.01	0.05	0.9124	0.08	0.04	0.085179 .
Gender									
Female/Other	1			1			1		
Male	0.04	0.02	0.0519 .	0.02	0.03	0.369	0.06	0.03	0.039 *
Highest level of education attained									
High School & Other	1			1			1		
Diploma/Certificate/College Degree	0.06	0.03	0.0564 .	0.01	0.04	0.734	0.12	0.05	0.012099 *
Bachelor Degree or Higher	0.02	0.03	0.5643	-0.02	0.04	0.638	0.06	0.04	0.175907
Family structure									
Other	1			1			1		
Single	0.02	0.05	0.722	0.01	0.07	0.86405	0.00	0.08	0.97751
Live with Parents	0.04	0.06	0.526	0.09	0.09	0.345409	0.02	0.09	0.81752
Live with Partner & Children	-0.01	0.05	0.852	-0.04	0.07	0.597267	0.02	0.07	0.77051
Live with Partner no Children	-0.04	0.05	0.406	-0.07	0.07	0.288155	0.00	0.07	0.95588
Single Parent w/ Children	0.04	0.07	0.591	0.08	0.10	0.446011	0.02	0.09	0.8282
Housing type									
Other	1			1			1		
Townhouse	0.11	0.06	0.0631 .	0.09	0.08	0.273	0.15	0.09	0.1199
Low-rise Apartment	-0.01	0.06	0.8984	-0.01	0.07	0.907	-0.01	0.10	0.9313
High-rise Apartment	-0.03	0.05	0.597	-0.05	0.07	0.462	0.02	0.09	0.8629
Single Family/Semi Detached	-0.02	0.05	0.7184	-0.01	0.06	0.841	-0.01	0.09	0.9334
Employment Status									
Working Full Time/Part Time	1			1			1		
Unemployed/unable to work	0.09	0.04	0.0265 *	0.13	0.05	0.00882 **	-0.02	0.08	0.8263
Student	0.05	0.06	0.4764	0.04	0.07	0.59185	0.05	0.12	0.6892
Retired	-0.10	0.02	1.79e-05 ***	-0.13	0.03	8.89e-05 ***	-0.07	0.03	0.0373 *
Current ownership of bicycle									
No	1			1			1		
Yes	0.08	0.02	5.53e-05 ***	0.05	0.03	0.0639 .	0.12	0.03	4.58e-05 ***
Current primary mode of transportation for commute (under fair weather conditions)									
Automobile	1			1			1		
Public Transportation	0.08	0.03	0.00102 **	0.06	0.03	0.0708 .	0.10	0.04	0.0176 *
Active Transportation	0.03	0.03	0.309	-0.01	0.03	0.8262	0.12	0.05	0.0271 *
Other	-0.05	0.05	0.35956	-0.02	0.07	0.7529	-0.09	0.07	0.2384
Length of commute									
Less than 30 Minutes	1			1			1		
30-60 Minutes	0.03	0.03	0.271	0.05	0.03	0.093888 .	-0.02	0.04	0.656124
60 Minutes and Over	-0.01	0.05	0.81	-0.02	0.07	0.771731	-0.01	0.06	0.927161

I do not travel for work/school	-0.12	0.02	8.08e-07 ***	-0.11	0.03	0.000806 ***	-0.13	0.04	0.000256 ***
Factor 1: Weather & Climate	-0.07	0.06	0.259	-0.13	0.08	0.0808 .	0.02	0.10	0.873
Factor 2: Quick & Predictable	0.13	0.07	0.0756 .	0.15	0.09	0.112	0.09	0.11	0.399
Factor 3: Active, Flexible, & Cost Effective	0.38	0.08	5.62e-07 ***	0.19	0.10	0.0628 .	0.65	0.12	1.18e-07 ***
Residential Location									
Suburban	1								
Urban	0.02	0.02	0.292						
Does facility connect you to all your typical destinations?									
No/Unsure	1			1			1		
Yes	0.09	0.02	4.14e-06 ***	0.11	0.03	3.7e-05 ***	0.07	0.03	0.0363 *
There are different transport options to conveniently get to my destinations									
Disagree	1			1			1		
Agree	0.07	0.02	0.0032 **	0.04	0.03	0.217	0.09	0.03	0.00567 **
I see people in neighbourhood walking/cycling often									
Disagree	1			1			1		
Agree	0.06	0.02	0.0118 *	0.05	0.04	0.162	0.06	0.03	0.058 .
Walking/cycling are a practical way to get to my destinations									
Disagree	1			1			1		
Agree	0.12	0.02	1.21e-08 ***	0.08	0.03	0.00355 **	0.19	0.03	2.74e-08 ***
Many people I know walk/cycle									
Disagree	1			1			1		
Agree	0.08	0.02	0.000108 ***	0.07	0.03	0.00807 **	0.08	0.03	0.00834 **
The roads are not too congested									
Disagree	1			1			1		
Agree	0.08	0.02	0.000217 ***	0.09	0.03	0.00449 **	0.08	0.03	0.00858 **
My neighbourhood streets are safe for all road users									
Disagree	1			1			1		
Agree	0.06	0.02	0.00512 **	0.04	0.03	0.164	0.09	0.03	0.00313 **

