Understanding University Students' Intercity Transport Mode Choice: A Case Study of the University of Waterloo Students' Travel Behavior Between the Region of Waterloo and the Greater Toronto and Hamilton Area

by

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Author's Declaration

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

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Abstract

The ongoing population growth is an essential driver to support the Greater Golden Horseshoe (GGH)'s long-term economic development and competitiveness, but it could also create substantial issues and challenges on the region's transportation system. The Ontario provincial government, as well as the municipal governments in the GGH, have been aware of the current high level of automobile dependency and its negative consequences on the region's socioeconomic development. Several collaborative initiatives have been being taken to diversify the existing transportation system and encourage the use of transit and active modes of transportation. This research aims to understand what are the factors that affect University of Waterloo students' intercity mode choice, and the significance levels of the identified influencing factors on their intercity mode choice between automobile modes (driving, carpooling, Uber and taxi) and non-automobile modes (bus and train). It also investigated the students' attitudes towards the proposed high-speed rail in Ontario and their intended behavior of using it when traveling between the Region of Waterloo and the Greater Toronto and Hamilton Area (GTHA).

The results revealed that the students' intercity mode choice behavior varies according to their trip frequencies and their primary destinations in the GTHA, and whether or not having the Presto card and motor vehicle availability are the two most influential factors at the 1% significance level on their intercity mode choice. Moreover, the study also found the students have overall positive attitudes towards the high-speed rail in Ontario. Several recommendations were subsequently proposed based on the research findings, which focus on increasing the non-automobile mode share in the intercity travels and adequately engaging the university population in the planning process of the HSR project.

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List of Abbreviations

GGH	Greater Golden Horseshoe
GRT	Grand River Transit
GTHA	Greater Toronto and Hamilton Area
HSR	High-Speed Rail
LRT	Light Rail Transit
MNL	Multinomial Logit Model
RER	Regional Express Rail
TOD	Transit-Oriented Development
TPB	Theory of Planned Behavior
TTC	Toronto Transit Commissions

1. Introduction

1.1 Research Background

As one of the most populous and thriving regions in North America, the Greater Golden Horseshoe (GGH) attracts thousands of people to move to here from other parts of Canada and around the world, in pursuit of high quality of life and economic opportunities (Ontario Ministry of Municipal Affairs, 2017). With a projected increase of 39% of 2016's population, this region is expected to be home to 13.5 million people by 2041 (HEMSON, 2012).

The ongoing population growth is an essential factor to support GGH's long-term economic development and competitiveness, but it could also create substantial issues and challenges on the region's transportation system. According to the data from the 2011 Transportation Tomorrow Survey (TTS), total trips on an average weekday in the GGH increased by 105% from 1986 to 2011, while trips made by automobiles showed a much sharper increase at 128%, accounting for around 80% of all trips since 1990s. Rising travel demand would increase road traffic, resulting in more congestion and delayed movement of people and goods that cost billions of dollars in lost GDP every year (Ontario Ministry of Municipal Affairs, 2017). In addition to the economic loss, road transportation is also a significant source of air pollutant and greenhouse gas (GHG) emissions, representing 19% of total Canadian GHG emissions in 2009 (Transport Canada, 2017). The emissions have proved to be critical drivers of smog and acid rain, causing adverse health and environmental effects (Government of Canada, 2017).

The Ontario provincial government, as well as the municipal governments in the GGH, have been aware of the current high level of automobile dependency and its negative consequences on the region's socioeconomic development. Several collaborative initiatives have been being taken to diversify the existing transportation system and encourage the use of transit and active modes of transportation. For example, as the crown agency of the Government of Ontario, Metrolinx has adopted the Big Move plan since 2008 to improve its interregional rapid transit service (GO Transit) that serves the GGH. It has invested and will invest $16 billion in total by 2020 to intensify the GO Transit network by providing more frequent service, reduced travel time and higher service reliability (Metrolinx, 2013).

The agency has also been cooperating with the municipal governments in the Greater Toronto and Hamilton Area (GTHA), the most populated area in the GGH accounting for over 70% of the region's total population, to complement the local transit services (Clayton, 2015). Several light rail transit (LRT) lines have been proposed to construct in the area, aiming at enhancing the connectivity between GO transit stations and final destinations for the passengers. The Government of Ontario has also approved funding in an amount up to $7.15 million in 2017-18 to launch an initiative that will subsidize riders who transfer between TTC (Toronto Transit Commission) and GO Transit. This initiative would help GO Transit better integrate with local transit in the City of Toronto, the most populous municipality in the GGH (Metrolinx, 2017).

An effective solution to relieve road congestion and reduce people's reliance on automobile in the intercity travels is to introduce a new transport mode that can deliver a large number of passengers reliably and quickly, while having separated right-of-way from other traffic. High-

speed rail (HSR) therefore is identified as an ideal mode that can meet these requirements and has gained growing attention across the globe over the past decades (USHSR, 2017). Since the first high-speed rail system commenced commercial operations in Japan in 1964, there had been over 29,000 km of high-speed lines and 3,603 high-speed train sets in service in the world by 2015 (UIC, 2017).

Although the global high-speed rail networks are expanding at an astounding rate, the majority of progress has been made in Asian and European countries. The Canadian Federal Government and several provincial governments have also planned to build high-speed rail networks since 1960s, wherein one of the potential lines would be constructed in the southwestern Ontario that goes through the GGH. In December 2014, the Government of Ontario announced to build the phase 1 of the high-speed rail system, which is projected to be complete by 2025 (Government of Ontario, 2014). The phase 1 of the system is proposed to include four stops in the GGH, with two of them located in the GTHA and the others located in the Region of Waterloo and the City of Guelph respectively (Government of Ontario, 2017).

Sufficient and steady ridership is important to make the public transit financially sustainable and keep the service affordable. There have been several feasibility studies to forecast the intercity travel demand for the proposed high-speed rail service, by analyzing existing travel behavior and demographic data, as well as developing mathematical models. Nonetheless, little research has been done to understand the age-specific opinions on the high-speed rail service. For example, university students, the majority of whom are composed of Millennials[1], usually have fixed

[1] Millennials usually refer to a group of people who were born between 1982 and 2000 (Northern Illinois University, Faculty Development and Instructional Design Center, 2017).

schedules in studies, low vehicle accessibility and high mobility (Volosin, 2014). As a result of their unique demographic characteristics, the university students should use public transit more frequently than other adults, and therefore be more eager to see the government build the high-speed rail as an alternative transport mode for their intercity travels. However, it remains unclear about the specific attitudes of the university students towards the HSR and whether they would choose the HSR as their primary transport mode. To address the uncertainty, it is also necessary to examine the underlying factors that affect their current primary transport mode choice in the intercity travels.

1.2 Research Objectives and Questions

The main objective of this study is to understand the factors affecting University of Waterloo students' intercity transport mode choice and their attitudes toward the proposed high-speed rail service in Ontario. Given this context, this research seeks to address the following research questions in a logical order:

1. ***What factors would have influence on university students' primary transport mode choice in the intercity travels?***

Because no previous studies have particularly investigated the factors affecting university students' intercity transport mode choice, it is necessary to select the most relevant factors by broadly reviewing and summarizing existing literature in two directions. The first direction is to look up the research which studies the factors that influence general population's transport mode

choice; the second direction is to search the literature focusing on the influencing factors on university students' domestic travel behavior.

Different countries have different definitions of "intercity travel". In the U.S., intercity travels refer to the travels with distances of 50 miles (equivalent to 80.5 kilometers) or more (Yoshitsugu et al., 2014). For this research, intercity travels include all cross-municipality travels between the Region of Waterloo and the regional municipalities in the GTHA. Therefore, trips between the City of Waterloo and the City of Kitchener within the Region of Waterloo cannot be recognized as intercity trips. The other term in the first research question that should be clarified is the "primary transport mode". A typical intercity trip is usually composed of three phases: phase 1 is accessing to the intercity transport facility from the origin of the trip; phase 2 is using the intercity transport facility to travel to the terminus that is close to the final destination; phase 3 is traveling to the final destination from the terminus. Although there is no clear definition regarding the "primary transport mode" in the intercity trips, this research assumes that the transport mode used in the phase 2 of the trip is regarded as the "primary transport mode".

2. ***What are the characteristics of University of Waterloo students' current intercity travel behavior; what is the significance level of the influencing factors on their primary transport mode choice in the intercity travels?***

To resolve the second research question, on-campus revealed-preference (RP) survey will be conducted at the main campus of the University of Waterloo, to gather the demographic and recent intercity travel details data of the university students. Then, descriptive statistics will be

used to portray and visualize their intercity travel characteristics. To examine the significance level of the influencing factors on respondents' primary transportation mode choice behavior in the intercity travels, binary logit models will be used to estimate the coefficients. The Chapter 2 and 3 will provide further discussions regarding model choice, as well as data collection and analysis methods.

3. ***What are the attitudes towards the high-speed rail among University of Waterloo Students?***

The approaches used for answering this research question follow closely to a study in comparing attitudes and preferences for improved passenger rail service among urban areas in the south-central high-speed rail corridor in Texas (Sperry et al., 2011). Both studies employ the stated-preference (SP) techniques in the survey and use descriptive statistics to examine the attitudes in the communities along the proposed high-speed rail corridor. The Chapter 2 will review the literature and discuss in detail regarding how to identify respondents' attitudes towards taking the high-speed rail.

By answering the three research questions above, this study will first identify two featured segments of university intercity travelers: non-automobile travelers and automobile travelers. The findings could inform the transportation planners to enhance the intercity transit network and service, so as to induce more university students to take public transit in the GGH. In addition, this research also fills the gap in understanding the attitudes towards the HSR of a

specific group of population, which is beneficial for the provincial government to more accurately forecasting the travel demand of the new transport mode.

1.3 Thesis Structure

This thesis is comprised of 5 chapters. Chapter 1 introduces the background and study context of the research, as well as the specific research questions and objectives. Chapter 2 summarizes the reviewed literature that supports the research, including topics on Characteristics of University Students' Intercity Travel Behavior, Factors Affecting University Students' Intercity Transport Mode Choice, Transport Mode Choice Models and Theoretical Framework, Attitude and Transport Mode Choice, High-Speed Rail in Ontario, Canada, and Collection of Travel Behavior and Attitude Data. Chapter 3 describes the study areas and methods used for data collection and analysis. Chapter 4 provides the descriptions of the basic features of the sample data and the results of the model analysis. After that, Chapter 5 summarizes the research findings and provides recommendations, as well as highlights possible areas that could be further explored and studied.

2. Literature Review

2.1 Characteristics of University Students' Travel Behavior

Travel behavior refers to the study of what people do over space and how people move using transportation (Privitera, 2015). Although there is great heterogeneity of travel behavior characteristics among people, researchers have made great efforts to identifying homogenous travel behavior groups for a better understanding of the determinants of travel (Hanson & Huff, 1986). University students have thus been classified as one of the distinctive study populations in the travel behavior research and started drawing attention from scholars. After reviewing the literature, it could be found that majority of the studies related to university students' travel behavior are directed towards their local or short distance trips.

The uniqueness of university students' travel behavior characteristics is derived from their distinctive daily routines and lifestyles. Compared to other populations, they usually have more flexible and atypical compulsory activity schedules, because, for example, their class schedules may differ by day of the week and their working hours may not be regular either. A study conducted at Arizona State University (ASU) compared the travel behavior characteristics among students, staff, and faculty, which concluded that university students do differ from typical working adults (ASU staff members) as they usually make shorter distance for each travel but have more frequent trips over the day. Moreover, student travels tend to be distributed more evenly across the day, rather than primarily be made during classic AM and PM peak hours (Volosin, 2014).

In addition, university students are also a group of people with higher level of mobility, fewer family obligations and lower vehicle availability (Volosin, 2014). They rent a room or a unit on-or-off campus for residence, instead of living with their family members. The residential addresses of students enrolled in the co-op programs would be changed more frequently as they may have to move to different places during the work terms. Vehicle availability is strongly associated with individual economic factors, so people with stable and higher earnings are more likely to own the vehicle and use it as their primary transport mode (Blumenberg et al., 2012). University students usually have to face considerable economic pressure including high unemployment, uncertain job security, significant student loans and limited assets, which could account for their below-average vehicle availability and higher dependence on transit (Polzin et al., 2014).

The rest of studies focused on university and college students' intercity travel behavior have put specific emphasis on students' holiday travel behavior and its impact on tourism market (Babin and Kim, 2001; Bicikova, 2014; Hobson and Josiam, 1993; Hobson and Josiam, 1996, for example). Although university students' day-to-day or regular intercity travel behavior for business trips (commuting to school or work) have not been examined, these studies could partially characterize university students' mode and destination choices behavior for middle and long-distance travels. In the context of North America, Babin and Kim (2001) explored the satisfiers of travel behavior of international students who studied in the U.S., and claimed that international students' perceptions of safety, fun and educational benefits associated with a travel destination could influence the trip outcome. Another two studies conducted by Hobson and Josiam surveyed students at the University of Wisconsin-Stout for their travel behavior during

the college spring break. The first study found that Florida is the most popular destination among surveyed students and the majority of trips to spring break destinations are made by car (Hobson and Josiam, 1993). The second study examined the travel behavior of the university students over a four-year period, the findings from which implied that the overall spring break market is a relatively stable one as the number of student tourists remained remarkably constant over a four-year period (Hobson and Bharath, 1996).

2.2 Factors Affecting University Students' Intercity Transport Mode Choice

As mentioned in Section 2.1, there is a lack of comprehensive studies on investigating the factors affecting university students' intercity transport mode choice. Hence, the literature that has been reviewed is in two research directions respectively. The first direction is identifying what factors affect general population's transport mode choice primary in intercity travels, whereas the second is understanding the determinants of university students' transport mode choice.

2.2.1 Factors Affecting General Population's Transport Mode Choice

Many researchers and transportation planning practitioners have recognized the significant relationship between socio-demographic characteristics and transport mode choice (Hanson & Hanson 1981; Lu & Pas, 1999; Salloum, 2014; for example). Social-demographics refer to both social-economic and the role-related characteristics of the individual, such as occupation, employment condition, education, income, gender and age (Hanson & Hanson, 1981). In travel behavior studies, vehicle availability and driver's license holding are also considered for investigation (Lu & Pas, 1999). Most of the studies ask respondents' socio-demographic information in their surveys and analyze the variables to identify the linkage between transport

mode choice and sociodemographic characteristics (Data Management Group, 2011; Sperry et al., 2011, Peng et al., 2014, for example).

Basarić et al. (2016) analyzed travel characteristics data in Novi Sad, Serbia and found notable differences in travel purpose and mode choice between males and females. Their studies also revealed that age differences could contribute to different travel behavior among Novi Sad residents, as their mobility declines with age. Sperry et al. (2011) claimed that young adults who have experience riding the existing intercity passenger rail service are more likely to change their travel behavior to patronize the planned high-speed rail service than older adults. On the other hand, some scholars suggested that the difference in mode choice behavior among people at various age groups is because young people are generally more sensitive to travel costs than older people (Litman, 2004, for example). According to the study conducted by Gillen in the U.S. which focused on transit fare elasticities, riders aged between 17 to 64 had greater elasticity (-0.22) than those aged over 64 (-0.14) (Gillen, 1994). This result indicates that each 1.0 percent increase in transit fares would cause a 0.22 percent reduction in ridership among the young people and a 0.14 percent reduction in ridership among the old people. Peng et al. (2014) studied intercity travel choice behavior of residents in Zhenjiang, China by demographic and psychological factors, and found that respondents with fewer years of education are more likely to use the traditional train as intercity travel mode and those with higher incomes show more preference to the high-speed train. According to the findings from the 2011 Transportation Tomorrow Survey (TTS) which studied urban travel behavior of residents in the GGH, number of vehicles in household, availability of free parking at work and holding of regional transit pass

(GO Transit pass) are also influencing socio-demographic factors on individuals' transport mode choice (Data Management Group, 2011).

Apart from the socio-demographic characteristics, researchers note that trip characteristics and attributes of the transport facility could affect individuals' transport mode choice behavior as well (Kwan et al., 2018; Miskeen et al., 2013; Ortúzar & Willumsen, 2011; Racca & Ratledge, 2003). Trip characteristics are composed of travel purpose, origin/destination of travel, travel distance and travel frequency (Miskeen et al., 2013). Previous studies on people's intercity transport mode choice have also identified them as significant influencing factors (Behrens & Pels, 2011; Bergantino & Madio, 2017; Data Management Group, 2011, Forinash & Koppelman, 1993; Sperry et al., 2011, for example). According to an intercept survey conducted in Illinois, U.S. on passengers' long-distance travel behavior, passengers traveling for business are more likely to take flight, while the majority of car passengers are traveling for visiting friends or family members (Auld et al., 2016). By segmenting the sample population who had had intercity travel experiences between Bari and Brindisi in Italy into two groups, namely the business travelers and leisure travelers, Bergantino and Madio (2017) found that business travelers are more interested in minimizing in-vehicle time and in reducing the fragmentation of the journey (access/egress time), which is in contrast to leisure travelers who are more sensitive in ticket price increase when choosing the transport mode. A study of mode choice behavior for intercity business and personal/recreational trips on a high-speed corridor in China also indicated that the changing patterns of the modal share with increasing travel distance tend to be different between business and non-business travels (Wang et al., 2014).

In terms of the influence of origin and destination on transport mode choice, travelers who live in rural or suburban areas are more likely to use private automobiles than those living in urban areas. In the context of the GGH, Toronto has the highest share (nearly 30%) of transit users in that the city has the country's most extensive transit system, but in Kawartha Lakes, where it is served only by three transit routes, over 90% of the residents' travels are made by cars (Data Management Group, 2011). However, when rural or suburban areas are well connected with big cities by passenger rail transport, it is possible that rural and suburban commuters would choose the public transit as their primary intercity transport mode (Sperry et al., 2011). In addition, with the increase in travel distance between origin and destination, passengers' travel mode choice will significantly change due to the diversification of alternative travel modes (Yan et al., 2017). When the trip distance is within 100 km, the automobile is the dominant travel choice, but when the distance exceeds to 250 km, high-speed rail accounts for the highest mode share (Wang et al., 2014).

