UTTRI

Research Report

Vehicle for Hire Bylaw Review

Report 4: Evaluating the Impacts of Private Transportation Companies on Travel Behaviour through a Stated Preference (SP) Survey

Patrick Loa, Jason Hawkins, Khandker Nurul Habib

May 2019

UTTRI TECHNICAL SUPPORT FOR THE CITY OF TORONTO VEHICLE FOR HIRE BYLAW REVIEW

Report No: 4

Evaluating the Impacts of Private Transportation Companies on Travel Behaviour through a Stated Preference (SP) Survey

Patrick Loa, B.A.Sc.
Jason Hawkins, M.A.Sc

Khandker M. Nurul Habib, Ph.D., P.Eng

May 2019

UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING
Transportation Research Institute

TABLE OF CONTENTS

UTTRI

List of Tables **Page No.**

List of Figures **Page No.**

1. INTRODUCTION

This technical report presents the work undertaken in support of the City of Toronto's *Vehicle for Hire Bylaw Review* by the University of Toronto Transportation Research Institute (UTTRI) and it presents the analysis of the factors that influence the residents' (of the City of Toronto) choices of using or not using exclusive and shared ride-hailing services in the City. The investigation is based on data obtained through a specialized travel survey that uses a Stated Preference (SP) technique build on Revealed Preference (RP) information of daily travel.

The survey, named the "**S**urvey to **P**redict the **R**epercussions of the **I**ntroduction of **N**ovel **T**ransportation **N**etwork **S**ervices": (SPRINT), collected information from a random sample of residents (selected from a market research panel) of the City of Toronto. Respondents were asked a series of questions pertaining to personal and household characteristics, information on the extent to which respondents use ride-hailing services, and their familiarity with and perceptions of ride-hailing services. In addition, respondents were asked to complete a series of real (revealed) and hypothetical (stated) preference questions, which were used to understand the trade-offs that people make when choosing a mode of travel in the City.

The rest of this report is organized as follows. Section 2 summarizes the goals of and motivation for the survey and presents a discussion of the factors that influenced the design of each component of the survey. Section 3 provides an analysis of the data obtained through the SPRINT. The analysis of the results is comprised of three elements: descriptive statistics, usage, and perceptions of ride-hailing services, and model results. Section 4 summarizes the key findings of the report.

2. SURVEY DESIGN

This section presents a discussion of the various factors that influenced the design of the survey. The survey consists of four main components: household and personal socio-economic questions, stated preference experiments, attitudinal questions, and questions that pertain specifically to respondents who have used ride-hailing services (such as Uber and Lyft) in the recent past. The design of the survey used the knowledge of an extensive review of similar studies elsewhere, which is presented in the following sub-section.

2.1. Background: Review of existing literature

Since their introduction into the market, ride-hailing services have challenged and reshaped traditional perceptions of mobility and travel. The increasing prominence and popularity of ride-hailing services have motivated both researchers and policymakers to investigate the impacts of these services on travel behaviour. Within the growing body of research on ride-hailing services, studies can be grouped into three categories:

- Studies on the characteristics of ride-hailing users and ride-hailing trips,
- Studies on the factors that influence the adoption of these services, and
- Studies on the impacts that the use of ride-hailing has on the use of other modes

In the North American context, the potential impacts of ride-hailing services on public transit ridership have received a significant amount of attention, in part due to the tendency of large transit agencies to rely on fare revenues to help fund operations. Thus, agencies may suffer if public transit trips are replaced by ride-hailing trips.

In the literature, findings of studies that have investigated the impacts of ride-hailing services on public transit usage have been mixed. The common theme of these studies is that using ride-hailing services affects the use of public transit, however, the relationship can be both substitutive and complementary. For example, Clewlow & Mishra (2017) found that ride-hailing services tend to draw riders away from bus and light-rail services but also has the tendency to complement heavy rail services. Similarly, Rayle, Dai, Chan, Cervero, & Shaheen (2016) report that, while ride-hailing has the potential to cannibalize transit ridership, it also has the potential to serve smaller markets that could not be served efficiently by public transit. The nature of the relationship between public transit and ride-hailing services with respect to mode choice is summarized succinctly in Rodier (2018), who states that ride-hailing services tend to act as a substitute for other modes, rather than as a complement.

The influence of ride-hailing services on travel behaviour is not limited to public transit. For example, a survey of shared mobility users conducted the Shared-Use Mobility Center found that the use of shared modes (such as bike-sharing and ride-hailing) tends to affect the frequency with which a person drives. The results of the survey seem to imply that using a shared mode can result in a reduction of the frequency of which a user drives, particular when commuting, running errands, or participating in recreational activities (Shared-Use Mobility Centre, 2016). This result is somewhat echoed by Rodier (2018), who found that most ride-hailing trips are substitutes for auto and taxi trips, with the caveat that they are also often a substitute for transit and walking trips.

Overall, it is clear that the introduction and adoption of ride-hailing services have an influence on mobility and travel patterns, however, the exact nature and extent of this influence is dependent on a wide range of factors. Consequently, any efforts to understand the impacts that ride-hailing services are having travel behaviour and mobility in the City of Toronto will require data from residents of the City. Previous research clearly identifies that general travel surveys (travel diaries) or even observed details of ride-hailing trips made by people would not be sufficient to understand the impacts of the growing market of ride-hailing. Observations of such do not reveal the complicated role of different factors that affect the role of ride-hailing services in the competitive market of urban modes. So, to understand the impacts growing ride-hailing services in the City of Toronto, a web-based specialized survey was designed and conducted in May of 2019. It uses the approach of RP-off-SP to make the SP survey a realistic and relevant to the context of the current study. While the SP experiments were hypothetical, those were grounded on RP choices of travel mode made by the respondents in recent past. The survey, SPRINT, aimed to collect data that could provide insights into the socio-economic characteristics of ride-hailing users and the trade-offs that people make when choosing a mode of travel.