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Socio-Demographics: With regards to socio-demographic characteristics, older (age > 65) and retired individuals were less likely to consider shared e-bikes for their current trips, while those who were unemployed and making either less than $50,000, or greater than $100,000 (under the suburban model only) in annual household income were more amenable to considering adoption. It was also found that men, and individuals who held a diploma, certificate, or college degree, were more amenable to shared e-bikes within this study area. Additionally, there was a weaker association between those who reside in townhouses (p=0.0631) – though this association disappeared when the urban and suburban data subsets were layered onto the analysis, and as such, was not incorporated into the multivariate model. There was no statistical association between family structure and an individual's intent to consider shared e-bikes, and as a result, the family structure variables were also left out of the multivariate analysis.

Travel Behaviours & Attitudes: The preliminary bivariate logistic regression model also identified statistical associations between travel-related attitudes and the potential to consider using shared e-bikes. Respondents who currently own a bicycle were more amenable to shared e-bikes, with a stronger statistical association within the suburban data subset than the urban data subset. It is likely that bicycle owners are generally more comfortable cycling, and are thus more amenable to shared e-bikes.

Individuals who used public transit as their primary mode of transportation were also more likely to consider shared e-bikes, again with a stronger association within the suburban data subset. Active transportation modes (walking and cycling) were also shown to be positively associated with intent to consider shared e-bikes within only the suburban data subset. This is in line with previous literature that found bike sharing schemes to be more substitutive of sustainable modes of transportation, such as public transit, walking, and cycling rather than moving people away from their automobiles (Shaheen & Martin, 2015; Shaheen et al., 2012). Individuals who do not commute to work or school are less likely to consider shared e-bikes, while those with a commute time between 30-60 minutes were not associated with intent to consider shared e-bikes (p=0.05).

Finally, those who preferred their trips to be active, flexible, cost-effective, and environmentally friendly (factor 3) were more likely to consider shared e-bikes. Weather/climate (factor 1), and quickness/predictability (factor 2) were not associated with the intent to consider shared e-bikes, and as such were not included in the multivariate model.

Neighbourhood Built Environment & Perceptions: Residential location (urban versus suburban neighbourhood) of the respondent was not statistically associated with the intent to adopt shared e-bikes. However, individual environmental characteristics were also explored in the bivariate model through questions relating to the respondent's perception of that neighbourhood, which help to characterize the environments in which they reside. All seven questions that characterize the respondent's perception of their environment were shown to be statistically significant, and thus, included in the multivariate model.

4.3 Multivariate Logistic Regression Model Results

Results from the multivariate logistic regression models are presented in Tables 7, 8, and 9, and include a model with the overall dataset (table 7), a model using only the urban data subset (table 8), and a model using only the suburban data subset (table 8). The dependent variable in these models is the respondent's self-reported intention to consider using shared e-bikes if they were to become available in their neighbourhoods on a pay-per-use basis. The results are expressed in terms of odds ratios (OR), which represents the odds of shared e-bike adoption, in relation to the various independent variables examined in this model, and adjusting for other confounding effects.

4.3.1 All Respondents

Many of the statistical associations that were present in the previous bivariate models become much less obvious when other factors are taken into consideration. For example, a respondent's age was no longer correlated with the likelihood of shared e-bike adoption when other socio-demographic characteristics, travel attitudes, and/or environmental perceptions were included in the model (Models 1, 2, and 3 in Table 7), while gender (men), income (under $50,000), education (diplomas/certificates/college degrees), and employment (unemployed or unable to work) were all still significant contributors in explaining the behavioural intent to adopt shared e-bikes.

Additionally, while a respondent's retirement status remains significant with other socio-demographic variables taken into account, it loses its correlation when travel attitudes and/or environmental perceptions were incorporated.