Trip frequency is used to describe how often people travel (on a fixed route) over a designated period of time. The frequency of long-distance journeys has significant linkage with travelers' income and mode choice behavior (Rohr et al., 2008). Compared to frequent travelers, occasional travelers are more sensitive to ticket prices in intercity transport mode choice (Bergantino & Madio, 2017).

Attributes of the transport facility are the third group of influencing factors on mode choice, which are primarily composed of objective and quantitative factors, including the components of

travel time, components of monetary costs, availability and cost of parking, and reliability of travel time and regularity of service (Ortúzar & Willumsen, 2011).

Total travel time in a journey consists of the in-vehicle time of all used transport and aggregated intra-modal and (or) inter-modal transfer time. In many intercity travel behavior studies, researchers focus on the impact of access and egress time on respondents' mode choice (Behrens & Pels, 2012; Forinash & Koppelman, 1993; Goel & Tiwari, 2015; Li & Sheng, 2015; Wong & Habib, 2015, for example), where access time refers to the required travel time from a traveler's home location to the specified intercity mode departure station, and egress time is defined as the travel time from the intercity mode arrival station to the final destination. In forecasting the travel demand of the proposed high-speed rail service along the Windsor-Quebec Corridor in Canada, Wong and Habib (2015) suggested that intercity travelers are more concerned about access to and egress from transit stations than the main in-vehicle travel while choosing intercity travel modes, so transportation planning authorities should give careful considerations on transit station accessibility for the success of any innovative travel mode. Li and Sheng (2016) investigated the mode choice behavior of intercity-passengers among air transport, HSR, and Air and HSR (AH) integration services in China, finding that when total travel distance is within the range of 1,200 km to 1,600 km, passengers feel less sensitive to the connection time of mode AH, which becomes the most competitive mode compared to the direct HSR and air transport services.

In consideration of the total travel cost of a journey, transit fares, tolls, fuel and other operating costs are usually examined as influencing factors (Ortúzar & Willumsen, 2011). Findings from a

research carried out in China suggested that increases in travel costs on the use of HSR, buses, and autos running on the toll roads (expressways) would prevent modal shifts from automobiles running on the free provincial non-expressways to these models (Li et al., 2014). In Berkeley California, government subsidizing transit is a considerable factor that induces the students and faculty and staff members at the University of California, Berkely to choose public transport (Proulx et al., 2014). Lane (2009) also found that in major U.S cities, higher gas prices could lead to slightly increase in transit ridership, because low-income automobile owners who are struggled to afford the gas costs are more likely to shift to transit at this time. In addition, Mudigonda et al. (2014) claimed that transit-oriented development (TOD) could help travelers reduce the costs of transportation by inducing them to shift to public transit from driving, so they can save money on driving costs (including fuel, wear and tear, and depreciation).

For automobile owners, availability and costs of parking at destination play a significant role in determining their travel mode choice. Due to the intensive development and relatively limited parking supply, parking rates in downtown areas are usually higher than in suburban and rural areas, which could discourage travelers from using private vehicles when they travel to downtown. As the second most expensive city to park in Canada (City News, 2011), Toronto has the largest mode share in transit among the municipalities in the GGH, more than double the rate than Peel Region, which has the second largest mode share in transit (Data Management Group, 2011). In addition, Ng (2014) investigated the impact of university parking pricing on shifting mode choice of UC Berkeley staff members and faculty, finding that staff members are less price sensitive to changes in parking pricing because they prefer to park on campus more than faculty do, and the staff members usually live further away from campus. Bridgelall (2014) further

suggested that universities could cooperate with local transit authorities to develop real-time information technology to inform users about bus arrival times or campus parking spot availability, which may change user's perception about the cost and convenience of a particular mode.

For both private vehicle and transit users, travel time reliability and service regularity are two more factors affecting their transport mode choice (Bhat & Sardesai, 2005; Chang & Stopher, 1981, for example). Generally, travelers inherently place a value on the certainty presented by a reliable transport mode, which is independent of any consequences at either the origin end or the destination end of the trip. In the meantime, they would feel stressful and anxious when there is uncertainty imposed by an unreliable transport system (Bhat & Sardesai, 2006). Travelers usually seek a compromise between affordable travel costs, and relatively high reliability and regularity of service in the mode choice. A study on the auto drivers' choice between regular lanes and high-occupancy toll (HOT) lanes along the interstate I-15 corridor in the US revealed that when the travel time in regular lanes is very unpredictable, exceeding a certain threshold level, drivers are willing to pay very high toll to use the HOT lane (Ghosh, 2001). However, the level of sensitivity to service reliability would vary among travelers, as commuters with inflexible work schedule would be more impacted by the travel time unreliability of the transport facility (Bhat & Sardesai, 2006). Considering the relatively high uncertainty in travel time of road transport due to traffic congestion, Bhat and Sardesai (2006) suggested that a well-designed commuter rail transit system would have potential to shift travelers from driving to public transit.

2.2.2 Factors Affecting University Students' Transport Mode Choice

After reviewing the relevant literature, it is argued that the socio-demographic factors chosen by the researchers to understand their influence on university students' transport mode choice are slightly different from those examined in the general population's transport mode choice studies. Given the fact that majority of university students are in the similar age range and have no stable income resources, individual income and age are usually excluded from examined factors that may influence university students' transport mode choice. Researchers assumed that most of the university students have a limited budget for living and traveling in that they have to pay tuition fees for university, and taking courses or doing research to complete the degree, while not able to have a long-term and full-time job to get a decent salary (Cartenì et al., 2017). In Canada, although university students ranged in age from 10 to 98 years old, over 75% of them were between 17 and 27 years of age (Statistic Canada, 2007). Therefore, it can be assumed that the impact of age difference among university students on their travel mode choice is not as substantial as that among people in all age groups.

However, some studies suggest that university students would show different behavior in transport mode choice by residency status, level of education, residential location and enrolment status as well. Field (1999) explored the difference in the travel behavior between international students and domestic students studying at the Clemson University in the U.S. He found that domestic students are more likely to travel by car than international students, while hardly using train or bus for trips. Akter (2016) also revealed that international students are more preferred to use the university shuttle service for on-campus travels than domestic students do, by analyzing the data conducted at the University of Toledo in Ohio. She argued that international students

taking the shuttle bus specifically for social needs, on which they can communicate and make new friends from the university.

In addition, there could be a significant difference in transport mode choice between undergraduate and graduate students. Compared to undergraduate students, graduate students prefer walking to driving a car for on-campus trips, because they are probably more aware of sustainability and healthy lifestyle (Akter, 2016). For commuting trips to campus, Volosin (2014) found that graduate students at Arizona State University (ASU) are more likely to drive along, while undergraduate students show a higher percentage of using walking mode. For students of Ohio State University who live off-campus, driving is the also the most popular commuting mode among graduate students, while walking is most favored by undergraduate students (Akar et al., 2012). The difference in the modal split in commuting between graduate and undergraduate students can be attributed to their residential locations, namely the distance to campus. Undergraduate students, especially those in their first year, are usually required to live on campus, or they prefer to live close to campus. Therefore, they are more likely to walk or use the bicycle for commuting. In contrast, many graduate students and the rest of undergraduate students who seek affordable housing usually live further away from campus, so their interest in carpooling or driving would increase with distance from campus (Akar et al., 2012; Raj, 2014).

Moreover, a few studies indicate that university students in different employee status would vary in travel behavior. Eom et al. (2009) found that full-time working students are less likely to travel compared to part-time, volunteer and unemployed students. A study conducted at

Dalhousie University in Canada also revealed that university students involved in paid work are more likely to walk or take transit for traveling (Daisy et al., 2018).

2.3 Transport Mode Choice Models and Theoretical Framework

2.3.1 Aggregate and Disaggregate Models

In the early stage of transport mode choice studies up to the late 1970s, aggregate models, which primarily focus on mode choices made by average individuals for trips between geographical zones, were widely used by planners and engineers to predict travel demand or identify the significance levels of the influencing factors (Barff et al., 1982). However, as indicated by Domencich & McFadden (1975), there are several faults and shortcomings in the aggregate modeling approach to predict urban travel demand:

1. The aggregate models are basically non-behavioral. They replicate the results of conditions existing at the time of survey and provide little or no guidance to the effects on travel decisions in travelers' circumstances or in the terms upon which they are not offered competing alternatives in the transportation environment.
2. Except for the modal choice function, the models are basically not policy-oriented. The effects of the variables which policy-makers are able to control are excluded from the trip generation and attraction functions and applied very mechanically, and to a limited extent at best, in the trip distribution function……
3. Their models are based on data representing zonal aggregates of trips and socioeconomic conditions. This obscures much of the information in the data, and together with the lack of a behavioral structure, makes the models very difficult to generalize from city-to-city.

As a result of these issues of the aggregate models, many researchers started to develop "disaggregate models", which have become increasingly popular since the 1980s and can offer substantial advantages over the aggregate models while remaining practical in many application studies (Ortúzar & Willumsen, 2011). Data for disaggregate models are collected at the individual or household level, but disaggregate-model parameters are always estimated across individuals or household for a sample or subsample of the population (Barff et al., 1982). The application of the disaggregate modeling approach could undoubtedly improve the precision of parameter estimates, while providing the models with a much broader range of explanatory variables (Ben-Akiva & Lerman, 1985). Amongst the disaggregate models, discrete choice models are mostly used for modeling travelers' mode choice. In the following section, the theoretical framework of the discrete choice models will be explained, followed by the introduction of two most representative discrete choice models.

2.3.2 Discrete Choice Models and Theoretical Framework

In general, discrete choice models postulate that the probability of individuals choosing a given option is a function of their socioeconomic characteristics and the relative attractiveness of the option (Ortúzar & Willumsen, 2011). The most common theoretical framework of the discrete choice models is the random utility theory (Domencich & McFadden, 1975), which assumes that travelers seek to maximize his/her utility when making this choice. In discrete choice modeling, utility equations are developed to estimate the total utility of traveling by a particular mode, given the relevant influencing factors as reviewed before. To predict the probability of an individual choosing a particular travel mode, the individual's utility for that mode is transformed into a probability curve using a mathematical function such as the logit models (Ortúzar &

Willumsen, 2011). The logit models are the most commonly used transport mode choice models (Ben-Akiva & Lerman, 1985; Domencich & McFadden, 1975). Based on the number of available values of the dependent variable, there are two basic types of logit models: binary logit model and multinomial logit model (MNL).

Binary Logit Model

The binary logit model refers to a logistic regression model in which the number of values of the dependent variable is two. In real practices, researchers adopt the binary logit model to evaluate the factors that influence travelers to choose one mode over the other mode. Winn (2005) applied the model to analyze what are the most influential factors for travelers to choose casual carpooling over public transit in Houston, Texas, where he found that travelers on commute trips are more likely to casual carpool. Similarly, a study conducted in Metro Manila, Philippines also employed the binary logit model to estimate the probability of the residents to choose public transport over private transport for traveling, with the consideration of four factors (Doroy et al., 2016).

Multinomial Logit Model (MNL)

The multinomial logit model is sometimes considered as an extension of the binary logit model, as it has more than two values. The probability of choosing option *i* (*iq*) among all the alternatives (*q*) in a multinomial logit model is defined as

$$P_{iq} = \frac{\exp(\beta\ V_{iq})}{\sum_{A_j \varepsilon A(q)} \exp(\beta\ V_{jq})}$$

Where *q* is the alternative mode choice set, and *iq* is one of the modes in the alternative mode choice set (Ortúzar & Willumsen, 2011).

Moreover, there are also other logit models existing, such as the nested logit model and the conditional logit model. Given the complexity of implementation and relatively low popularity in mode choice analysis, they are not further discussed in this research.

2.4 Attitudes and Transport Mode Choice

As discussed in Sections 2.2 and 2.3, the influence of objective factors (such as socio-demographic information, trip characteristics and attributes of transport facility) on travelers' mode choice behavior has been widely studied based on the utility theory. However, many argued that the subjective factors of the decision makers should also be incorporated in the analysis of their mode choice so as to better understand and predict people's behavior. This implies researchers to study travel behavior in-depth from the socio-psychological perspective (Ajzen, 1985; Ben-Akiva et al, 1999; Lanzini & Khan, 2016, for example). Among various theoretical frameworks, the Theory of Planned Behavior (TPB) is one of the most popular theory frames of reference that has been applied to investigate and explain human behaviors across multiple disciplines (Ajzen, 1991). According to the theory, human behavior is affected by behavioral *intention*, which is in turn formed by the *attitude towards the behavior*, *subjective norm*, and *perception of behavioral control*, as shown in Figure 2.1. Generally, the more favorable the attitude and subjective norm, and the greater the perceived control, the stronger should be the person's intention to perform the behavior (Ajzen, 2006). However, the relative importance of the three conceptually independent determinants of intention in the prediction of

intention may vary across behaviors and situations (Ajzen, 1991). Thus, there is a growing interest in particularly studying the influence of one or two of the factors on person's behavior, and some studies have revealed the sole effect of *attitudes towards behavior* on travelers' intention to change mode choice (Hsiao & Yang, 2010; Johnson, 1977, Kroesen et al., 2016, Rutkowski, 2016, for example).

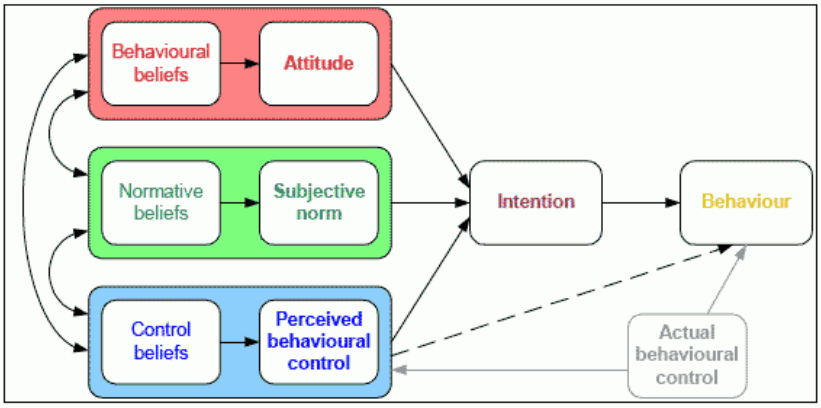

Figure 2. 1: Framework of TPB (Ajzen, 2006)

Attitude toward the behavior is derived from the beliefs about the likely outcomes of the behavior and the evaluations of these outcomes (behavioral beliefs) (Ajzen, 2006). In other words, the behavioral beliefs are the people's overall general feelings toward their behavior (Kaewkluengklom et al., 2016). Some studies suggest that there is a direct positive influence of traveler's attitudes towards a certain transport mode on their intention or behavior to choose the mode (Johnson, 1977; Kroesen & Chorus, 2017; Kroesen et al., 2017, for example). Kaewkluengslom et al. (2016) studied the relationship between the attitudes of the private vehicle and public transport users towards a planned Bus Rapid Transit (BRT) system in a Thailand city, and their intention to use it in the future. They found that travelers who have a

more positive attitude toward BRT, are more willing to use it in the future, indicating that the planning authority should induce travelers to build a favorable attitude towards the new transport system by introducing the advantages of the BRT system to the public. Beirao & Cabral (2007) also suggested that improving the image and levels of service being offered can attract potential users to the public transport service.

Travelers' overall attitudes towards a transport mode can be interpreted as their specific attitudes towards the various attributes of the transport facility. Johnson (1977) studied ten different attributes of transport facility and their relative importance as influences on choices among car, bus and BART (Bay Area Rapid Transit) for traveling to work in the San Francisco Bay Area. The ten attributes were measured by asking a sample of 258 commuters to rate their satisfaction with the three transport modes. By calculating the average ratings of the studied transport modes for each attribute, the researcher found substantial differences in evaluations between the car and the two transit modes. Compared to the BART and bus, the car is rated as much higher on total travel time, dependability and flexibility, but as inferior in regards to safety from accidents. In addition, some travelers consider the environmental impact as a supplementary attribute of the transport modes, which would promote their sustainable and environmentally-friendly travel behavior (Elias & Shiftan, 2012; Fridgen, 1994). Harvey et al. (2014) studied travel attitudes of long-distance travelers in the UK, who found that high-speed rail commuters are more favorable to sustainable transport than weekly air commuters. However, they also suggested that persuading the use of high-speed rail cannot be done just on environmental grounds and other aspects of attitudes should also be incorporated to work better.

For intercity travelers who choose HSR over other transport modes, their positive attitudes towards the HSR may also be affected by novelty seeking, which is a personality trait defined as the desire to seek out new stimuli (Hirschman, 1980). Hsiao and Yang (2010) analyzed the attitudes of 330 college students from a university in Taiwan toward their intention to take the Taiwan HSR. Findings from their research indicated that novelty seeking has indirect significant influences on college students' intention to take HSR via attitude toward HSR. Harvey et al. (2014) also implied that young and male respondents are more desired to seek out new stimuli, so they usually have more a positive attitude toward technological products and feel more excited and enjoyable on using the HSR service than using the traditional rail service.

The differences in travel attitudes between car drivers and public transport users arise not only from the distinctive external attributes among various transport modes, but from their varying levels of recognition of travel needs and purchasing powers (Hebel & Wolek, 2016). For example, individuals who are concerned about travel time, flexibility of departure time, and the ability to stop on the way to and from destination are more likely to drive along to the destination (Akar et al., 2012), while those who place affordable travel costs as priority are more willing to use public transit for commuting (Grdzelishvili & Sathre, 2011). It is also worth to note that travelers' attitudes toward a transport mode may differ spatially and can be influenced by individual's previous experience and knowledge. Sperry and Morgan (2011) compared the attitudes towards a proposed high-speed rail service among residents living in three communities in Texas, US, who found that although residents from all three communities are generally favorable with the proposed intercity HSR service, there appears to be different levels of agreement in regards to the impacts of the rail service on local development among the three

studied communities. They also noticed that the communities, where more residents have experiences riding the traditional rail services or HSR services outside of Texas, are slightly more acceptable to the proposed high-speed rail service.