All else being equal, men (OR=1.05), respondents with income less than $50,000 (OR=1.08), those with education at diploma/certificate/college degree levels (OR=1.05), and those who are unemployed (OR=1.14) are more likely to be amenable to adopting shared e-bikes if they were to become available in their neighbourhoods, indicating a preference for this micro-mobility option among men and respondents with lower incomes (some of whom are unemployed). The results of the analysis on socio-demographic factors are somewhat surprising, given that the majority of current literature on bike share and e-bikes (there is very little literature on demographic factors for shared e-bikes) found that while bike share and e-bike users tended to be men and those with higher educations (as with our results here) they also tended to be younger with higher levels of income, which is contrary to the results of this analysis (Shaheen & Cohen, 2019; Shaheen, Martin, Chan, Cohen, & Pogodzinski, 2014; Shaheen, Martin, Cohen, & Finson, 2012; Fishman et al., 2013; Cherry & Cervero, 2007).

From a travel behaviour and attitudes perspective, respondents that currently own a bicycle (OR=1.04) remained significant throughout both models 2 and 3, indicating that those who have experience cycling were more amenable to consider shared e-bikes. Additionally, respondents who preferred an active lifestyle and environmentally-friendly transportation choices, and also cost-effective and time-flexible transportation options (Factor 3) were more likely to consider shared e-bikes if and when they are available (OR=1.04). Respondents who did not travel for work or school were significantly correlated under all three models, and were less likely to adopt shared e-bikes (OR=0.9), which makes sense given that these respondents likely have minimal day-to-day travel patterns, while those who had 30-60 minute commutes were no longer correlated when the addition of other travel attitudinal and neighbourhood perceptions factors were incorporated in the model. Finally, those who responded with public transportation as their primary commute mode were no longer associated with the likelihood of considering shared e-bikes once neighbourhood perceptions were incorporated, while respondents who mainly used active modes of transportation (walking and cycling) actually became more significantly negatively associated with likelihood of adoption once the environmental conditions were added (OR=0.93), implying that those who currently travel by walking or cycling are less amenable to shared e-bike adoption when all factors are considered.

Lastly, the environmental factors (Model 3) of having different transportation options available, seeing people walk and cycling in the neighbourhood, knowing many people who walk and cycle, and perceived street safety for all road users, lost their significance when incorporated into the model alongside other variables. However, environmental factors that were shown to have positive statistical significance in explaining a respondent's likelihood of shared e-bikes included facility connections to important destinations (OR=1.05), perception that walking and cycling are practical forms of transportation to reach important destinations (OR=1.07), and perception that the roads are not too congested (OR=1.06). Again, residential location (urban vs. suburban) was not included in the multivariate model as it was not shown to be statistically significant within the bivariate model. While our previous hypothesis expected a significant difference in attitudes towards shared micro-mobility between urban and suburban built forms (Shaheen & Cohen, 2019; Fishman, 2016; Shaheen et al., 2014), it is likely that the neighbourhood-level environmental perceptions listed above (like facility connections, walkability, and bike-ability) have a greater influence on intent to use shared e-bikes than its status as an urban or suburban neighbourhood.

4.3.2 Urban versus Suburban Differences

The statistical significance of several variables changes when the multivariate models are broken out by the urban and suburban subsets of data (Tables 8 and 9). The following analysis and discussion compares the differences in correlates between urban and suburban locations.

For socio-demographic characteristics under the urban data subset, gender (male) is no longer associated with intent to use shared e-bikes. Income (<$50,000) also lost its association with intent to adopt shared e-bikes under model 1, though it regains its association under models 2 and 3 (OR=1.07). Additionally, unemployment remains significant under all 3 models for the urban subset (OR=1.17).

Under the suburban subset, gender (male) continues to be positively associated with intent to use shared e-bikes under model 1 – however, this association disappears once travel behaviour and neighbourhood environment factors are considered. Income (<$50,000) and education (diploma/certificate/college degree) for the suburban subset remains significant throughout all 3 models (OR=1.09 for both), while employment (unemployed/unable to work) loses its association with intent to use shared e-bikes under all 3 models. These results for both the urban and suburban respondents are again, surprising, given previous literature on bike share and e-bikes that found users of these systems tended to be men with higher levels of income (Shaheen & Cohen, 2019; Shaheen, Martin, Chan, Cohen, & Pogodzinski, 2014; Shaheen, Martin, Cohen, & Finson, 2012; Fishman et al., 2013; Cherry & Cervero, 2007).

For travel behaviours and attitudes under the urban subset, only respondents who do not travel for work or school remained statistically significant throughout all models, representing a decreased likelihood of considering use of shared e-bikes (OR=0.91). All other variables under model 2 lost their correlation with propensity for shared e-bikes when other factors were incorporated. However, when environmental factors were added, primary commute mode (active transportation) became negatively associated (OR=0.93), implying that those who walk and cycle in urban neighbourhoods are less amenable to shared e-bike adoption with all other factors considered. This finding is surprising given Shaheen & Martin's (2015) study that found modal shifts away from public transit and other active modes (walking and cycling) due to public bike sharing schemes that tend to be more substitutive of the aforementioned modes in urban environments with high-density cores. Finally, bicycle ownership and respondents who preferred an active lifestyle, environmentally-friendly transportation choices, and also cost-effective and time-flexible transportation options (Factor 3) were no longer statistically significant for the urban subset in models 2 or 3.

By contrast, under the suburban subset, bike ownership and respondents who preferred an active lifestyle, environmentally-friendly choices, and cost-effective and flexible transportation options (factor 3) are positively statistically correlated with intent to use shared e-bikes once environmental factors are added in (OR=1.06 and OR=1.07, respectively). Similar to the urban subset, those who do not travel for work or school remain negatively associated with propensity to consider using shared e-bikes (OR=0.88). Primary commute mode (active transportation) is no longer associated with intent to use shared e-bikes under the suburban subset.

Finally, the environmental factors under Model 3 for the urban data subset generally follow the same statistical significance of the overall dataset, with the exception of "walking and cycling are a practical way to get to my destinations" which was no longer statistically associated with intent to consider shared e-bikes. Residing near a bicycle facility that connects to important destinations (OR=1.08) and the opinion that neighbourhoods roads are not too congested (OR=1.07) remain positively associated with intent to use shared e-bikes under the urban subset.

By contrast, under the suburban subset, the only factor to remain positively associated with intent to use shared e-bikes is the perception that “walking and cycling are a practical way to get to important destinations” (OR=1.11).

In summary, the socio-demographic characteristics of individuals who might consider shared e-bikes between urban and suburban respondents are not too dissimilar, with the exception of unemployment (which is positively associated for the urban respondents, while not associated for suburban respondents), and education (where having a diploma, certificate, or college degree is positively associated for suburban respondents, and not associated for urban respondents). For travel behaviours and attitudinal factors, urban respondents who use an active primary mode of transportation (walking or cycling) are less likely to consider shared e-bikes, while there is no association of this factor for suburban respondents. Additionally, suburban respondents who currently own a bicycle, and those who prefer active, environmentally friendly, cost effective, and flexible trips are positively associated with intent to use a shared e-bike. Finally, for environmental characteristics, facility connections and the perception that streets are not too congested are positively associated with intent to use shared e-bikes for urban respondents, while for suburban respondents, only those who believe walking and cycling are practical ways to get to their destinations are more amenable to shared e-bikes.

Table 7: Multivariate logistic regression on overall dataset of self-reported intention to consider shared e-bikes (n=1,640)