2.5 High-Speed Rail in Ontario, Canada

The idea of implementing high-speed rail services in Canada was first proposed in the 1960s, as a result from the desire to update its passenger rail service by the Canadian National Railway Company (CN Rail) (CN Rail, 1966). In 1968, four years after world's first high-speed rail service began to operate on the Tokaido Shinkansen line in Japan, a sleek, new lightweight passenger train, also known as the Turbo-Train, entered service to serve passengers traveling between Toronto and Montreal (IGOR SIKORSKY, 2012). Powered by the gas turbine, the Turbo-Train can travel at speeds up to 274.8 km/h, while the highest speed it made in Canada is 226.2 km/h (Langton, 2008). However, the speed of the Turbo-Trains for regular service in Canada was limited to 153 km/h due to the large number of grade-crossings on the route (Allen, 1992). The Turbo Train's last run in Canada was in 1982, when they were all replaced by the LRC trainsets from Bombardier Transportation. The locomotive of the LRC is capable of 125 mph (201 km/h), but is restricted to 100 mph (161 km/h) maximum speed in service in Canada, because the country does not have any 125 mph tracks (Rapido Trains Inc., 2015).

Several years after the withdrawal of the Turbo Train service, the VIA rail, merged from the old CN Rail and Canadian Pacific (CP) passenger services (VIA Rail, 2018), restarted the interest in constructing high-speed rail along the Quebec-Windsor corridor (see Figure 2.2), and several feasibility studies have been done since the 1980s (Association des économistes Québécois,

2016). With the total length of over 1,200 kilometers, the Quebec-Windsor corridor, which goes through Ontario and Quebec provinces, is the most densely populated and most industrialized area of the country with 18 million inhabitants, concentrating 60% of Canadian population and two of the nation's most populated cities (Toronto and Montreal) (SNCF, 2010).

Figure 2. 2: Quebec-Windsor Corridor Passenger Train Map (VIA Rail, 2017)

The corridor has been identified by the studies with massive potential for growth in passenger volume and revenue, thus should be planned a new high-speed rail service to promote the corridor's future social and economic development (Bombardier, 1990; Rapid Train Task Force, 1991, for example). However, ABB (1990) also indicated that the HSR in Canada would remain a vision without the financial support and a clear commitment from all levels of government particularly the federal government. In 1995, another report funded by the governments of Canada, Quebec and Ontario was released, in which it presents the results of the Quebec-Windsor HSR feasibility study. The report also suggests that while HSR in the corridor is technically feasible and can provide enormous environmental and economic benefits, large

financial commitments should be secured from the federal government to proceed with the project (Transport Canada et al., 1995). Later in the 1990s, the Lynx Consortium proposed to build and operate the high-speed train using a Public-Private Partnership (P3) model, but the parliamentary committee overseeing the project "shelved the proposal in favor of the status quo": cheaper, but slower, conventional trains (Greenlaw, 2007; House of Commons, 1998; Katz-Rosene, 2013).

Turing to the 21st century, the plan of implementing HSR service in the Quebec-Windsor corridor was put back on the agenda (Dupuis, 2011). In 2009, the federal government together with the governments of Ontario and Quebec awarded a $3-million contract to the EcoTrain consortium, to update the 1995 study on the feasibility of high-speed rail in the Quebec-Windsor corridor (Transport Canada, 2009). The report was released in 2011, which justified the plan to build a high-speed rail system. It evaluated two representative technologies for the proposed system: one is the diesel-powered 200 km/h trainset and the other is the electric powered 300 km/h trainset. With the recommendation that both technologies could be suitable for the needs expressed in the corridor, it estimated the initial investment costs of the project at $18.9 billion for the diesel-powered trainset or $21.3 billion for the electric-powered trainset in 2009 dollars (EcoTrain, 2011).

In December 2014, the Government of Ontario announced that it was taking the next step to build the high-speed rail line that would connect Windsor, London, Kitchener-Waterloo, and Toronto (also called Toronto-Windsor Corridor), by initiating the environmental assessment (EA) (Ontario, 2014). One year after, the Government of Ontario appointed David Collenette, a

former federal Minister of Transport, as Special Advisor to assist the province in bringing the HSR to the Toronto-Windsor corridor (Government of Ontario, 2015). Mr. Collenette submitted his final report on recommendations for high-speed rail in the Toronto-Windsor corridor in December 2016, where he proposed the future HSR system with recommended phasing, station locations and alignment (see Figure 2.3). He also highlighted that the province should implement electrified 250 km/h HSR technology for the Toronto-Windsor corridor, and should continue to seek funding and procurement approvals required to obtain consultant services for the EA and associated design work. According to his scenario, the phase 1 of the proposed HSR system will include 5 stops that connect Toronto, Pearson Airport, Guelph, Kitchener-Waterloo and London, with the estimated total travel time of 73 minutes (Collenette, 2016).

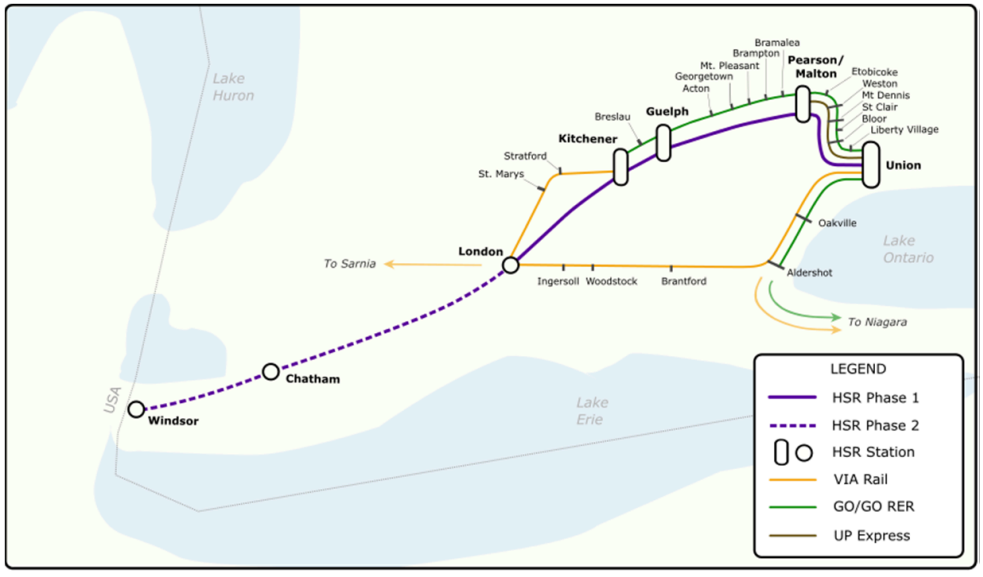

Figure 2. 3: Proposed Future HSR System and Phasing (Collenette, 2016)

In May 2017, the Government of Ontario announced that it was moving ahead with preliminary design work on the HSR project and investing $15 million in a comprehensive environmental

assessment (Government of Ontario, 2017). Followed by the announcement, the HSR Planning Advisory Board was established in October, 2017, to provide strategic support for the project (Ontario, 2017). According to the HSR project timeline, the formal environmental assessment process is projected to begin in Spring 2018, and the phase 1 of the HSR between Toronto and London is projected to be complete by as early as 2025, with final extension to Windsor by as early as 2031 (Government of Ontario, 2017).

2.6 Collection of Travel Behavior and Attitude Data

The most common method of collecting data for analyzing the influencing factors on travelers' mode choice and their attitudes towards a new transport mode is through surveys like household surveys, workplace survey, destination survey, and intercept survey. Computer-assisted personal interviewing (CAPI), which replaces paper-and-pen methods of survey data collection by using a portable computer, has gradually become a popular method since the late 1980s (Kalfs, 1995). After the interview, the data will be recorded and stored on the computer automatically. Another form of CAPI is the computer-assisted self-interviewing (CASI), where the interviewer hands over the computer to the respondent for a short-period, but she/he remains available for instructions and assistance (Ravi Sekhar, 2014).

In this research, two types of data will be collected. The first type of data is the Revealed Preference (RP) data, which are used to model the respondents' intercity transport mode choice; the second type of data is the Stated Preference (SP) data, which will be analyzed for understanding their attitudes towards the HSR. The advantages and disadvantages of the RP and the SP data will be discussed below respectively.

Revealed Preference (RP) Data

Revealed preference data represent data collected based on the events that have been observed to have actually occurred (Hensher et al., 2005). For example, Eluru et al. (2012) employed the web-based survey to collect the regular commuting pattern data of students, faculty and staff from McGill University in Canada, for analysis of the factors influencing the respondents' mode and route choices in trips commuting to the university. Wang et al. (2014) also used the revealed preference data to measure the significance levels of the identified attributes that affect intercity travelers' mode choice behavior along the Yong-Tai-Wen multimodal corridor in China. They conducted a survey in July 2010 at high-speed rail and intercity bus stations, and highway rest areas along the corridor, by randomly inviting the travelers to fill out the questionnaire focusing on collecting the information on their socioeconomic attributes and travel history.

There are several advantages of the RP data. The collection of RP data represents the collection of data on real-life choices, so if PR data are collected on a representative sample of the population, researchers can in theory replicate the actual mode shares in the market. The RP data also have high reliability, as the researchers can obtain similar results up to a sampling error (Hensher et al., 2005). In addition, it is relatively not difficult to collect the RP data in large quantities (Dumoint & Falzarano, 2012).

However, RP data can only reflect the existing market space, so they cannot predict the future travel demand, especially if new travel modes with much innovations are introduced to the market (Hensher et al., 2005). With RP data, researchers can only obtain the information on the

chosen alternatives, but they could have little knowledge about the alternatives that travelers considered and did not select (Dumoint & Falzarano, 2012). Besides, there is also a possibility that the collected RP data are not accurate as the respondents may not be able to remember their recent travel history (travel costs, travel time, travel distance, etc.) and give vague answers to the questions (Stangeby, 2000).

Stated Preference (SP) Data

Stated Preference (SP) data represent choices made in a hypothetical scenario, or data on what decision-makers say they would do (Dumoint & Falzarano, 2012). To collect SP data for mode choice analysis, many researchers present respondents with a series of hypothetical travel scenarios, in which the non-existence mode with pre-specified attribute levels is included as one of the choices, and inquire about the respondents' mode choice (Bergantino & Madio, 2017; Li & Sheng, 2016; Wong & Habib, 2015, Yang et al., 2009, for example). Other researchers collect SP data to understand respondents' attitudes towards new travel modes and their intentions to use the modes in the future (Fujii & Garling, 2002; Kaewkluengklom et al., 2017; Sperry & Morgan, 2011, for example).

The advantages of SP data are obvious. They provide reliable estimates of the relative importance of the features, and enable testing new travel mode or attribute levels that do not currently exist. Moreover, SP data can also enrich the choice model by easily matching choice behavior with socio-demographic data, allowing robust understanding of how individuals make choices (Dumoint & Falzarano, 2012). In terms of the limitations of SP data, because both alternatives and choices in the stated preference survey are not based on actual mode

alternatives, some unreasonable choices could be conflicted with the actual choices, thereby affecting the goodness-of-fit of the model (Li, 2017).

3. Methodology

3.1 Study Areas

3.1.1 Region of Waterloo and GTHA in the GGH

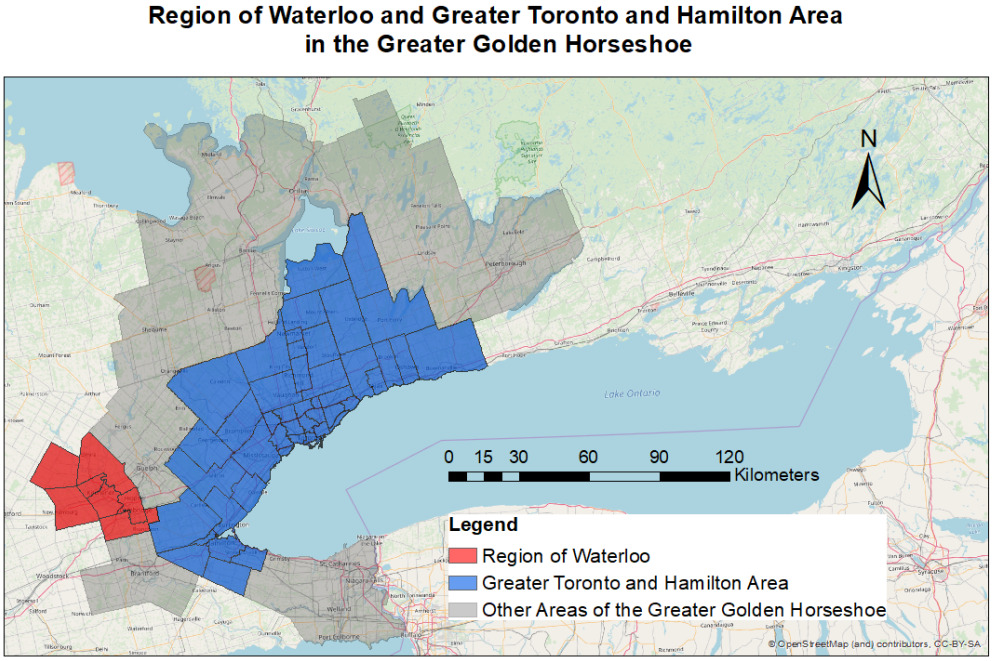

Figure 3. 1: Study Areas Map

Source: Compiled by author. Base map: Open Street Map

Boundary Map Source: Data Management Group of the TTS 2011

Figure 3.1 shows the locations of the GTHA and the Region of Waterloo in the GGH. The GTHA is also called the Inner Ring of the GGH, which is Canada' most populated metropolitan area that has 6,417,516 population according to the 2016 Census. With a total area of 8,262.62 km^2, the GTHA is composed of the City of Toronto and the regional municipalities of Halton, Peel, York and Durham (Statistics Canada, 2016). As a fast-growing area with its projected population increasing to 9.6 million by 2041, the GTHA is also the most popular and attractive

destination in the GGH for the Millennials, accounting for 71.4% of the region's Millennials and more than 90% growth in this generation (Calyton, 2015).

Lying in the Outer Ring of the GGH, the Region of Waterloo is the westernmost regional municipality in the area whose southeast corner shares the border with the GTHA. As home to two universities and one college, the regional municipality has a total population of 585,500 by the end of 2016, while 50,350 of them are full-time post-secondary students (Region of Waterloo, 2017). The total number of full-time students enrolled in the three higher education institutions[2] is 60,940 in Fall 2016, but 10,590 of them either commute to school from their homes in other municipalities or work temporarily elsewhere for their co-op work terms, and thereby are not included in the region's total population (Region of Waterloo, 2017). Students enrolled in the University of Waterloo were chosen as the representative samples for this research for two reasons. This is because the University of Waterloo is the most populated higher education institution in the Region of Waterloo, which has 41,510 full-time enrolled students in Fall 2016, accounting for over 58% of the region's total full-time enrolled post-secondary students (Region of Waterloo, 2017).

[2] The three higher education institutions are University of Waterloo, Wilfrid Laurier University and Conestoga College.

3.1.2 Existing Transport Means Between the Region of Waterloo and the GTHA

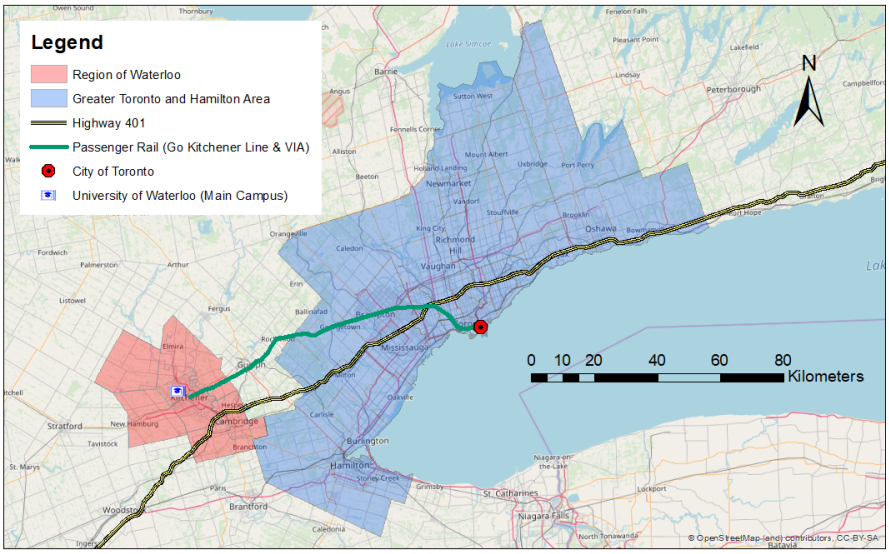

Figure 3. 2: Current Major Ground Transport Networks Between the Region of Waterloo and the GTHA

Source: Compiled by author. Base Map: Open Street Map

Transport between the Region of Waterloo and the GTHA is facilitated by air, rail and road networks. In this section, various private and public transport services that are being offered between the two regions will be introduced.

Air Transport

Since November 2017, FlyGTA airlines have launched air services, with eight-seat multi-engine aircraft, between Billy Bishop Airport (CYTZ) in Downtown Toronto and Region of Waterloo International Airport (CYKF) in Breslau, a community located in the township of Woolwich (CTV, 2017). The airlines offer three flights per day in each direction during weekdays, taking around 20 minutes for a single journey (FlyGTA, 2018). As the fare of a single journey ticket is

excessively high at $129 and no public transit connects the airport with the urban cores of the Region of Waterloo, this research will not include the airport transport as an alternative in surveying university students' intercity mode choice.

Rail Transport

As shown in Figure 3.2, there is one rail line that connects the Region of Waterloo with the GTHA, on which Go Transit and Via Rail provide regular passenger rail services for commuters. As a part of the Quebec City – Windsor rail corridor, the rail line starts from the Union Station in Downtown Toronto and ends at the Kitchener Railway Station in Downtown Kitchener, which also passes through the Peel Region and the Halton Region.

GO Transit offers the service available every 30 minutes during weekday rush hour from Kitchener Railway Station to Union Station in the morning (around 5:00 am to 7:00 am), and from Union Station to Kitchener Railway Station in the afternoon/evening (around 5:00 pm to 7:00 pm). Apart from in Toronto, each train makes stops in the Peel Region and the Halton Region, with total travel time ranging from 105 minutes to 150 minutes. The fare of a single journey ticket between the Union Station and the Kitchener Railway Station for an adult without the Presto card is at $17.7 (March, 2018), while Presto card users can receive a 10% discount for the first 35 rides, an 88% discount for the 36 to 40 rides, and a 100% discount for the subsequent rides in the same month (GO Transit, 2018). As for VIA Rail, it offers two trains in each direction per day throughout the week. Because the service makes fewer stops than the GO Transit service along the route, the total travel time is around 95 minutes. The fare of a single

journey ticket is as low as $22, but riders cannot use the Presto card to pay the fare and receive any discount (VIA Rail, 2018).

Road Transport

The majority of intercity trips rely on the Ontario Highway 401 corridor (as shown in Figure 3.2), which extends across the south of the GTHA and the Region of Waterloo. For automobile drivers and carpooling passengers, the travel distance from the University of Waterloo to the Downtown Toronto via Highway 401 is about 115 km, with total travel time ranging from 100 minutes to 150 minutes depending on the traffic. In addition to use private vehicles, travelers can also choose taxi and bus services as alternatives. Waterloo Taxi offers door-to-door service for people who travel from the Region of Waterloo to the GTHA. A sample rate for a trip starting from Downtown Kitchener to Downtown Toronto is $194 included HST (Waterloo Taxi, 2018). Travelers usually have to book in advance to use the taxi service.

Apart from the taxi service, there are several intercity bus carriers serving between the two regions, whereas the terminal stations of most of the bus services in the Region of Waterloo are at either the main campus of the University of Waterloo or Downtown Kitchener. GO Transit and Greyhound provide various intercity bus routes that directly connect the Region of Waterloo with the Halton Region, the Peel Region, the York Region and the City of Toronto. The two-way services begin at 5:00 am and end at 11:40 pm, with the frequency of 55 minutes to 120 minutes. Total travel time varies from 70 minutes to 120 minutes, depending on the origin and destination. The fare of a single journey ticket for GO Transit bus users is no more than $20, and Presto card holders can receive the same kind of discount as those who use the GO Transit train service (Go

Transit, 2018). For travelers who take the Greyhound bus, the single journey ticket fare can be as low as $9.50 if the travelers book online in advance (Greyhound, 2018). Moreover, Fedbus provides limited bus services in the evening time, which travel between the University of Waterloo and various destinations in the GTHA, including York Region, Halton Region, City of Toronto and City of Hamilton (Fedbus, 2018). Coach Canada specializes in operating the bus routes (also called Mega Bus) traveling between the Region of Waterloo and the City of Hamilton, which provides six services for each direction per day. The total travel time is around 90 minutes, with a single journey ticket fare as low as at $10 (Coach Canada, 2018).

3.1.3 Review of the Transportation Plans of the Municipalities Along the Toronto-Kitchener Rail Corridor

By reviewing the official transportation planning documents of the municipalities along the Toronto-Kitchener railway corridor, it can be found that all of the municipalities have emphasized the importance of enhancing the connectivity between local transit systems and the intercity GO Transit system. Table 3.1 summarizes the highlighted findings from the reviewed documents. However, the latest versions of the transportation plans from four of the five selected municipalities were published more than five years ago, which could not better reflect current intercity travel pattern and be used as the guideline to address current intercity transportation issues. There should be a better coordination and cooperation between the regional municipal governments and the provincial government in order to accommodate the growing travel demand in the GGH.

Table 3. 1 Examples of Highlights from the Selected Transportation Plans

Municipality	Document Reviewed	Year of Release	Highlights
City of Toronto	Transportation Master Plan – City of Toronto	2017	The proposal of a transit hub, specifically to connect regional GO bus services to the Consumers Road Business Park, is identified to provide the choice of taking transit to the area for longer distance trips via GO bus.
Region of Peel	Peel Long Range Transportation Plan	2012	The role of Peel Region in increasing transit ridership is to work with and support Brampton Transit, Mississauga Transit and GO Transit in maximizing the efficiency of their systems through infrastructure improvements and policy

			implementation.
Region of Halton	Halton Region Transportation Master Plan 2031	2011	The external transit demand will largely be met by planned improvements in the GO Transit network (rail and bus).
County of Wellington	Guelph-Wellington Transportation Study	2005	Review the growing inter-regional travel between Guelph/Wellington, Region of Waterloo and the GTA, and identify opportunities for transit initiatives to serve this need.
Region of Waterloo	Regional Transportation Master Plan	2011	The Region will continue to work with the Province and Metrolinx to pursue the extension of GO Transit service into the Region. The Region has also completed a study indicating the feasibility of extending GO Transit rail service from

			Milton to Cambridge, and this initiative has also been recommended as a long-term initiative in the draft GTA West Transportation Development Strategy.

3.2 Methods of Data Collection

This section describes the data collection activities related to this research that took place at the main campus of the University of Waterloo. First, the design of the web-based survey questionnaire is discussed. Second, the details of the administration of the survey questionnaire, including sampling methods and strategies to recruit the students from the University of Waterloo to complete the survey, are outlined.

3.2.1 Survey Questionnaire Design

The survey questionnaire, titled "A Survey of Understanding University of Waterloo Students' Intercity Transportation Mode Choice", was designed using SurveyMonkey, an online survey tool. The survey questionnaire contains four pages, with at most 17 questions to answer.

The page one contains a short message to the participant explaining the purpose of the study, the number of questions in total and the estimated completion time. Next, the respondent is asked to provide some socio-demographic information, including gender, current level of study, residency

status, registration status in Winter 2018 term, current residential location, holding of driver's license, holding of a Presto card, and private vehicle availability. The page two asks the respondent's intercity travel behavior between the Region of Waterloo and the GTHA during the recent two months. The respondent is first asked about his/her frequency of intercity travels, whereas a round trip counts as one time. If the respondent indicates 0 time, then he/she will be directed toward the page four to answer the remaining questions. Otherwise, he/she will be directed to the page three, where the respondent is asked to indicate his/her primary purpose of traveling, primary transport mode, primary destination and average one-way travel time among all the intercity trips that he/she has made during the designated period. After the completion of these questions, the respondent will also be directed toward the page four. The revealed-preference data collected above are used to model university students' current mode choice in the intercity travels.

In the page four, the respondent is first asked about his/her experiences riding the high-speed rail in any countries. Next, the respondent is presented with a description of the planned high-speed rail service in Ontario, including the proposed maximum speed of the train, station locations, completion time and estimated travel time from the Region of Waterloo stations to other stations. After that, the respondent is asked to rate his/her understanding and attention about the proposed high-speed rail service on a five-point similarity scale. Next, the respondent is asked about his/her attitude toward the high-speed rail from various aspects and his/her potential use of the high-speed rail for intercity commuting. A five-point agreement scale ranging from *strongly agree* to *strongly disagree* is utilized on these questions. At the end of the questionnaire, a hypothetical scenario consisting of a non-business trip from the University of Waterloo to

Downtown Toronto is displayed to the respondent. Given this scenario, the respondent is presented with one "stated preference" question asking him or her to select among driving a private vehicle, taking GO bus, or taking the high-speed rail for this hypothetical trip. Theoretical travel time and total travel cost for all three means, as well as service frequency for the GO bus and the high-speed rail are incorporated in the question to add realism to the question. A copy of the survey questionnaire can be found in Appendix A of this thesis. The study has got ethics clearance from Office of Research Ethics, at the University of Waterloo, Ontario, Canada.

3.2.2 Survey Administration

The survey questionnaire is administered to a sample of respondents who were registered as full-time students at the main campus of the University of Waterloo in the Winter 2018 term. Although the participants were randomly selected from the students, the sex ratio among the samples is controlled to be approximate 1:1 to make sure that the ratio can reflect the actual sex structure of the student population and the results are not sensitive to gender[3].

Although the survey questionnaire was designed using an online survey tool, it was not distributed through the Internet. The researcher recruited potential participants by booking a booth in the Student Life Centre at the University of Waterloo and preparing a poster for the students who passed by. The face-to-face recruitment process is to ensure that all the participants in this survey are enrolled students in the Winter 2018 term.

[3] According to the statistics, in Fall 2017 term, the sex ratio among the University of Waterloo students was approximately 1.14:1 (University of Waterloo, 2018).

A pilot survey took place on the 5th of March 2018. All qualified participants were presented with an information letter, and were informed that the data would be analyzed anonymously and be destroyed after the completion of the study. The verbal consent was given individually before initiating each interview, and after being informed by the researcher about the objective of the study and the subsequent treatment of the information obtained via the forthcoming interview. The survey employed the computer assisted self-interviewing (CASI) technique, whereby the researcher handed over his laptop to the respondent, who were then presented with a web page of the questionnaire created by the SurveyMonkey. The researcher stood by and remained available for instruction and assistance about the questionnaire. Once the respondent completed the questionnaire by clicking the submission button at the end of the page, the data would be stored in the SurveyMonkey account of the researcher, which would then be downloaded to researcher's laptop for analysis. The researcher collected ten responses in total during the pilot study, while the average questionnaire completion time was 12 minutes. In the meantime, the researcher also collected the feedback from the respondents to learn if they had any issues while understanding the questions and answering them, who then found that the respondents would like to see the questions presented in a more straightforward way. Therefore, the researcher made a revision on question 17 in the final version of the survey questionnaire, where three simple tables summarizing the travel information of each of the travel option replaced the flow charts that also provided transfer information to the respondents. The data collected through the pilot study are not used for final results analysis.

The formal survey was conducted from 11 am to 5 pm on each of the days between March 12 (Monday), 2018 to March 16 (Friday), 2018, following the same procedures as described in the

phase of pilot survey. During the survey period, a total of 261 University of Waterloo students were approached, while 228 of them agreed to participate in the survey and 216 respondents completed the survey questionnaire. Among the 216 completed responses, 195 of them were identified as valid responses that would be used for data analysis. The average completion time among the 216 respondents is 11 minutes.

3.3 Methods of Data Analysis

This section describes the methods used to analyze the data collected through the survey for answering the second and the third research questions. First, the descriptive statistics tool of Excel is employed to analyze the basic features of the data, which could demonstrate the socio-demographic information, characteristics of current intercity travel behavior, and attitudes towards the HSR of the university population. As for question 15 and question 16, because respondents were asked to rate on a Likert scale for each of them, a score will be assigned to each of the options, as shown in Table 3.2. In this context, 5 equals to either extremely familiar or strongly agree, while 1 equals to either not at all or strongly disagree. The mean score among the samples for each of the question will be measured, which can reflect the university population's overall knowledge and attention about the HSR, as well as their attitudes towards the HSR. Moreover, the question 16 consists of a series of sub-questions examining to what extent that the respondents have positive attitudes towards the HSR from various aspects, so the Cronbach's Alpha is used to test the internal consistency for the group of questions. This step can be achieved with the application of the SPSS.

Table 3. 2 Likert Scale Scoring

Score Assignment	5	4	3	2	1
Level of Understanding	Extremely familiar	Moderately familiar	Somewhat familiar	Slightly familiar	Not at all
Level of Agreement	Strongly agree	Agree	Neither disagree of agree	Disagree	Strongly disagree

As discussed in the Chapter 2, logit models are widely used to examine the significance level of the factors on travelers' mode choice. Because this research aims to understand what and how the identified factors affect University of Waterloo students' current mode choice between non-automobile modes and automobile modes, the binary logit model is selected for analysis. In the survey questionnaire, data collected from question 1 to question 13 are for modeling. Table 3.3 illustrates the dependent variable and independent variables used for binary logit regression. There are one dependent variable (Y_i) collected from the question 12, and twelve independent variables (X_1 to X_{12}) collected from other questions. Because most of the variables used for modeling are categorical variables (except for the X_{12}), these variables are categorized into two groups and dummy coded using 1 & 0 values. The 1 & 0 herein are not numerical values but are used to distinguish between the two groups.

Table 3. 3 Descriptions of Dependent Variable (Y_i) and Independent Variables (X_1 to X_{12})

#	Variable Name	Variable Type (and Options)	Dummy Variable Definition	Note
Y_i	Primary Transport Mode (PTM)	**Categorical Variable:** -GO Train -VIA Rail -GO Bus -Greyhound Bus/Mega Bus/Fed Bus -Taxi -Uber -Carpooling -Driving	**1**, for users choosing non-automobile transport modes, including: -GO Train -VIA Rail -GO Bus -Greyhound Bus/Mega Bus/Fed Bus **0**, for users choosing automobile transport modes, including: -Taxi -Uber -Carpooling -Driving	Dependent Variable
X_1	Gender (GEN)	**Categorical Variable:** -Male -Female	**1**, for Male **0**, for Female	
X_2	Current Level of Study (CLS)	**Categorical Variable:** -Undergraduate -Graduate	**1**, for Graduate **0**, for Undergraduate	
X_3	Holding of International Student Visa (HISV)	**Categorical Variable:** -Yes -No	**1**, for Yes **0**, for No	Residency Status
X_4	Whether or not a full-time co-op student in Winter 2018 (Enrolment Status, ES)	**Categorical Variable:** -Yes -No	**1**, for Yes **0**, No	

X_5	Residential Location (RL)	**Categorical Variable:** -On Campus or Near the Campus of the University of Waterloo -On Campus or Near the Campus of the Wilfrid Laurier University -Downtown Kitchener -Other Parts of the Region of Waterloo -GTHA (exclude Durham Region) -Durham Region	**1**, for locations with relatively high intercity transit accessibility, including: -On Campus or Near Campus of the University of Waterloo -On Campus or Near Campus of the Wilfrid Laurier University -Downtown Kitchener -GTHA (excluding Durham Region) **0**, for locations with relatively low intercity transit accessibility, including: -Other Parts of the Region of Waterloo -Durham Region -Others	"Near Campus of the University of Waterloo" refers to the location within 1 km of the Davis Centre Library. "Near Campus of the Wilfrid Laurier University" refers to the location within 1 km of the University/King. Durham Region is the only regional municipality in the GTHA where there is no non-transfer bus and train service from or to the Region of Waterloo. Therefore, the researcher assumes that this region is the only one in the GTHA that has relatively low transit accessibility from and to the Region of Waterloo and should be categorized in an independent category.
X_6	Holding of Driver's License (HDL)	**Categorical Variable:** -Yes -No	**1**, for Yes **0**, for No	A driver's license equivalent to the Ontario G2 or G is considered as an available driver's license.
X_7	Holding of Presto Card (HPC)	**Categorical Variable:** -Yes -No	**1**, for Yes **0**, for No	Holding of Transit Pass
X_8	Motor Vehicle Availability (MVA)	**Categorical Variable:** -Yes -No	**1**, for Yes **0**, for No	Availability means owning a motor vehicle and having regular access to it recently.

X_9	Trip Frequency (TF)	**Categorical Variable:** -Over 15 Times -11~15 Times -8~10 Times -4~7 Times -1~3 Time(s) -0 Time	**1**, for frequent intercity travelers, including those who had travelled greater or equal to 8 times during the two months. **0**, for non-frequent travelers, including those who had traveled greater or equal to 1 time but fewer than 8 times.	
X_{10}	Primary Purpose of Traveling (PPT)	**Categorical Variable:** -Business -Personal	**1**, for Business **0**, for Personal	Business trips refer to any trips to respondents' co-op education employment, general employment or any educational activities such as meetings and conferences.
X_{11}	Primary Destination When Traveling from the Region of Waterloo to the GTHA (PD)	**Categorical Variable:** -City of Toronto -Halton Region -Peel Region -City of Hamilton -York Region -Durham Region	**1**, for all regions except for the Durham Region **0**, for Durham Region	
X_{12}	On Average One-way Travel Time (OOTT)	**Continuous Variable**	**None**	Respondents input the number of minutes for answering this question.

In the binary logit regression, one category variable is set as the base group to which the other category is compared. In this research, all categorical variables with the value of 0 are set as base groups. For example, the "users choosing the automobile transport mode" category is set as the base group to compare against the "users choosing the non-automobile transport mode" category.

The probability of an individual choosing a non-automobile transport mode for the intercity travel can be expressed in the form of logit regression equation as below:

$$Logit\ (P) = \ln(\frac{P}{1-P}) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_{16} X_{16}, where\ P\ (y_i = 1|x_i)$$

which can also be transformed into:

$$P\ (y_i = 1|x_i) = \frac{exp^{logit\ (P)}}{1 + exp^{logit\ (P)}}$$

In the first equation, $\frac{P}{1-P}$ is the odds, representing the ratio of the probability that users choose the non-automobile transport modes, compared to the probability that users choose the automobile transport modes. The range of the $\frac{P}{1-P}$ is (0, +∞). $\ln(\frac{P}{1-P})$ is the logarithm (log) of the odds, which has infinite range (-∞, +∞). Moreover, β_0 represents the constant coefficient of the *Logit (P)*, and β_1 to β_{16} represent the coefficients of the corresponding independent variables of the model. Positive coefficients would indicate a higher likelihood that users choose the non-automobile transport mode.

The SPSS is used to perform binary logit regression for this research. Firstly, an initial model including all of the 12 independent variables (X_1 to X_{12}) will be run. Then, the model will be refined by dropping off some of the independent variables and rerun several times. By comparing the values of -2 log likelihood and pseudo R-squared of each model, the one with the highest goodness-of-fit will be selected for further interpretation. In the model, each of the

independent variables is assigned a p-value and an odds ratio, so the significance level of the factor and to what extent does it affect respondents' intercity mode choice can be measured.

4. Research Findings

This chapter presents the results of data analysis, in which the research questions in this study can be mostly answered. The findings from Section 4.1.2 could answer the former half of the second research question "*What are the characteristics of University of Waterloo students' current intercity travel behavior?"*, while the latter half of this research question "*To what extent do the factors have the influence on their primary transport mode choice in the intercity travels*?" can be answered through the findings presented in Section 4.2. Section 4.1.3 will present the findings to answer the third research question "*What are the attitudes towards the high-speed rail among University of Waterloo Students?*".

4.1 Descriptive Statistical Analysis

4.1.1 Socio-demographic Characteristics of the Respondents

Table 4.1 summarizes the socio-demographic characteristics of the survey respondents, all of whom were full-time students at the University of Waterloo in Winter 2018 term. Among the 195 participants, there are 100 males and 95 females. This gender ratio is very close to the officially reported ratio between males and females in Fall 2017 (1.13:1). The ratios between undergraduates and graduates, and between international students and non-international students in this sample group are also similar to the official data (University of Waterloo, 2018)[4]. Because this survey was conducted on campus, many of the co-op students who were working this term had not been approached. Therefore, this sample group is not representative in reflecting the actual ratio between co-op students and non-co-op students (University of Waterloo, 2018)[5].