	OVERALL MODEL											
	Model 1: Socio-demographic Characteristics				Model 2: Model 1 + Travel Behaviours & Attitudes				Model 3: Model 2 + Neighbourhood Env & Perceptions			
Variable	**Coef**	**S.E**	**OR**	**P-Value**	**Coef**	**S.E**	**OR**	**P-Value**	**Coef**	**S.E**	**OR**	**P-Value**
Intercept	0.19	0.02	1.21	< 2e-16 ***	0.15	0.03	1.16	3.39e-08 ***	7E-02	3E-02	1E+00	0.03943 *
Age: > 65	-0.04	0.03	0.96	0.17704	-0.02	0.03	0.98	0.576651	-1E-02	3E-02	1E+00	0.63885
Gender: Male	0.05	0.02	1.05	0.01835 *	0.05	0.02	1.05	0.019331 *	5E-02	2E-02	1E+00	0.02030 *
Income												
<50,000	0.08	0.03	1.08	0.00272 **	0.09	0.03	1.09	0.001543 **	8E-02	3E-02	1E+00	0.00271 **
>100,000	0.01	0.02	1.01	0.76791	0.00	0.02	1.00	0.92328	-7E-04	2E-02	1E+00	0.97561
Education: Diploma/certificate/college	0.05	0.02	1.05	0.02934 *	0.06	0.02	1.06	0.013688 *	5E-02	2E-02	1E+00	0.01859 *
Employment Status:												
Unemployed/unable to work	0.07	0.04	1.08	0.07700 .	0.13	0.04	1.14	0.002506 **	1E-01	4E-02	1E+00	0.00186 **
Retired	-0.08	0.03	0.92	0.00526 **	-0.01	0.03	0.99	0.879227	-5E-03	3E-02	1E+00	0.87541
Bike Ownership					0.06	0.02	1.06	0.004821 **	4E-02	2E-02	1E+00	0.04157 *
Primary Mode												
Public Transportation					0.04	0.03	1.04	0.101103	2E-02	3E-02	1E+00	0.43719
Active Transportation					-0.02	0.03	0.98	0.343862	-7E-02	3E-02	9E-01	0.01592 *
Length of Commute												
30-60 Minutes					0.02	0.02	1.02	0.510069	2E-02	2E-02	1E+00	0.42564
Do not travel for work/school					-0.11	0.03	0.89	0.000331 ***	-1E-01	3E-02	9E-01	0.00075 ***
Factor 3: Active, Flexible, & Cost Effective					0.06	0.01	1.06	1.26e-05 ***	3E-02	1E-02	1E+00	0.01013 *
Facility connects to my destinations									5E-02	2E-02	1E+00	0.01662 *
Different options to conveniently connect me to my destinations									2E-02	2E-02	1E+00	0.3998
I see people in my neighbourhood walk/cycle									-6E-03	3E-02	1E+00	0.81956
Walking/cycling are practical way to get to my destinations									7E-02	2E-02	1E+00	0.00666 **
Many people I know walk/cycle									3E-02	2E-02	1E+00	0.23849
Roads not too congested									6E-02	2E-02	1E+00	0.01192 *
Neighbourhood streets safe									2E-02	2E-02	1E+00	0.36425

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Table 8: Multivariate logistic regression on urban subset of self-reported intention to consider shared e-bikes (n=934)

	URBAN-ONLY MODEL											
	Model 1: Socio-demographic Characteristics				Model 2: Model 1 + Travel Behaviours & Attitudes				Model 3: Model 2 + Neighbourhood Env & Perceptions			
Variable	**Coef**	**S.E**	**OR**	**P-Value**	**Coef**	**S.E**	**OR**	**P-Value**	**Coef**	**S.E**	**OR**	**P-Value**
Intercept	0.22	0.03	1.24	9.4e-16 ***	0.18	0.04	1.19	8.69e-06 ***	0.07	0.05	1.07	0.1713
Age: > 65	-0.03	0.04	0.97	0.50007	-0.01	0.04	0.99	0.73783	-0.03	0.04	0.97	0.52125
Gender: Male	0.04	0.03	1.04	0.11754	0.05	0.03	1.05	0.08106 .	0.05	0.03	1.05	0.06461 .
Income												
<50,000	0.06	0.03	1.06	0.07444 .	0.08	0.03	1.08	0.02200 *	0.07	0.03	1.07	0.03896 *
>100,000	-0.02	0.03	0.98	0.46924	-0.03	0.03	0.97	0.38565	-0.03	0.03	0.97	0.42069
Education: Diploma/certificate/college	0.02	0.03	1.02	0.46983	0.02	0.03	1.02	0.56783	0.02	0.03	1.02	0.56282
Employment Status:												
Unemployed/unable to work	0.11	0.05	1.12	0.03011 *	0.16	0.05	1.18	0.00227 **	0.16	0.05	1.17	0.00262 **
Retired	-0.12	0.04	0.89	0.00354 **	-0.04	0.05	0.96	0.3967	-0.03	0.05	0.97	0.49391
Bike Ownership					0.04	0.03	1.04	0.14781	0.02	0.03	1.02	0.50673
Primary Mode												
Public Transportation					0.04	0.03	1.04	0.27009	0.02	0.04	1.02	0.59835
Active Transportation					-0.03	0.03	0.97	0.31705	-0.08	0.04	0.93	0.04442 *
Length of Commute												
30-60 Minutes					0.04	0.03	1.04	0.23333	0.05	0.03	1.05	0.16177
I do not travel for work/school					-0.11	0.04	0.90	0.01030 *	-0.10	0.04	0.91	0.02332 *
Factor 3: Active, Flexible, & Cost Effective					0.03	0.02	1.03	0.11057	0.00	0.02	1.00	0.81362
Facility connects to my destinations									0.08	0.03	1.09	0.00285 **
Different options to conveniently connect me to my destinations									0.02	0.03	1.02	0.5153
I see people in my neighbourhood walk/cycle									0.01	0.04	1.01	0.84153
Walking/cycling are practical way to get to my destinations									0.05	0.03	1.05	0.12023
Many people I know walk/cycle									0.04	0.03	1.05	0.16776
Roads not too congested									0.07	0.03	1.08	0.01866 *
Neighbourhood streets safe									0.00	0.03	1.00	0.86661