[4] In Fall 2017, the ratio between undergraduates and graduates was 6.92:1; the ratio between international students and non-international students is 1:3.62 (University of Waterloo, 2018).

[5] In Fall 2017, the ratio between co-op students and non-co-op students is 1.30:1 (University of Waterloo, 2018).

In terms of the current residential area, 95% of respondents reported locations in the Region of Waterloo, whereas the majority of them were living on campus or near the campus of either the University of Waterloo or the Wilfrid Laurier University. Only 10 respondents reported living in the GTHA or other areas outside of the GTHA and the Region of Waterloo. Although two-thirds of the respondents had driver's license equivalent to Ontario's G2 or G, only 26% of the sampled population owned a motor vehicle and had regular access to it recently. In contrast to the low rate of car availability, more than half (54%) of the respondents had Presto card, which could be used on various intercity and local public transit systems in the GGH.

Table 4. 1 Socio-demographic Characteristics of Respondents

Socio-demographic Characteristics		**All Respondents (N = 195)**
Q1: Gender	Male	51%
	Female	49%
Q2: Current Level of Study	Undergraduate	87%
	Graduate	13%
Q3: Holding of International Student Visa	Yes	22%
	No	78%
Q4: Full-time Student on Co-op in Winter 2018	Yes	34%
	No	66%
Q5: Current Residential Area	On campus or near the campus of University of Waterloo	55%
	On campus or near the campus of the Wilfrid Laurier University	18%
	Downtown Kitchener	4%

	Other parts of the Region of Waterloo	18%
	GTHA (excluding Durham Region)	2%
	Durham Region	0%
	Others	3%
Q6: Holding of Driver's License	Yes	67%
	No	33%
Q7: Holding of Presto Card	Yes	54%
	No	46%
Q8: Motor Vehicle Availability	Yes	26%
	No	74%

Table 4.2 presents the selected results of the crosstab analysis, which is to test the independence between the two categorical variables. A p-value less than 0.05 indicates that there is a statistically significant association between the two variables, and a higher value of the Pearson Chi-Square could reveal a stronger association (Laerd Statistics, 2018). It can be seen from the table that significant associations occur between whether or not students have the international visa and motor vehicle availability (p-value is 0.018), as well as between whether or not students have a Presto card and motor vehicle availability (p-value is 0). The rate of car availability among the 153 non-international respondents is 30.1%, more than double the rate among the rest of international students (11.9%). It is also not surprising that only 29.4% of the respondents with car availability owned the Presto card, less than half of the rate among those without a motor vehicle (62.5%). Although some studies suggest the gender difference in car ownership due to economic inequality (Giuliano & Dargay, 2006; Van Acker & Witlox, 2010, for example), a significant association between the two variables were not found in this survey (p-value is 0.96). The rates of car availability in both male and female respondents are around 26.0%. A full crosstab of the socio-demographic characteristics can be found in Appendix 2.

Table 4. 2 Crosstab Analysis Results of the Selected Socio-demographic Characteristics

The Relationship Between	Pearson Chi-Square	df	p-value
Gender (Q1) and Motor Vehicle Availability (Q8)	0.003	1	0.96
Holding of International Student Visa (Q3) and Motor Vehicle Availability (Q8)	5.627	1	0.018
Holding of Presto Card (Q7) and Motor Vehicle Availability (Q8)	16.591	1	0

4.1.2 Characteristics of University of Waterloo Students' Current Intercity Travel Behavior

The survey of this research asked the student respondents about their intercity travel history during the recent two months. This time frame is roughly from the mid of January 2018 to the mid of March 2018. During this period, the students had an extra week free of class (also known as "reading week"), and they might spend this week either by staying at home or going somewhere else. Figure 4.1 shows the distribution of intercity trip frequency among the sampled population. It can be seen from the figure that nearly 90% of the respondents had traveled at least once between the Region of Waterloo and the GTHA during the recent two months, but the majority of them had traveled less than once a week. For the respondents who reported having the intercity travel experience, 94% of them indicated their primary purpose of traveling for personal reasons, which include visiting families or friends, shopping, having medical appointments, etc. The remaining 6% of the respondents claimed that the majority of intercity trips they had made were related to co-operative employment, general employment or any educational activities such as meetings and conferences.

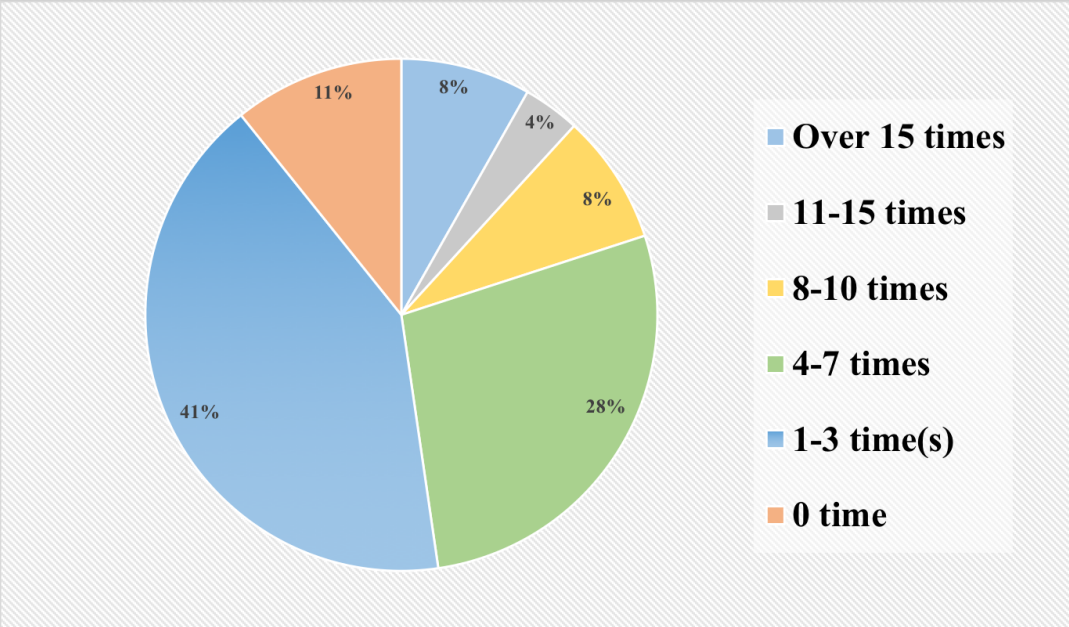

Figure 4. 1 Trip Frequency Distribution of the Respondents

（Q9: How many times have you traveled between the Region of Waterloo and the GTHA during the recent two months?）

Figure 4.2 illustrates the primary intercity transport mode share of the respondents. It can be found that private automobiles (including driving and carpooling) are the dominant form of transportation, favored by more than half of the intercity travelers (52%). There is also a large percentage of travelers (46%) using the intercity bus services (GO Bus/Greyhound Bus/Mega Bus/Fed Bus) as their primary transport modes. For students without car availability, taking buses sometimes is a better option than sharing rides with strangers, as they do not have to book trips with unknown drivers in advance and bus services are usually more reliable and safer for long-distance trips. Considering that there are very few rail services or the high traveling costs, it is reasonable that only 2% of the travelers chose either the GO Train/VIA Rail or Taxi as their primary transport mode.

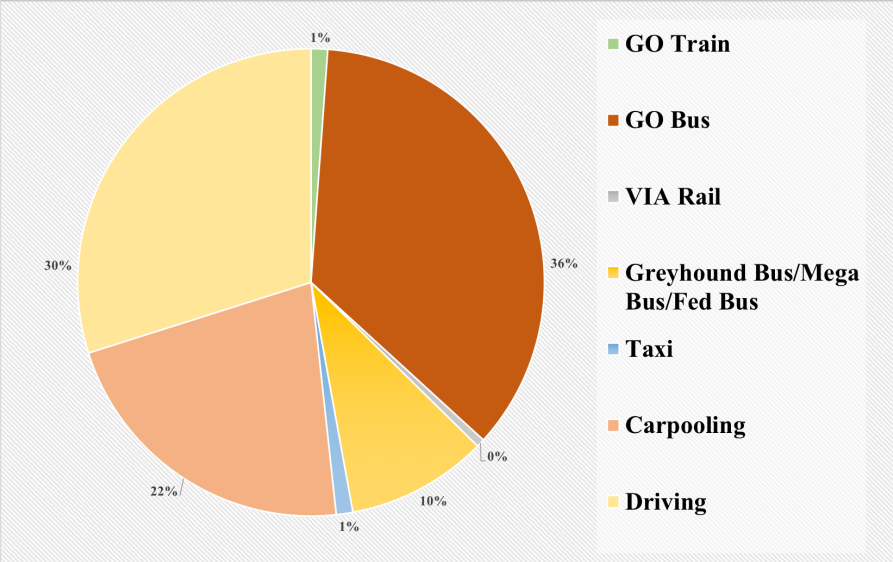

Figure 4. 2 Primary Intercity Transport Mode Share of the Respondents

(Q11: What is your primary transport mode when you have traveled between the Region of Waterloo and the GTHA during the recent two months?)

Table 4.3 demonstrates the differences in the socio-demographic information of the respondents by the four most popular intercity transport modes. To compare the socio-demographic data among each transport mode and with that of the overall responses (see Table 4.1), the most iconic features of each transport mode users can be illustrated. From the socio-demographic data of the respondents who primarily chose to drive in the intercity travels, it can be found that males were a little bit more likely to drive than females because the percentage of males who drove is 8% higher than that among the overall respondents. Among the 52 car drivers, 86% of them were domestic students, the figure of which was also 8% higher than the overall data. Compared to international students, domestic students could drive their family members' vehicle for traveling, even if they do not own a personal motor vehicle. This assumption can be proven by their rate of vehicle availability, as 23% of them did not own a vehicle and not have regular access to it

recently. Moreover, the percentage of the car drivers who lived close to either the University of Waterloo or the Wilfrid Laurier University is 21% lower than that among the overall sampled population, but almost one-third of them still had the Presto card.

Carpooling is the second most popular automobile mode chosen by the respondents, but the socio-demographic characteristics of the carpooling passengers are quite different from those of the car drivers in some aspects. First, 53% of the carpooling passengers were females, which is higher than the percentages of both car drivers and the overall sampled population. There is also a significantly higher proportion of carpooling passengers who were not full-time students on co-op in Winter 2018 term, compared to 67% among car drivers and 66% among all of the respondents. Next, 69% of them lived close to the two universities. This figure is much higher than that of the car drivers, but is slightly lower than that of the overall respondents. Besides, the carpooling passengers have a much lower rate of holding the driver's license but a higher rate of holding the Presto card than car drivers. None of them owned a motor vehicle at the time of the survey.

GO Bus is the most popular intercity transport mode chosen by 62 of the respondents. The genders among the GO Bus riders are split very close to evenly, with a slight skew toward females. 58% of them were not full-time students on co-op in Winter 2018, the percentage of which is 8% lower than that of the overall respondents. GO Bus riders have the largest proportion of living close to the two universities and having the Presto card among the four transport modes' users, but they have the second-lowest rate of vehicle availability ahead of the carpooling passengers. Similarly, Greyhound Bus, Mega Bus and Fed Bus see the largest

proportions of female riders and graduate riders among the four transport modes. 88% of these intercity bus riders lived close to the two universities. This percentage is slightly lower than that of the GO Bus riders, but significantly higher than those of the car drivers and carpooling passengers. Because the passengers cannot use the Presto card to pay the fare for these three intercity bus services, only 59% of them had the card. This percentage is still higher than those among the car drivers and the carpooling passengers.

Table 4. 3 Socio-demographic Characteristics of Respondents by Transport Mode

Socio-demographic Characteristics		**Primary Intercity Transport Mode**			
		Driving (N=52)	**Carpooling (N=38)**	**GO Bus (N=62)**	**Greyhound Bus/Mega Bus/Fed Bus (N=17)**
Q1: Gender	Male	58%	47%	45%	41%
	Female	42%	53%	55%	59%
Q2: Current Level of Study	Undergraduate	90%	84%	84%	82%
	Graduate	10%	16%	16%	18%
Q3: Holding of International Student Visa	Yes	14%	18%	26%	24%
	No	86%	82%	74%	77%
Q4: Full-time Student on Co-op in Winter 2018	Yes	33%	21%	42%	29%
	No	67%	79%	58%	71%
	On campus or near campus of University of Waterloo	42%	42%	66%	76%

Q5: Current Residential Area	On campus or near campus of the Wilfrid Laurier University	10%	27%	27%	12%
	Downtown Kitchener	6%	5%	0%	6%
	Other parts of the Region of Waterloo	29%	21%	7%	6%
	GTHA (excluding Durham Region)	7%	0%	0%	0%
	Durham Region	0%	0%	0%	0%
	Others	6%	5%	0%	0%
Q6: Holding of Driver's License	Yes	92%	50%	63%	53%
	No	8%	50%	37%	47%
Q7: Holding of Presto Card	Yes	33%	45%	84%	59%
	No	67%	55%	16%	41%
Q8: Motor Vehicle Availability	Yes	77%	0%	6%	12%
	No	23%	100%	94%	88%

Figure 4.3 summarizes the cross-tabulation analysis results between primary transport mode choice and trip frequency. For travelers who chose to drive as their primary transport mode, there is a higher likelihood that they made trips with no less than 11 times in the recent two months. GO Bus riders were the second most frequent travelers who usually made trips between 4 to 10 times in the recent two months, while carpool passengers tend to be the least frequent travelers as they were more likely to make just 1 to 3 times of trips in the recent two months.

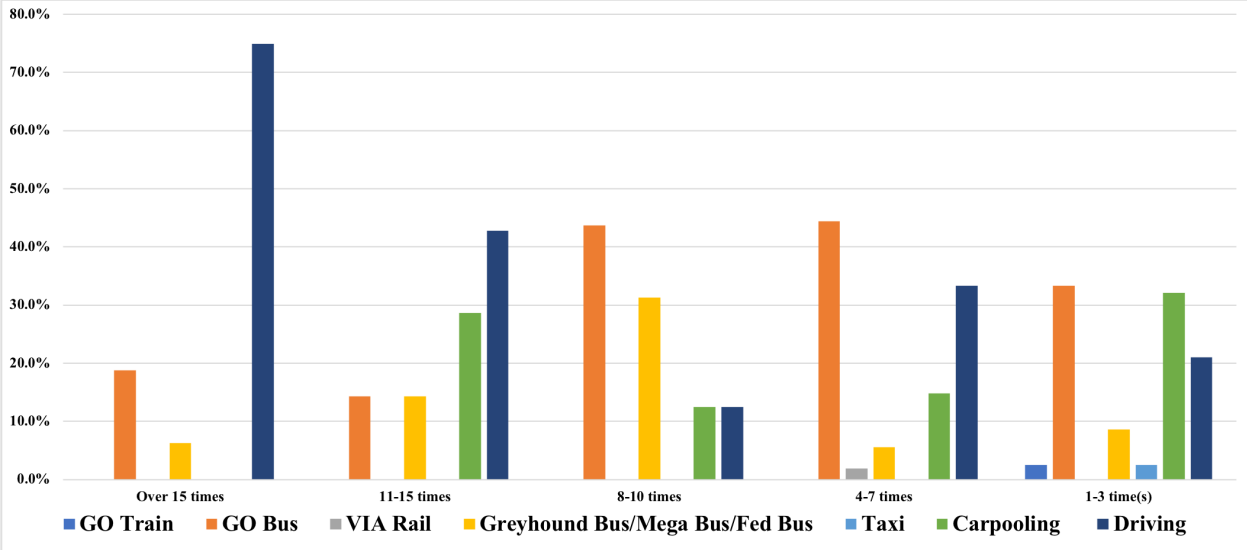

Figure 4. 3 Respondents' Primary Transport Mode Choice by Trip Frequency

According to Figure 4.4, nearly 60% of the respondents reported having the City of Toronto as their primary travel destination, followed by the Region of Peel (17%) and the Region of York (14%). The remaining 10% of the respondents indicated their primary destinations in other areas of the GTHA. Figure 4.5 compares the mode share by the three most popular primary destinations. Among the three municipalities, the Region of Peel has the largest mode share of non-automobile transport modes (63%), with 60% of the respondents choosing the GO Bus for traveling. As the most populous regional municipality west of the City of Toronto in the GTHA, the Region of Peel has two intercity bus terminals where the majority of GO Bus services departing from the Region of Waterloo will make stop. The GO Bus Route 25 departing from the University of Waterloo provides regular services throughout the week that could carry passengers to the Square One, a main transit hub and the city centre of the City of Mississauga, in two hours. The GO Bus Route 30 departing from the Downtown Kitchener connects the region with the Bramalea GO Station, a multimodal transit hub in the City of Brampton. Although the Greyhound Bus services make stops in Mississauga at Pearson International

Airport, the stop location is on the outskirt of the region and relatively far away from the urban core areas of both Mississauga and Brampton. This could explain why very few numbers of travelers whose primary destination was the Region of Peel chose Greyhound Bus as their primary transport mode.

Compared to the Region of Peel, Toronto sees a smaller but more diversified share of non-automobile transport modes, with all of the four modes being selected by the respondents. Although GO Bus services have much tighter schedules than the other three transit services, most of the GO Bus passengers have to make a transfer in the Peel Region before they arrive in Toronto, which would extend the total travel time and add more uncertainty to their journeys, particularly in snowing days. For passengers whose destinations are in Downtown Toronto, taking the rail transport or Greyhound bus could be a more reliable option. In addition, because there are quite limited GO Bus services just on Friday and Sunday between the Region of Waterloo and the Region of York, it is not surprising that this region has the least share of non-automobile transport modes among the three regional municipalities.

In addition, due to the relatively small population size and tiny urbanized area, the Region of Halton sees significantly insufficient travel demand from and to the Region of Waterloo, although the two regions are directly connected by the GO Kitchener line. As a result, the long-term inadequate ridership might discourage the GO Transit from intensifying the rail services along the corridor, as well as expedite the introduction of the HSR service.

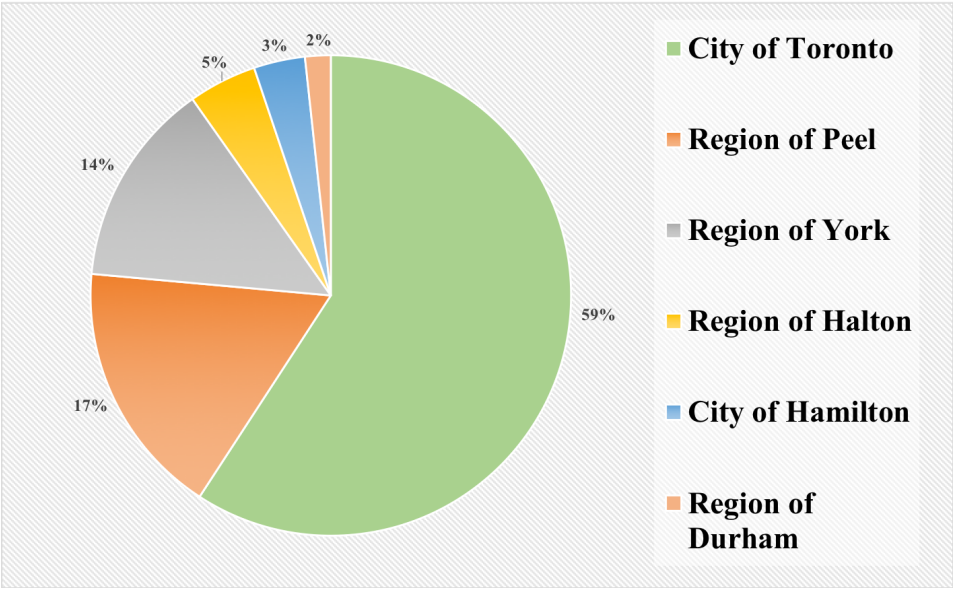

Figure 4. 4 Breakdown of Primary Travel Destination of the Respondents

(Q12: What is your primary destination when you travelled from the Region of Waterloo to the GTHA during the recent two months?)

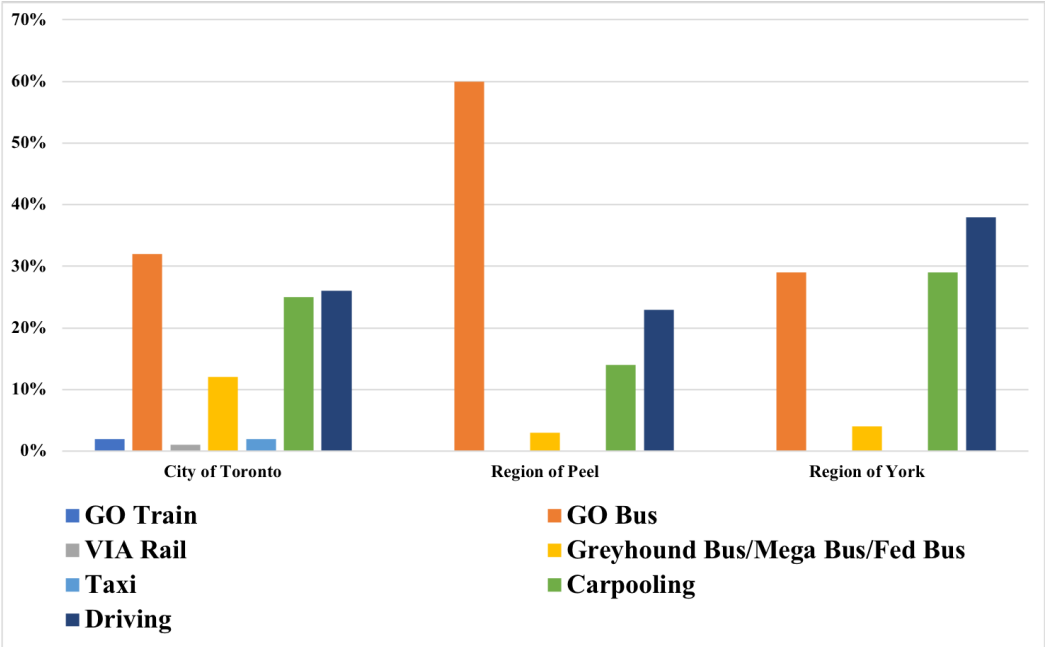

Figure 4. 5 Comparison of Mode Share by Primary Destination

Figure 4.6 displays the distribution of on-average one-way travel time of the respondents. The blue columns represent the counts of the travel time falling within a specified time interval, whereas the orange broken line portrays the cumulative percentage of the time distribution. Although the respondents would have more than one destinations in the GTHA during the recent two-month period, about 90% of them answered this question based on the calculation of average travel time they spent on traveling to their primary destination in the GTHA, according to the following up interview conducted by the researcher after they completed the questionnaire. The average one-way travel time among the 174 respondents was 107 minutes, with 35 minutes being the shortest time and 240 minutes being the longest time. From the histogram, it can be found that the average one-way travel times among nearly 70% of the respondents are ranging from 61 minutes to 120 minutes, depending on their original/destination and the use of transport modes. Nevertheless, it should be recognized that significant errors could happen when the respondents were asked to recall such details of their trips during the recent two months. As mentioned in Section 3.2.2, in the stage of data processing, 21 responses were removed from the dataset as these answers indicated either a too short (less than 35 minutes) or too long (more than 240 minutes) travel time that might not be able to happen in reality.

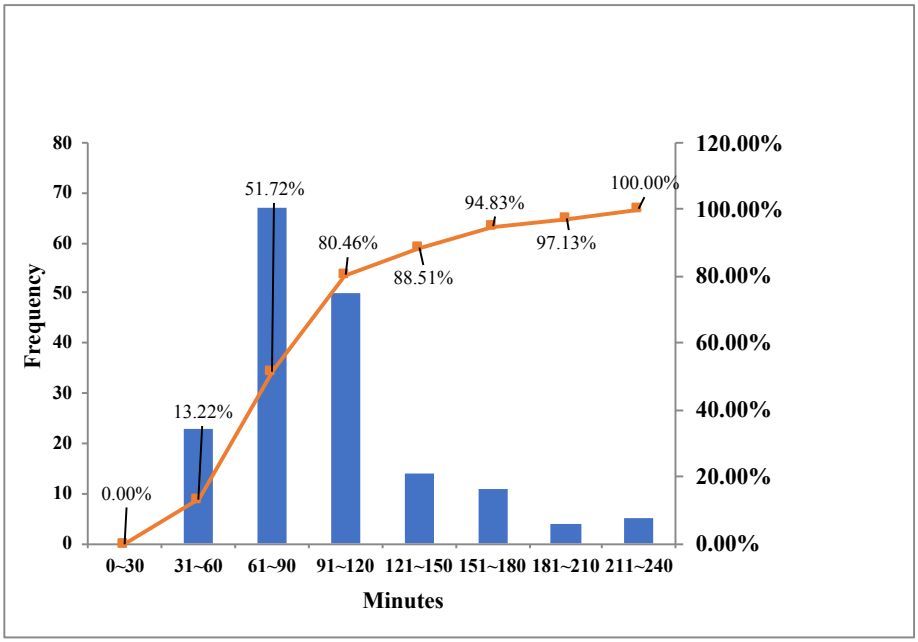

Figure 4. 6 Average One-Way Travel Time of the Respondents

(Q13: How much time on average have you spent on the one-way trip between the Region of Waterloo and the GTHA during the recent two months?)

4.1.3 Attitudes of University of Waterloo Students Towards the High-Speed Rail.

As the theory of planned behavior (TPB) states, humans' attitude is one of the key driver's in forming their behavioral intention, which has a profound influence on their actual behavior (Ajzen, 2006). This section evaluates the respondents' overall attitudes towards the high-speed rail, and then analyzes how the attitudes would affect their intended behavior in using this transport mode in the future.

As shown in Table 4.4, among the 195 respondents, less than half of them had experiences riding HSR. Because Canada's Turbo Train service terminated in 1982, it would be impossible for most of them to have the relevant riding experience. The only HSR service on operation in North America is the Acela Express, along the 735 km Northeast Rail Corridor in the Northeastern

United States between Washington, D.C. and Boston, MA. Although the maximum speed of the Acela Trains could reach 240 km/h (150 mph), the average travel distance per hour of the entire journey is only around 100 km, which is just about half of the travel distance of the Tokaido Shinkansen HSR service in Japan (NTSB, 2014). Therefore, some of the Acela Express passengers may not realize that it is the high-speed rail service. For the majority of the respondents who reported having HSR experiences, their experiences should be derived from the HSR services in Western European and Eastern Asia countries.

After the respondents answered the question 14, they were then presented with a paragraph introducing the background of the HSR planning in Ontario. They were then asked to rate their level of understanding and attention about the HSR. According to Table 4.5, over 40% of the respondents had never heard about the proposed HSR project that connects the Region of Waterloo with the GTHA. The average score among all the respondents is 2.1, indicating that the university population had a slight familiarity with this project. This could because there is still a long time between now and the projected completion time of phase 1 of the HSR. By the year of 2025, most of the survey participants should have graduated from the University of Waterloo and they may have left from the region. Therefore, the proposed HSR service would not affect their travels between the Region of Waterloo and the GTHA during their period of studies in the University, and there are no incentives for them to be concerned about the HSR project. In addition, unlike the numerous public attention to the ION light rail transit which is about to serve the University of Waterloo in early 2018, it is rare to see any on-street promotions about the HSR project on the campus of the University and in the Region of Waterloo. The Victoria/King Transit Hub in Downtown Kitchener, where the high-speed trains will make stops, has not been

erected until April of 2018 as well. As a result, it is not surprising that the HSR project has received very little attention from the university students.

Table 4. 4 Respondents' Experience Riding HSR

Q14: Have you ever had experiences riding high-speed rail in any countries?			
	Yes	No	
Count	84	111	195
Percentage	43%	57%	100%

Table 4. 5 Respondents' Knowledge and Attention About the HSR in Ontario

Q15: Please indicate your level of understanding and attention about the proposed high-speed rail in Ontario.						
	Not at all familiar (1)	**Slightly familiar (2)**	**Somewhat familiar (3)**	**Moderately familiar (4)**	**Extremely familiar (5)**	
Count	80	47	43	20	5	195
Percentage	41%	24%	22%	10%	3%	100%

In the following question, the respondents were asked to indicate their level of agreement on a series of six favorable statements related to their perceptions of the advantages of the HSR compared to the existing intercity transport modes, and the potential usage of the HSR in the future. Using a five-point agreement scale as discussed in Section 3.3, items considered in this question could reflect the respondents' attitudes towards this new intercity transport mode. Table 4.6 demonstrates the mean score for each of the six statements among the 195 respondents. It can be found from the table that the sampled population appeared to agree that traveling on HSR would be more enjoyable, more efficient and more environmentally-friendly than driving or taking a bus because all of the mean scores are slightly higher than 4. They rated the last item highest with a mean score of 4.16/5, indicating their more positive attitudes towards using the

HSR as their primary intercity transport mode if the one-way fare between the two regions could be as low as $20. The mean scores of the first and the fifth statements are slightly below 4, which could also suggest that the respondents hold more or less positive attitudes that traveling on the HSR would be safer and more reliable than driving. Standard deviations were also calculated for the six statements, which could measure the dispersion of the attitude among the sampled population. A higher value of the standard deviation shows a wider difference of the same opinion. It can be seen that all the standard deviations are below 1 and ranging from 0.73 to 0.92, suggesting that the sampled population, university students, are relatively homogeneous in considering the potential impact of the HSR on their travel behavior. At the end of the table, the value of the Cronbach's Alpha is demonstrated, which is to test if all the six statements are reliable enough to measure the respondents' level of positive attitudes towards the HSR. Generally, a Cronbach's Alpha value of 0.70 is good and acceptable. Because the alpha value for these statements are 0.743, it can be assumed that the six statements have a high level of internal reliability to reflect the respondents' positive attitudes towards the HSR.

Table 4. 6 Attitudes Toward the HSR of the Respondents

Number	Attitudinal statements regarding the HSR	Mean score among all respondents	Standard Deviation
1	Traveling on the HSR would be safer than driving or taking a bus.	3.86	0.79
2	Traveling on the HSR would be more enjoyable than driving or taking a bus.	4	0.81
3	Traveling on the HSR would be more efficient than driving or taking a bus.	4.06	0.83
4	Traveling on the HSR would be more environmentally-friendly than driving or taking a bus.	4.15	0.73
5	Traveling on the HSR would be more reliable than driving or taking a bus.	3.75	0.92
6	I would choose the HSR as my primary transport mode if the one-way fare between the Region of Waterloo and the GTHA could be as low as $20.	4.16	0.9
	Cronbach's Alpha	0.743	

As mentioned in Section 3.2.1, in the last question, the respondents were asked to choose a travel option under a hypothetical scenario where the HSR service has been available between the Region of Waterloo and the GTHA. For the total travel cost of the option 1, the gas cost was calculated based on the reference unit price of the regular unleaded gasoline at self-service filling stations in January 2018 in Toronto from the Statistics of Canada, which was 124.5 cents per liter (Statistics Canada, 2018). The parking cost data was derived from the Impark, which is $15 for 4-hour parking on Saturday (Impark, 2018). For the total travel cost of the option 2, the fare of the HSR was estimated from the official document "Preliminary Business Case for High Speed Rail on the Toronto to Windsor Corridor", in which it suggested that the range of a one-way trip fare between Kitchener/Waterloo and Toronto should be from $25 to $30 (Ontario Ministry of

Transportation, 2016). This study used $27.5 as the one-way HSR fare to calculate the total travel cost. The estimated travel time of taking the GRT from the Davis Centre Library to the Kitchener-Waterloo HSR station was based on the projected travel time of the ION rapid transit line, which was about 12 minutes (Region of Waterloo, 2009). In addition, for all of the three travel options, the travel costs and travel time of the existing transport modes were referenced from Google Maps and the official websites of the public transit authorities (Metrolinx, GRT and TTC).

As can be seen in Figure 4.7, 45% of the respondents chose the travel option 2, in which the HSR is the primary intercity transport mode, under this hypothetical scenario. The percentage of the respondents choosing the travel option 1 is just slightly lower at 41%. Compared to the travel option 1, the respondents who chose the option 2 should pay $10 more to reduce the total travel time by 10 minutes, which seems not be an attractive deal. Moreover, travelers who use the public transport modes should strictly follow the service schedule to make sure they can arrive at the destination on time, so the travel option 2 provides much less flexibility for passengers than travel option 1. However, the advantage of the travel option 2 is that travelers would feel more relaxed when they are on board a train than driving along the entire route. Taking the HSR should be also safer than driving in the extreme weather days. Although the total travel cost of the option 3 is the lowest among the three options, just 15% of the respondents chose it, probably due to the much longer total travel time than the other two options.

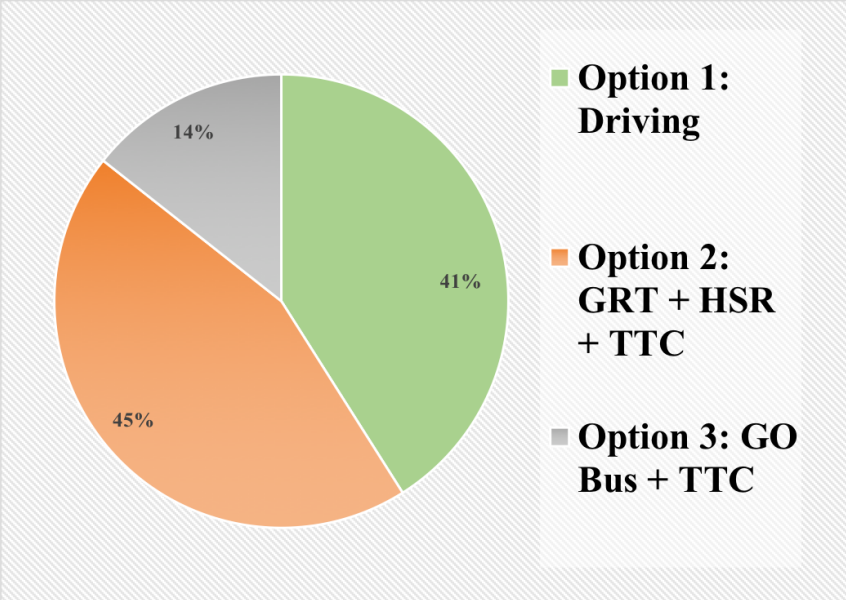

Figure 4. 7 Stated Choice of Travel Option of the Respondents

(Q17: Under the hypothetical situation, which option would you choose for your trip?)

Table 4.7 presents the crosstab analysis results between the socio-demographic or the trip characteristics variables and respondents' stated choice. Although only the p-value of the relationship between Q11 and Q17 is less than 0.05, there are still some associations that should be further analyzed in other relationships. In the relationship between Q8 and Q17, 21% of the respondents who chose the travel option 2 (GRT + HSR + TTC) owned a motor vehicle and had regular access to it recently, which is lower than the rate of car availability among all of the 195 respondents (26%). From the relationship between Q14 and Q17, it can be found that 64% of the respondents who chose the travel option 2 did not have experiences riding HSR in any other countries. This figure is also 7% higher than the percentage of the overall population who had not ridden HSR before. In the relationship between Q11 and Q17, the much lower p-value implies that the respondents stated choice behavior has strong association with their current intercity mode choice. 68% of the respondents who chose the travel option 3 also adopted the

non-automobile transport modes as their current primary intercity transport modes, which is significantly higher than the percentage of the overall sampled population who adopted the non-automobile transport modes (47.1%). Similarly, 63% of the respondents choosing the travel option 1 primarily used automobile in their intercity travels, higher than the percentage of the automobile users among the 174 respondents (52.9%).