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Table 9: Multivariate logistic regression on suburban subset of self-reported intention to consider shared e-bikes (n=706)

	SUBURBAN-ONLY MODEL											
	Model 1: Socio-demographic Characteristics				Model 2: Model 1 + Travel Behaviours & Attitudes				Model 3: Model 2 + Neighbourhood Env & Perceptions			
Variable	**Coef**	**S.E**	**OR**	**P-Value**	**Coef**	**S.E**	**OR**	**P-Value**	**Coef**	**S.E**	**OR**	**P-Value**
Intercept	0.14	0.03	1.16	3.38e-06 ***	0.12	0.04	1.12	0.00140 **	0.06	0.04	1.06	0.16484
Age: > 65	-0.06	0.05	0.94	0.1854	-0.01	0.05	0.99	0.87842	0.01	0.05	1.01	0.880887
Gender: Male	0.07	0.03	1.07	0.0307 *	0.05	0.03	1.05	0.08731 .	0.05	0.03	1.05	0.129654
Income												
<50,000	0.10	0.04	1.11	0.0197 *	0.09	0.04	1.10	0.03550 *	0.09	0.04	1.09	0.037867 *
>100,000	0.05	0.03	1.05	0.1704	0.03	0.03	1.03	0.31362	0.03	0.03	1.03	0.352699
Education: Diploma/certificate/college	0.08	0.03	1.09	0.0120 *	0.09	0.03	1.10	0.00416 **	0.09	0.03	1.10	0.005119 **
Employment Status:												
Unemployed/unable to work	-0.03	0.08	0.97	0.675	0.03	0.08	1.03	0.68584	0.04	0.08	1.04	0.59975
Retired	-0.04	0.04	0.96	0.3553	0.03	0.05	1.03	0.59983	0.02	0.05	1.02	0.718092
Bike Ownership					0.07	0.03	1.08	0.01911 *	0.06	0.03	1.06	0.045279 *
Primary Mode												
Public Transportation					0.05	0.04	1.05	0.23848	0.04	0.04	1.04	0.406028
Active Transportation					0.07	0.05	1.08	0.17254	0.02	0.06	1.02	0.701134
Length of Commute												
30-60 Minutes					-0.01	0.04	0.99	0.73326	-0.01	0.04	0.99	0.71889
I do not travel for work/school					-0.13	0.05	0.88	0.00758 **	-0.13	0.05	0.88	0.008782 **
Factor 3: Active, Flexible, & Cost Effective					0.09	0.02	1.09	2.74e-06 ***	0.07	0.02	1.07	0.000524 ***
Facility connects to my destinations									0.00	0.03	1.00	0.887378
Different options to conveniently connect me to my destinations									0.01	0.03	1.01	0.72333
I see people in my neighbourhood walk/cycle									-0.01	0.03	0.99	0.676667
Walking/cycling are practical way to get to my destinations									0.10	0.04	1.11	0.010076 *
Many people I know walk/cycle									0.01	0.04	1.01	0.67579
Roads not too congested									0.02	0.03	1.02	0.512089
Neighbourhood streets safe									0.05	0.03	1.05	0.139304

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

4.4 Challenges and Limitations

There are several key challenges and limitations present within the study design, one of which is a sampling bias within the data. From a socio-demographic perspective, 26% of the overall sample were over 65 years of age compared to 17% for the overall GGH region, 52% were men compared to 48% for the GGH region, 66% earned more than $50,000 per year before taxes compared to the Ontario median income of $74,287 (mean income is not reported under Statistics Canada), and 6% were unemployed compared to Ontario's rate of 5.5% (Statistics Canada). Demographic statistics reported by Statistics Canada can be viewed in Tables 10, 11, 12, and 13. A limitation of this study is the existence of sampling bias in regards to the response rates among genders and respondents older than 65. Using weighted data that is better representative of the study area's population would increase the value of this study. It is evident that respondents of this survey skewed older in age, and many indicated they did not work or are retired. As such, the respondents could have been separated as those who have to commute, and those who do not commute for a further layer of analysis.

Additionally, "How many cars/automobiles do you have in your household?" was a question that was added into the online survey late, thus not all respondents have an entry for this variable. As such, it was not included as a variable within the analysis. This is another limitation of the study, as it could be hypothesized that automobile ownership correlates with intentions to adopt e-bike share – particularly when compounded with other variables in a multivariate model (such as family structure, location, or perceptions of road congestion).

The data from this survey is also designed around a study of cycling, and as such, the sample is not necessarily a true representation of all urban and suburban neighbourhoods in the region. This is another limitation of the study that could be addressed in the future by selecting neighbourhoods within the GGH at random, without the selection criteria of proximity to major streets.

Information on the respondent's first- and last-mile travel in regards to their commute would also have added a valuable layer to the analysis. Much of the current literature on bike share schemes stress the importance that these systems can play in helping to bridge first- and last-mile gas within transportation systems to encourage multimodal trips (Shaheen, 2019; DeMaio, 2009, Fishman, Washington, Haworth, 2013).

Finally, it is worth noting that the data on intent to adopt shared e-bikes (the key research question) was self-reported; it is unclear whether these respondents would truly use shared e-bikes if they were to become available. There may be some nuance missing within this answer, and as such, future research could make attempt to better contextualize this self-reported intent.

Chapter 5 Conclusion

This study investigated factors influencing an individual's self-reported intent to consider replacing some of their current trips with shared e-bikes if they were to become available in their neighbourhoods on a pay-per-use basis. From a preliminary descriptive analysis of the data collected, it was revealed that a similar proportion (20% of suburban respondents and 22% of urban respondents) of people living in urban and suburban areas are willing to consider using shared e-bikes to replace some of their current trips. Additionally, it appears that in urban environments, shared e-bike systems are more likely to replace transit and walking trips (32% and 31%, respectively), while in suburban environments, they are more likely to replace car trips (28%). Given that a similar proportion of respondents indicated they are willing to consider shared e-bikes in both urban and suburban areas, a possible implication of this finding is that shared e-bike systems might show more promise in substituting private automobile trips in suburban neighbourhoods where suburban respondents have shown more promise in replacing car trips.

In addition, socio-demographic characteristics, travel behaviours and attitudes, and environmental factors and perceptions were all significant variables in explaining a respondent's propensity to adopt this mode of shared micro-mobility. While some of the results of the analysis were to be expected given existing literature, many of the outcomes were surprising and novel to this study. The results for the overall dataset indicate that the preference for shared e-bikes is generally greater among men, unemployed individuals, and those with lower incomes. The results of the analysis on socio-demographic factors are somewhat surprising, given that the majority of current literature on bike share and e-bikes found that while bike share and e-bike users tended to be men and those with higher educations (as with our results here) they also tended to be younger with higher levels of income, which is contrary to the results of this analysis (Shaheen & Cohen, 2019; Shaheen, Martin, Chan, Cohen, & Pogodzinski, 2014; Shaheen, Martin, Cohen, & Finson, 2012; Fishman et al., 2013; Cherry & Cervero, 2007). However, these findings shift when looking at the urban and suburban subset of individuals; gender (men) for both urban and suburban areas was no longer associated with propensity to consider shared e-bikes, and unemployment was no longer associated with intent to use shared e-bikes in the suburban context.

While current bicycle ownership is positively associated with intent to use shared e-bikes under suburban settings, it loses its significance under urban settings, indicating that those who own a bicycle (and thus, likely have experience cycling) are more likely to consider shared e-bikes in suburban neighbourhoods. Respondents in suburban neighbourhoods who preferred active, environmentally friendly, cost effective, and flexible transportation options (factor 3) were more likely to consider use of shared e-bikes when compared to respondents that valued the same factors in urban neighbourhoods. Under both urban and suburban contexts, those individuals who indicated they don’t commute for school or work were less likely to consider use of shared e-bikes. Additionally, respondents in urban settings who indicated they walk or cycle (active transportation) as their main commute mode are less amenable to considering shared e-bike use, which is surprising given Shaheen & Martin’s (2015) study that found modal shifts away from public transit and other active modes (walking and cycling) due to public bike sharing schemes that tend to be more substitutive of the aforementioned modes in urban environments with high-density cores.

Finally, factors of neighbourhood perceptions that were positively associated with intent to use shared e-bikes for urban neighbourhoods includes bicycle facilities that connect to the respondent's important destinations and a perception that the neighbourhood roads are not too congested. By contrast, neighbourhood factors that were positively associated with intent to use shared e-bikes for suburban neighbourhoods includes only the opinion that walking and cycling are practical ways of reaching the respondent's important destinations.