Table 4. 7 Crosstab Analysis Results of the Question 17

The Relationship Between	**Pearson Chi-Square**	**df**	**p-value**
Holding of Presto Card (Q7) and Option Under the Hypothetical Situation (Q17)	0.323	2	0.851
Motor Vehicle Availability (Q8) and Option Under the Hypothetical Situation (Q17)	4.059	2	0.131
Primary Transport Mode (Q11) and Option Under the Hypothetical Situation (Q17)	7.636	2	0.022
Experience riding HSR (Q14) and Option Under the Hypothetical Situation (Q17)	3.862	2	0.145

Table 4.8 also demonstrates the crosstab analysis results, which compare the differences of the mean scores of the six attitudes (as shown in Table 4.6 above) by the respondents' stated choice results. There are no significant differences in the aggregated mean scores among the three groups of the respondents', with the group of the respondents who chose the travel option 2 (GRT + HSR + TTC) having the highest scores. It is interesting to see that the respondents who chose the travel option 1 (driving) more agreed that traveling on the HSR would be more

environmentally-friendly than driving or taking a bus. Another thing that should be noted is the respondents who chose the option 3 (GO Bus + TTC) have the strongest intention to use the HSR as their primary intercity transport mode if the one-way fare between the Region of Waterloo and the GTHA could be as low as $20.

Table 4. 8 Comparison of the Mean Scores of the Attitudes by Respondents' Stated Choice Results

Attitudinal statements regarding the HSR	Mean score among all respondents	Mean score among the respondents who chose the option 1 in Q16	Mean score among the respondents who chose the option 2 in Q16	Mean score among the respondents who chose the option 3 in Q16
Traveling on the HSR would be safer than driving or taking a bus.	3.86	3.81	3.92	3.79
Traveling on the HSR would be more enjoyable than driving or taking a bus.	4	3.83	4.2	3.89
Traveling on the HSR would be more efficient than driving or taking a bus.	4.06	3.83	4.25	4.11
Traveling on the HSR would be more environmentally-friendly than driving or taking a bus.	4.15	4.24	4.2	3.75
Traveling on the HSR would be more reliable than driving or taking a bus.	3.75	3.55	3.98	3.61
I would choose the HSR as my primary transport mode if the one-way fare between the Region of Waterloo and the GTHA could be as low as $20.	4.16	3.93	4.31	4.36
Aggregated mean score	23.98	23.19	24.86	23.51

4.2 Binary Logit Regression Analysis

4.2.1 Calibration of Binary Logit Models

As discussed in Section 3.3, the purpose of conducting binary logit regression is to understand the significance level of the identified independent variables (X_1 to X_{12}) that affect University of Waterloo students' intercity mode choice between non-automobile transport modes and automobile transport modes (Y_i). The first step of performing the binary logit regression is to run

a benchmark model that includes all of the identified 12 independent variables using the SPSS. Then, it is necessary to calibrate the model by adjusting the number of input independent variables and rerun the model several times. Finally, a model with the greatest goodness-of-fit to data is selected, in which the significance levels of all independent variables are further examined. Quite a number of models have been run and analyzed, and Table 4.9 presents the model calibration results with five of the most representative models, in which the first model is the benchmark model. To measure the goodness-of-fit of a model, several indicators in the table should be assessed. First, the Hosmer and Lemeshow Test is used to determine if the model is correctly specified. In other words, a misspecified model could have biased coefficients and error terms, and tend to have biased parameter estimations (Statistics How To, 2018). Generally, a low p-value less than 0.05 under the section of the test would suggest that the model is biased and should be rejected. As can be seen from the table, the p-value of each of the five models is much higher than 0.05, so all of them pass the test. Then, to figure out which model has the greatest goodness-of-fit to data, the values of the -2 log likelihood and the pseudo R-squared under the model summary section should be compared. Unlike linear regression with ordinary least squares estimation, there is no R-squared statistic in the logit regression to explain the proportion of variance in the dependent variable that is explained by the predictors, but the pseudo R-squared (Nagelkerke R-Square) could still roughly tell people how well the model fits the dataset. A higher value of the pseudo R-squared implies a better model, while the value of the -2 log likelihood should be smaller. Among the five binary logit models, the first benchmark model has the lowest -2 log likelihood and the highest pseudo R-squared. This is not a surprising result as it suggests that all of the identified factors have influences on University of Waterloo students'

intercity mode choice. In the next section, the estimated coefficients of the independent variables and their significance levels in the first model will be interpreted.

Table 4. 9 Model Calibration Results

Model Number	Number of Independent Variables Included	Inlcuded Independent Variables	Model Summary		Hosmer and Lemeshow Test		
			-2 Log Likelihood of Model	Nagelkerke R Square (Pseudo R-squared)	Chi-square	df	p-value
1	12	All	173.849	0.425	2.708	8	0.951
2	8	X_7 and X_8	182.864	0.377	9.308	8	0.317
3	8	X_1 to X_4, X_6, and X_9 to X_{12}	230.104	0.078	7.315	8	0.503
4	4	X_9 to X_{12}	231.253	0.07	7.044	8	0.424
5	4	X_5, X_7, X_8 and X_{12}	184.388	0.369	8.869	8	0.354

4.2.2 Interpretation of the Binary Logit Model Results

Table 4.10 demonstrates the estimated coefficients and the significance levels of the independent variables in the first binary logit model. As the base group for the dependent variable is the automobile transport modes, a positive and higher coefficient suggests an increased likelihood of the respondents using non-automobile transport modes in the intercity travels. The p-value indicates the significance level of the independent variable, with a smaller p-value indicating a lower risk of concluding that the estimated coefficient is significantly different from 0 (null hypothesis). Although generally only the independent variables with p-value equal or less than 5% are considered as statistically significant and we can reject the null hypothesis, it does not mean that other independent variables in this model do not have influences on the respondents' intercity mode choice. Therefore, this section will also briefly review some of the independent variables with p-values greater than 5%.

As can be seen from the table, X_5 (Current Residential Location), X_7 (Holding of the Presto

Cars) and X_8 (Motor Vehicle Availability) have the significance levels less than 1%. X_5 and X_7 have the positive influence on the respondents' intercity mode choice, whereas X_8 has the negative influence. The odds ratio could tell us the strength of such influence. In the X_5, for the respondents who reported living in the locations with relatively high intercity transit accessibility, the odds of using the non-automobile modes in the intercity travels are 4.82 times higher than the odds for the respondents who were living in the locations with relatively low intercity transit accessibility. In other words, the respondents who were living on campus or near the campus of the University of Waterloo or the Wilfrid Laurier University, or in Downtown Kitchener or the GTHA (excluding Durham Region) have much higher likelihood of traveling by the non-automobile transport modes than others who were living in other parts of the Region of Waterloo, Durham Region or otherwise. In the X_7, for the respondents who had the Presto card, the odds of using the non-automobile modes are 3.18 times higher than the odds for the respondent who did not have the card. Because X_8 has a negative estimated coefficient, it means that for the respondents who owned a motor vehicle and had regular access to it, the odds of using the non-automobile modes are less than 13% of the odds for the respondents without car availability. In addition, X_{12} (Average One-way Travel Time) has the significance level less than 0.05, but its absolute value of the estimated coefficient is much smaller than those of the X_5, X_7 and X_8. This is because the unit price of the X_{12} is the minute. Considering that the total travel time among the respondents is ranging from 35 minutes to 240 minutes, it can be assumed that the longer the travel time a respondent reported, there is a higher likelihood that the respondent used the non-automobile transport mode for the intercity travel.

Among the other independent variables, X_2 (Current Level of Studies) has a p-value very close to

0.05 at 0.092. It could be inferred that the respondents who were graduates in Winter 2018 are more likely to use the non-automobile modes than others who were undergraduates when traveling between the Region of Waterloo and the GTHA. This finding extends the argument that graduate students are more likely to use non-automobile modes for on-campus trips as they might be more aware of environmental sustainability (Akter, 2016). In the meantime, even if many undergraduate students are less financially prepared to own a car, they might still be able to share rides with their family members or friends in the intercity travels. In addition, X_4 (Enrolment Status), X_9 (Trip Frequency) and X_{10} (Primary Purpose of Traveling) have larger significance levels less than 0.2. Although there is higher risk that the estimated coefficients of the three independent variables are not different from 0, their influences on students' intercity mode choice may still exist. In the X_4, the respondents who were coop students are more likely to use the non-automobile modes than the non-coop students. One of the possible reason is that many of the coop students were working in downtown areas where the parking rates are significantly higher, so they may tend to use public transit for commuting. In the X_9, the respondents who had intercity travel experiences at least once a week during the recent two months are more likely to use the non-automobile transport modes than others. This finding is partially consistent with the observation from Figure 4.3 that the intercity bus is the most popular traveling method among the respondents who had 8 to 10 times of traveling experiences in the recent two months. In the X_{10}, business travelers are more likely to use the non-automobile transport modes than non-business travelers. The reason behind this observation might be similar as the one behind the X_4, as the students did not use the automobile transport modes for business travels in order to save the parking costs.

Due to the significantly high p-values of the other independent variables, this study would assume that these variables may not have significant influences on students' intercity mode choice. Overall, this model could correctly estimate 72.4% of the total variations.

Table 4. 10 Results of the First Binary Logit Model

	B (Estimated Coefficient)	**Standard Error**	**df**	**p-value (Significance Level)**	**Exp(B) (Odds Ratio)**
X_1 (Gender)	-0.148	0.382	1	0.697	0.862
X_2 (Current Level of Study)	1.022	0.607	1	0.092*	2.779
X_3 (Holding of International Student Visa)	0.369	0.507	1	0.466	1.447
X_4 (Enrolment Status)	0.598	0.416	1	0.151	1.818
X_5 (Residential Location)	1.573	0.589	1	0.008***	4.821
X_6 (Holding of Driver's License)	-0.029	0.435	1	0.947	0.972
X_7 (Holding of Presto Card)	1.157	0.410	1	0.005***	3.180
X_8 (Motor Vehicle Availability)	-2.073	0.583	1	0***	0.126
X_9 (Trip Frequency)	0.644	0.495	1	0.193	1.904
X_{10} (Primary Purpose of Traveling)	1.246	0.875	1	0.154	3.478
X_{11} (Primary	-1.919	2.339	1	0.412	0.147

Destination)					
X_{12} (On Average One-way Travel Time)	0.011	0.005	1	0.03**	1.011
Constant	-1.503	2.442	1	0.538	0.223

***Significance level less than 1%
**Significance level less than 5%
*Significance level less than 10%
Y_i is the dependent Variable.
Percentage Estimated Correctly of the Model: 72.4%

5. Discussion and Conclusion

5.1 Discussion

5.1.1 Findings Highlights

Chapter 2 answers the first research question by reviewing the relevant literature and Chapter 4 answers the second and the third research questions through the analysis of the survey data. By understanding University of Waterloo students' current intercity travel behavior and the significance levels of the influencing factors on their intercity mode choice, two featured segments of the intercity travelers can be identified.

Automobile-Oriented Intercity Travelers

In this research, the automobile-oriented intercity travelers mainly refer to the University of Waterloo students who travel between the Region of Waterloo and the GTHA either by driving the personal vehicle or sharing rides with other drivers. However, there are significant differences in the socio-demographic and trip characteristics between automobile drivers and carpooling passengers.

Car drivers are more likely to be males, and to be either Canadian citizens or permanent residents. They are less likely to live close to the University of Waterloo or the Wilfrid Laurier University and have the Presto card. The majority of them have a drivers' license equivalent to Ontario's G2 or G and own a personal vehicle with recently regular access to it. Car drivers are more likely to be frequent intercity travelers as more than 70% of the respondents who had over 15 times of intercity travel experiences chose to drive. Moreover, the Region of York and the City of Toronto see a large portion of driving's mode share.

In contrast, carpooling passengers have a higher likelihood to be females and to be non-co-op students. The majority of them live close to the two universities but the percentage is slightly lower than that among the total respondents. Approximately half of them do not have the Presto card and the driver's license, and the car availability rate among them is as low as 0. Carpooling passengers tend to be non-frequent intercity travelers as carpooling is the second most popular travel method among the respondents who had 1 to 3 time (s) of intercity travel experiences in the recent two months. On the other hand, it can also be inferred that because it is not easy for the carpooling passengers to always find a driver whose departure time and trip destination fit their needs, they are less likely to become frequent intercity travelers as those drivers. The Region of York and the City of Toronto also have a great split of carpooling's mode share.

Non-Automobile-Oriented Intercity Travelers

The majority of non-automobile-oriented intercity travelers in this research are composed of GO Bus riders and the other three intercity bus services (Greyhound Bus/Mega Bus/Fed Bus) riders. GO Bus riders are more likely to be females and live close to the two universities. They usually have the Presto card and do not own a personal vehicle. These travelers contain the largest percentages of the respondents who were full-time students on co-op in Winter 2018 and who were holding the international student visa among the four most popular transport modes' users. GO Bus is the most popular travel method among the respondents who had 4 to 10 times of travel experiences in the recent two months and the Region of Peel sees the largest proportion of GO Bus's mode share.

Similarly, the other three intercity bus services have the highest percentages of female travelers and graduate travelers among the four most popular transport modes. Most of these travelers live close to the two universities and do not own a personal vehicle, and more than half of them do not hold the Presto card. The three intercity bus services are the second most popular travel method among the respondents who had 8 to 10 times of intercity travel experiences in the recent two months and the City of Toronto is the primary destination for most of these intercity bus travelers. Similar to the carpooling passengers, these intercity bus travelers cannot become extremely frequent travelers as well due to the low flexibility and long travel time of the bus journeys.

In addition, this study also investigated the students' attitudes towards the proposed high-speed rail in Ontario and their intended behavior of using it when traveling between the Region of Waterloo and Downtown Toronto. The results indicate that although the students were slightly familiar with the proposed HSR service, they have overall positive attitudes towards the service. Under the hypothetical situation where the HSR service is available, 41% of the respondents would choose the HSR as their primary transport mode when traveling from the Region of Waterloo to Downtown Toronto. However, the other 15% of the respondents who chose the GO Bus travel option expressed numerous interests in using the HSR if the one-way fare between the Region of Waterloo and the GTHA could be as low as $20, but they had the lowest level of agreement that traveling on the HSR would be more environmentally-friendly than driving or taking a bus. It is also found that students' current intercity mode choice would affect their stated choice behavior.

In the following section, several recommendations will be made based on the research findings, with the emphasis on reducing university students' automobile dependency in the intercity travels and promoting the HSR throughout the public engagement process.

5.1.2 Recommendations

Although the automobile is still playing a significant role in people's daily travel activities in the GGH, both the provincial and federal governments are making long-term progress to improve and expand public transit for domestic and intercity travels. By analyzing the intercity travel characteristics of the University of Waterloo as well as summarizing the observations of the researcher, this study could inform planners and policymakers to increase the non-automobile mode share in the intercity travels between the Region of Waterloo and the GTHA by providing the following recommendations.

First, the Metrolinx should speed up the pace to expand the use of the Presto card and make it easier for the residents living in the outer-ring of the GGH to obtain the card and add funds. The research findings have verified that university students holding the transit pass are more likely to utilize the non-automobile modes in the intercity travels (Brown et al., 2003; Heath & Gifford, 2002). However, only GO Bus and GO Train riders are currently able to use the Presto card for fare payment. The 2015-2020 Metrolinx Five Year Strategy outlines the objective to enhance fare payment convenience by further developing the Presto offering, which implies to make the smart card more applicable for use on other services in the future (Metrolinx, 2014). Extending the use of the transit pass is technically feasible and has been practiced in many countries. A successful case is the Suica in Japan, which was initially used as a fare card for riding the trains

offered by the East Japan Railway Company (JR East) and gradually became a popular cashless payment method in the Tokyo metropolitan area. Up till now, the Suica not only can be used on various railway and bus services offered by other public and private transportation carriers in the Tokyo metropolitan area, but it is also available for making purchases in many convenience stores and restaurants in the area. JR East also has signed agreements with other transportation companies across the nation to expand the service area of the Suica beyond the Tokyo metropolitan area (JR East, 2018). Therefore, it is expected to see that the Presto card can be used for fare payment in other intercity transport services in the GGH, such as Greyhound Bus and VIA Rail. Moreover, the Presto card could also be integrated with smartphones so that passengers can use their mobile devices to make the payment even if they forget to bring the card with them.

Currently, people can obtain a new Presto card in two ways. One is to order a card online, which will be mailed to the customer in 7-10 business days. The other is to purchase the card at any Customer Service Outlet, or at a Ticket Vending Machine or a Fare Vending Machine. In the GTHA and Ottawa, customers can also buy the card at nearly 400 Shoppers Drug Mart locations (Presto Card, 2018). However, in the Region of Waterloo, there is only one venue located in the Kitchener Railway Station where people can buy the card and add funds in person, which might discourage the prevalence of the card among the university students. More Ticket Vending Machines or Customer Service Outlets should be deployed close to the two universities so that passengers can purchase the card and load funds immediately and more easily.

To attract more frequent intercity travelers to use the public transit, Metrolinx could somehow lower the discount threshold for student Presto card holders who ride the GO Train and the GO Bus. According to the survey results, the majority of university students who made more than 15 intercity trips per month would choose to drive, whereas significant discounts will apply to GO Transit passengers with the student Presto card only if they have made more than 30 trips per month. If the student Presto card users could receive more fare deduction in their first 15 to 20 trips in a month, more student travelers might shift mode from driving to taking the GO Transit.

Second, it is important to improve the local transit accessibility because intercity travelers are more concerned about access to and egress from transit stations than the main in-vehicle travel in the mode choice (Wong & Habib, 2015). In the Region of Waterloo, the phase 1 of the ION rapid transit is expected to start operation in early 2018, which would reduce the travel time by half from the University of Waterloo to the Kitchener railway station. The rapid transit service will also facilitate the residents living in the northwest of the City of Waterloo and the southeast of the City of Kitchener to travel to the intercity transit stations. This would be beneficial to increasing the ridership in the non-automobile modes. In the GTHA, several LRT and BRT projects are undergoing construction for the same reason to enhance the connectivity between the intercity transit stations and the final destinations of the passengers in the future. A couple of multi-modal transit hubs like the Union Station in Downtown Toronto are also proposed to build in the GGH. These hubs, such as the one at the Pearson International Airport, would serve as the regional transportation centres accommodating various transport modes, so travelers could have more options to travel to their final destinations from the hubs.