In summary, the socio-demographic characteristics of individuals who might consider shared e-bikes between urban and suburban respondents are not too dissimilar, with the exception of unemployment (which is positively associated for the urban respondents, while not associated for suburban respondents), and education (where having a diploma, certificate, or college degree is positively associated for suburban respondents, and not associated for urban respondents). For travel behaviours and attitudinal factors, urban respondents who use an active primary mode of transportation (walking or cycling) are less likely to consider shared e-bikes, while there is no association of this factor for suburban respondents. Additionally, suburban respondents who currently own a bicycle, and those who prefer active, environmentally friendly, cost effective, and flexible trips are positively associated with intent to use a shared e-bike. Finally, for environmental characteristics, facility connections and the perception that streets are not too congested are positively associated with intent to use shared e-bikes for urban respondents, while for suburban respondents, only those who believe walking and cycling are practical ways to get to their destinations are more amenable to shared e-bikes.

This study presents a novel research that highlights the extent to which residents are willing to replace some of their current trips with shared e-bikes, the current modes they are willing to replace, the socio-demographic, attitudinal, and environmental factors that influence this intent, and the differences in the influence of these factors from respondents in urban and suburban settings. As such, the findings reported in this study can be useful for transportation planners in evaluating the feasibility of implementing shared e-bike schemes in urban and suburban areas, and justifying their decisions. For example, one possible implication from the findings of this study is that shared e-bikes may show more promise of substituting private automobile trips in suburban neighbourhoods, given the finding that similar proportions of people are willing to consider shared e-bikes in urban and suburban neighbourhoods, yet more suburban respondents indicated they are willing to replace car trips. This finding, corroborated by other findings (such as future e-bike surveys inquiring about first- and last-mile connections in suburban neighbourhoods), could help inform the implementation of a shared e-bike scheme in suburban neighbourhoods. As such, this study may further be useful for transportation planners who are considering how to *optimally* implement shared e-bike systems in both urban and suburban contexts, and for policymakers to make more informed decisions on shared e-bike regulations that enable and encourage more active, sustainable modes of transportation. For example, planners may use the finding that urban respondents are more likely to replace transit trips, and less likely to consider using shared e-bikes if their primary mode is active (walking or cycling) to inform the strategic placement of e-bike docking stations (e.g. along transit lines to help relieve rush hour congestion) within urban areas, such as Toronto or Hamilton.

Since 2015, a handful of cities within the US with conventional bike share systems have begun expanding their fleets to include some e-bikes in attempts to help offset traffic congestion and carbon emissions, while promoting healthy, active lifestyles by reducing barriers to cycling. Consequently, nearly all existing schemes in the US have experienced growth in usage rates since their implementation, indicating a very real interest among residents and potential for significant modal shifts. The research presented here can aid in this growth by both justifying the strategic design of existing electric bike sharing systems, and guiding the implementation approaches for any future expansions within these systems. Further, the potential role the public sector plays in regulating shared e-bikes should be considered, given that shared mobility schemes commonly require a unified effort involving private, public, and nonprofit providers of service.

E-bike sharing systems have yet to be implemented within any Canadian cities, though the Toronto Parking Authority, which oversees Toronto's Bike Share, had recently announced plans for the addition of 300 e-bikes to the system in 2020 (Smee, 2020). Toronto's Bike Share is currently centered around the urban core of Toronto, with a small number of docking stations along the urban peripheries. The 2020 expansion includes pilot programs that expand the bike share system outside of the urban core, specifically, into Scarborough and North York (Smith, 2020), areas that have suburban characteristics. Though it is unclear whether these pilot programs will include e-bikes in their fleet, the research presented in this paper could inform the potential inclusion of e-bikes in suburban communities of Scarborough and North York. The study is particularly valuable in this scenario since the sample focuses on potential users of the system rather than current ones, providing planners in Bike Share Toronto the applicable information and decision making tools to guide this potential expansion of shared e-bikes into the suburbs.

To further investigate propensity of considering shared e-bike systems, future research could address some of the challenges and limitations outlined in section 4.5. A new survey with more in-depth questions around demographics, attitudes, and built environment could be distributed – for example, questions identifying information about first- and last-mile connections could add more value to the study. Additionally, use of geographic information systems (GIS) could be incorporated to perform analysis of built-form impacts on intent to use shared e-bikes – for example, plotting respondents who live in close proximity to a bike share station may result in novel analysis on whether those with regular access to bike share are more amenable to shared e-bikes. Finally, further research should incorporate the use of weighted data to be more representative of the study area's actual socio-demographic distribution.

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