Last, the intercity transportation carriers, especially the GO Transit, could optimize the service routes and upgrade the facilities to increase the ridership in the bus and train services. From the perspective of the researcher, there are two major obstacles that could discourage people from taking the GO Transit when traveling between the Region of Waterloo and the GTHA. First, the total travel time by taking the GO Bus is usually more than doubled compared to drive as there are too many stops along the route. Second, it is pretty hard to find a free parking lot close to the GO Bus station uncles you arrive in the early morning. As the solutions, GO Bus could offer more frequent non-transfer or non-stop services between the University of Waterloo and the City of Toronto or the Region of York throughout the week. It is also necessary to improve the park and ride facilities at the intercity transit stations so as to allow more residents who do not live close to the intercity transit stations to drive there and transfer to the bus or train for the remainder of the journey. To increase the train ridership, the GO Kitchener line should be electrified and added more tracks to accommodate the hourly and two-way services between the Union Station and the Kitchener Railway Station.

As for the proposed high-speed rail in Ontario, although the research demonstrates that the university students have relatively low familiarity with the project, they have overall positive attitudes and huge interests towards this new technology. Therefore, planners still need to engage with these potential users who would be affected by the HSR service more actively in the following period of time. Several municipal engagement sessions have been held by the special advisory group of the HSR project in each of the four main station-area communities including the Region of Waterloo, but no specific session has targeted on the university students (Ontario Ministry of Transportation, 2018). As one of the important sources of the potential passengers,

the university students should have the opportunity to learn systematically about what environmental benefits that the HSR project could generate and what are the advantages of taking the HSR for intercity travelers, rather than driving or carpooling. The engagement process can be achieved through the Internet, so the university students can provide feedback and interact with the planners online anywhere and at any time.

5.2 Conclusion

5.2.1 Research Summary

This research seeks to understand what are the factors that affect University of Waterloo students' intercity mode choice, and the significance levels of the identified influencing factors on their intercity mode choice between automobile modes and non-automobile modes. It also investigated the students' attitudes towards the proposed high-speed rail in Ontario and their intended behavior of using it when traveling between the Region of Waterloo and the GTHA.

First, this research fills the literature gap in understanding the factors affecting intercity travel behavior of the university students. Compared to other adults who are either full time workers or retirees, the university students are more sensitive to costs over time, because they usually do not have stable income source. Therefore, they are in better favor of choosing the public transit when traveling. By reviewing the literature focused on either general population's intercity travel behavior and or university students' general travel behavior, twelve factors were selected for further analysis from three groups: 1) social-demographic characteristics of the travelers, 2) trip characteristics, 3) attributes of the transport facility. Then, the discrete choice models and their theoretical framework were systematically examined, and the binary logit model was chosen to

use for this research. The thesis also explored the relationships between the attitudes of the travelers and their travel behavior.

This study conducted a survey at the main campus of the University of Waterloo. The results from the descriptive statistical analysis revealed that the students' intercity mode choice behavior varies according to their trip frequencies and their primary destinations in the GTHA. Furthermore, the binary logit model quantified the significance levels of the identified factors, showing that whether or not having the transit-fare payment card and motor vehicle availability are the two most influential socio-demographic factors at the 1% significance level. University students' residential locations and their levels of study also have significant influence on their intercity mode choice. In addition, travel time is the only factor belonging to the group of trip characteristics that has strong association with university students' intercity mode choice. Moreover, the descriptive statistical analysis results also indicate that the University of Waterloo students have overall positive attitudes towards the high-speed rail in Ontario, and nearly half of them chose to use the HSR service to travel from the Region of Waterloo to Downtown Toronto under a hypothetical scenario where the HSR is available. The association was also found between the respondents' current intercity mode choice and their stated travel option choice. The respondents who utilize the automobile modes for their current intercity travels have a higher likelihood to select the driving option under the hypothetical scenario than the rest of non-automobile intercity travelers. Several recommendations were subsequently proposed based on the research findings, which focus on increasing the non-automobile mode share in the intercity travels between the Region of Waterloo and the GTHA, and adequately engaging the university population in the planning process of the HSR project.

5.2.2 Limitations

While the researchers attempted to obtain the data that can represent the whole population of the University of Waterloo, there were some limitations in the data collection process which may result in sampling bias and affect the result precision. First, as the survey was conducted on campus, a large number of co-op students who were working elsewhere were not approached, so the results may not completely reflect the intercity travel behavior and attitudes towards the HSR of the overall university population. Second, the survey asked the respondents' intercity travel history during the recent two months, but it was difficult for them to accurately remember all the details of the trips that they had made. Therefore, there could be discrepancies between the trip information they had provided and the actual trip conditions, especially for the trips they had made earlier. In addition, considering the total number of enrolled students in the University of Waterloo is more than 40,000, an ideal survey sample size with 5% margin of error and 95% confidence level should be more than 380 (SurveyMonkey, 2018). The sample size for this survey is 195, which means a greater margin of error at 7%, so there might be a larger amount of random sampling error in the results.

In regards to the survey questionnaire, the question 4 asked if the respondents were full-time students on co-op in Winter 2018, but it did not distinguish whether the students were in the academic term or work term at that time. According to the literature review, differences in travel behavior would exist between the university students who were having the class and who were working (Daisy et al., 2018). In the question 12, the respondents were asked to choose their primary destinations in the GTHA at the municipal level, the scale of which is too large that

would affect the accuracy of the results. Even if in the City of Toronto, for example, the levels of transit accessibility among the 140 neighborhoods are quite different. Therefore, it might be inappropriate to categorize the entire City of Toronto as the area with high intercity transit accessibility.

The page 4 of the survey questionnaire consists of a series of relevant questions that ask the respondents attitudes towards the proposed HSR, but the number of the questions is too limited to systematically explore their opinions and perceptions of the new transport mode. The only stated choice question sets a hypothetical scenario where the respondents could choose the HSR to Downtown Toronto for shopping, which overlooks what they would do after the activity. The respondents might have different travel options if they were told to either stay overnight in Toronto or go back to the Region of Waterloo immediately after shopping.

In the stage of data analysis, the researcher had roughly removed some invalid responses according to the answers in the question 12 (primary travel destination in the GTHA) and the question 13 (average one-way travel time), before conducting the descriptive statistical analysis and running the binary logit models. However, it is still not convincing that the remaining responses could almost reflect the real situations of the respondents. Moreover, the correlation analysis among the independent variables should have been performed before conducting the binary logit regression, so as to simplify the model calibration process.

5.2.3 Future Studies

Based on the limitations examined in Section 5.2.2, this study can be further improved in the following ways. During the data collection process, the survey questionnaire can be refined to investigate more details about the respondents. Although the majority of the students at the University of Waterloo are undergraduate students in the age range of 17 to 27 years who do not have stable income sources, there is a significant portion of graduate students who are much older and earn good income. Therefore, the future study should ask the respondents' age and household annual income as part of the socio-demographic information, as well as analyze their influences on the respondents' intercity mode choice. Some U.S. researchers found that the university students' travel behavior may be affected by their race (Akter, 2016; Volosin, 2014). As Canada has long been an immigration country with migrants from all over the world since its foundation, many universities in the nation have also seen ethnically diverse student population. It could be interesting in the further research to figure out if the university students with different race would significantly vary in the intercity travel behavior.

In addition, when the respondents are asked to indicate their primary travel destination, they can be provided with an interactive map on which they could choose their destinations at the community or the neighborhood level. Indeed, the achievement of the more accurate result should require a more advanced and professional online survey platform that could have access to the open database, such as the OpenStreetMap and the Google Maps. In the meantime, the range of the survey questions could be extended to cover more trip characteristics of the respondents, such as their average travel cost and the levels of satisfaction with their primary intercity transport mode. To better understand the respondents' attitudes towards the HSR, more

stated choice questions under different hypothetical scenarios can be added. It is interesting to see how the respondents would make different options if they are asked to travel to the Pearson International Airport where the HSR would make a stop. To obtain a larger sample size, the researcher could cooperate with the university to send the survey links to the student email addresses. More rules can be applied to filter the valid responses, for example, based on the survey completion time, or the consistency between the questions.

During the process of data analysis, nested logit regression can be employed to model the respondents' mode choice. Figure 5.1 demonstrates a possible formation of the nested logit model, which could more accurately measure the utility of each transport mode and reveal the differences among the transport modes under the same nest. Moreover, the respondents' attitudes towards the HSR could also be evaluated through logit modelling, so that the researcher could understand in-depth which aspect of the attitudes has the most influence on their intended mode choice behavior.

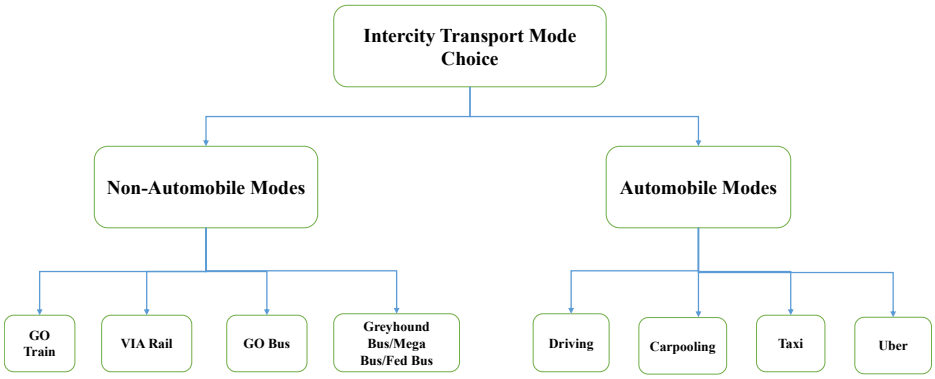

Figure 5. 1 One Possible Formation of the Nested Logit Model

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Appendix 1: Survey Questionnaire

Page 1:

Short Message:
Hello, my name is Yan Yu, a second year MES in Planning student from the University of Waterloo. I am conducting a survey for my Master's thesis to understand University of Waterloo Students' Intercity Transport Mode Choice. I kindly appreciate your participation to help my research by answering the following questions. This survey consists of at most 17 questions and should take no more than 12 minutes to complete. Your answers on the survey will be confidential and not used in any way to identify you.

Question 1. What is your gender?

a) Male b) Female

Question 2. What is your current level of study?

a) Undergraduate b) Graduate

Question 3. Are you on international student visa?

a) Yes b) No

Question 4. Are you a full-time student on co-op in Winter 2018?

a) Yes b) No

Question 5. Where are you currently living?

a) On campus or near the campus of the University of Waterloo (within 1 km of the Davis Centre Library)

b) On campus or near the campus of the Wilfrid Laurier University (within 1 km of the University/King)

c) Downtown Kitchener

d) Other parts of the Region of Waterloo

e) Greater Toronto and Hamilton Area (GTHA) (excluding Durham Region)

f) Durham Region

g) Others

Question 6. Do you have a driver's license equivalent to the Ontario G2 or G?

a) Yes b) No

Question 7. Do you have a Presto Card?

a) Yes b) No

Question 8. Do you own a motor vehicle and have regular access to it recently?

a) Yes b) No

Page 2:

Question 9. How many times have you traveled between the Region of Waterloo and the Greater Toronto and Hamilton Area (GTHA) during the recent two months? (a round trip counts as one time)

a) Over 15 times b) 11-15 times c) 8-10 times d) 4-7 times e) 1-3 time(s)

f) 0 time

Note: Respondents who choose the option from "a" to "e" will be directed towards the question 10, otherwise they will be directed towards the question 14.

Page 3:

Question 10. What is your primary purpose of traveling between the Region of Waterloo and the GTHA during the recent two months?

a) Business: *Any trips related to your co-operative education employment, general employment or any educational activities such as meetings and conferences.*

b) Personal: *Any trips for personal reasons, such as visiting family or friends, shopping, medical appointments, etc.*

Question 11. What is your primary transport mode when you have traveled between the Region of Waterloo and the GTHA during the recent two months?

a) GO Train b) VIA Rail c) GO Bus d) Greyhound Bus/Mega Bus/Fed Bus

e) Taxi f) Uber g) Carpooling h) Driving

Question 12. What is your primary destination when you travelled from the Region of Waterloo to the GTHA during the recent two months?

a) City of Toronto *(include Scarborough, Etobicoke, North York, York, East York and Old Toronto)*

b) Region of Halton *(include Halton Hills, Milton, Oakville, and Burlington)*

c) Region of Peel *(include Caledon, Brampton, and Mississauga)*

d) City of Hamilton

e) Region of York *(include King, Vaughan, Markham, Richmond Hill, Whitchurch-Stouffville, East Gwillimbury, and Georgina)*

f) Region of Durham *(include Brock, Uxbridge, Scugog, Pickering, Ajax, Whitby, Oshawa, and Clarington)*

Question 13. How much time on average have you spent on the one-way trip between the Region of Waterloo and the GTHA during the recent two months?

(Please only input the number of minutes you have spent below.)

_____ Minutes

Page 4:

Question 14. Have you ever had experiences riding high-speed rail (HSR) in any countries?

(High-speed rail refers to the rail transport with maximum operating speed no less than 200 km/h.)

a) Yes b) No

Background Introduction of Ontario's High-Speed Rail (HSR):

In December 2014, the Government of Ontario announced to build the phase 1 of the high-speed rail system, which is projected to be complete by 2025. The proposed system would implement electrified 250 km/h HSR technology, and the phase 1 of the HSR system will include 5 stops, which are Toronto (Union Station), Pearson Airport/Malton, Guelph, Kitchener-Waterloo and London (Ontario, 2014).

Below shows the estimated journey time of the HSR from the proposed Kitchener-Waterloo station (Victoria/King at Downtown Kitchener) to other stations.
Toronto Union Station: 48 minutes
Pearson Airport/Malton Station: 32 minutes
Guelph Station: 9 minutes
London Station: 25 minutes

Question 15. Please indicate your level of understanding and attention about the proposed high-speed rail in Ontario.

Extremely familiar	Moderately familiar	Somewhat familiar	Slightly familiar	Not at all familiar

Question 16. Please indicate your level of agreement with the following statements related to your use of the proposed HSR service.

Sample Rating Scale:

Strongly agree	Agree	Neither disagree of agree	Disagree	Strongly disagree

Statement 1: Traveling on the HSR would be safer than driving or taking a bus.

Statement 2: Traveling on the HSR would be more enjoyable than driving or taking a bus.

Statement 3: Traveling on the HSR would be more efficient than driving or taking a bus.

Statement 4: Traveling on the HSR would be more environmentally-friendly than driving or taking a bus.

Statement 5: Traveling on the HSR would be more reliable than driving or taking a bus.

Statement 6: I would choose the HSR as my primary transport mode if the one-way fare between the Region of Waterloo and the GTHA could be as low as $20.

Question 17. Now Imagine that the HSR service has been available for passengers and you are

planning a day trip alone departing at 10:30 am on Saturday from Davis Centre Library (University of Waterloo) to CF Toronto Eaton Centre (Downtown Toronto) for shopping. You will stay at the shopping centre for 4 hours. To travel to the destination for this trip, imagine you have three options:

Option 1: Drive yourself in your personal vehicle

Option 2: Take the GRT to the HSR station, ride the high-speed rail train similar to the one described in the "Background Introduction of Ontario's High-Speed Rail (HSR)", and take the TTC subway to the final destination

Option 3: Take Go Bus to Toronto Union Station and take the TTC subway to the final destination

The one-way travel time and travel cost for each of the three travel options are given below. For the travel option 1, travel cost includes gas cost and parking rates (HST included) at Eaton Centre. For the travel option 2 and 3, total travel time includes the access time from origin to transit station, transfer time between two transit modes and egress time from transit station to final destination; frequencies of the high-speed rail train and Go Bus services are also given respectively.

Under this hypothetical situation, which option would you choose for your trip from Davis Centre Library to CF Toronto Eaton Centre?

	Option 1
Total Travel Time	84 Minutes
Travel Cost (Gas Cost and Parking Rates for Four Hours)	$24
Frequency of Service	Anytime

	Option 2
Total Travel Time	73 Minutes
Travel Cost (Transit Tickets Price)	$34
Frequency of the HSR Service	Every 30 minutes

	Option 3
Total Travel Time	155 Minutes
Travel Cost (Transit Tickets Price)	$21
Frequency of the Go Bus Service	Every 30 to 60 minutes

End Message:
Thank you for participating in this survey! Your feedback is extremely valuable.

This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE # 22840). If you have questions for the Committee contact the Chief Ethics Officer, Office of Research Ethics, at 1-519-888-4567 ext. 36005 or ore-ceo@uwaterloo.ca.

For all other questions or if you have general comments or questions related to this study, please contact Yan Yu, School of Planning, at y282yu@uwaterloo.ca.

Appendix 2: A Full Crosstab of the Socio-demographic Characteristics

Question 1 (Q1) to Question 8 (Q8)

The Relationship Between	Pearson Chi-Square	df	p-value
Question 1 and Question2	1.974	1	0.116
Question 1 and Question 3	0.035	1	0.851
Question 1 and Question 4	3.472	1	0.062
Question 1 and Question 5	5.986	1	0.308
Question 1 and Question 6	0.164	1	0.685
Question 1 and Question 7	0.282	1	0.596
Question 1 and Question 8	0.003	1	0.960
Question 2 and Question 3	14.380	1	0.000
Question 2 and Question 4	6.668	1	0.010
Question 2 and Question 5	14.524	1	0.013
Question 2 and Question 6	0.355	1	0.551
Question 2 and Question 7	1.607	1	0.205

Question 2 and Question 8	0.331	1	0.565
Question 3 and Question 4	0.665	1	0.415
Question 3 and Question 5	4.276	1	0.510
Question 3 and Question 6	30.725	1	0.000
Question 3 and Question 7	0.835	1	0.361
Question 3 and Question 8	5.627	1	0.018
Question 4 and Question 5	8.665	1	0.123
Question 4 and Question 6	0.928	1	0.335
Question 4 and Question 7	5.131	1	0.162
Question 4 and Question 8	0.065	1	0.799
Question 5 and Question 6	6.649	1	0.248
Question 5 and Question 7	17.291	1	0.004
Question 5 and Question 8	14.535	1	0.013
Question 6 and Question 7	0.836	1	0.361
Question 6 and Question 8	30.588	1	0.000
Question 7 and Question 8	16.591	1	0.000