The following sub-section presents the implementation approach of the survey.

2.2. Survey Implementation

SPRINT was implemented using the Travel Internet Survey Interface (TRAISI) survey platform developed at the University of Toronto Transportation Research Institute (UTTRI). The use TRAISI platform enables the ability to adapt the stated preference (SP) portion of the survey based on the information of daily travel behaviour provided by the respondent. TRAISI has a map-based interface for the precise collection of address and other location-related information without the need for manual geocoding. In addition, TRAISI exploits the Google API to collect detailed level-of-service information alternative modes that are used by the respondents, which then can be used to create the SP scenarios. These all allow realistic SP experiment and reduces hypothetical biases in the SP data. The justification for the SP experiment in the survey will be discussed in more detail in section 2.3.2. The survey is conducted by randomly drawing samples from the members of a market research panel. The decision to recruit members of a market research panel to complete the survey, rather than recruit participants through other means, was made to help expedite the data collection process. Also, the recent experience of the authors of this report validates the fact that such a panel is more or less well represented to the general population of the City. The questionnaire of SPRINT is presented in the following sub-section.

2.3. Questionnaire Design

This section presents a summary of the factors that influenced the design of different components of the questionnaire. The design of the questionnaire was informed by the results of the literature review and a review of surveys on emerging mobility. The survey includes four types of questions:

- Household and socio-economic questions,
- Stated preference questions,
- Attitudinal questions, and
- Questions about the use of ride-hailing services

Household and socio-economic questions were included in order to identify similarities and differences between respondents who have previously used ride-hailing services and the residents of the City of Toronto. In addition, these information were utilized in the development of mode choice models. The SP questions, wherein respondents are asked to choose the mode that they would use to make a commuting or non-commuting trip, were included in order to understand the trade-offs that the respondents made when selecting a mode of travel (that goes beyond RP contexts). The attitudinal questions were included to provide insights into the role perceptions, attitudes, and familiarity play in the extent to which the respondents used (or did not use) ride-hailing services. This section presents questions that asked respondents to indicate their familiarity with ride-hailing services, the extent to which they agree or disagree with a certain statement, and the importance that they place of various aspects of travel. Finally, the questions pertaining to the use of ride-hailing services were included in order to identify the extent to which each respondent uses ride-hailing services. The designs of these sets of questions are discussed in more detail in the following sections.

2.3.1. Household and Socio-Economic Questions

The inclusion of questions related to the characteristics of the respondent and their household was motivated by the desire to account for the influence of such on the use of ride-hailing services. The rationale for this desire is two-fold. Firstly, studies that focus on the users of ride-hailing services often find that the demographics of this sub-group differ from those of the population as a whole. For example, Alemi, Circella, Handy, & Mokhtarian (2018) found that higher levels of both education and income were associated with a greater likelihood of using on-demand ride services. The same result was reported by Clewlow & Mishra (2017), who also found that the use of ride-hailing services tends to be more prevalent among younger people. In addition, the extent to which a person utilizes ride-hailing services tends to affect auto ownership (Alemi, Circella, & Sperling, 2017). Having questions of this nature in the survey can provide insights into whether this trend also applies to residents of the City of Toronto and can be used to define different archetypes of ride-hailing users. Secondly, the inclusion of socio-economic information in the specification of the mode choice model can provide insights into the extents to which different personal and household characteristics affect the mode choice process. The consideration of said characteristics can provide information that can be used to inform the development of policy.

The selection of the household and socio-economic questions that were included in the survey was based on the information collected in the Transportation Tomorrow Survey (TTS). The TTS is a cross-sectional household travel survey of the residents of the Greater Golden Horseshoe (GGH) that has been conducted every five years since 1986 (DMG, 2018). In addition to the questions that were included in the TTS, SPRINT also included two questions pertaining to ride-hailing. The first asked respondents to indicate whether they had ever installed a ride-hailing application on their smartphone. The second asked respondents to report whether they had ever used a ride-hailing service. These questions were added in order to develop a comprehensive system for categorizing respondents. Instead of the binary classification of users and non-users, these questions allow respondents to be placed into one of four categories:

- Persons who have never used a ride-hailing service,
- Persons who have a ride-hailing application installed on their smartphone but who have never used it,
- Persons who have used a ride-hailing service but have never hailed a ride using their own account, and
- Persons who have used their own account to rail a ride

The full list of household and socio-economic questions can be found in the *Household Attributes* and *Personal Attributes* section of Appendix A – Survey Questionnaire.

2.3.2. Stated Preference Questions

Stated preference (SP) questions are the core of the SPRINT. In contrast to revealed preference (RP) questions, which ask respondents to report the choices that they *have made recently*, SP questions ask respondents to report the choice that they *would make* in a hypothetical situation. Broadly speaking, SP questions ask respondents to select their preferred alternative from a set of alternatives, each of which is characterized by various attributes. For the SPRINT, respondents were asked to choose their preferred mode of travel for a given trip. An example is shown in Figure 1 below, where a respondent is asked to choose between seven alternatives, each of which are characterized by attributes such as travel time and travel cost.

Attributes	Obs. Mode (drive yourself)	Shared Ride Hail	Exclusive Ride Hail	Taxi	Transit	Bike	Walk	Driven by someone you know
Travel Time (mins)	20	28.6	26	26	29.9	10	36	20
Travel Cost ($)	5.40	8.93	18.11	31.8	3.10	-	-	5.40
Wait Time (mins)	-	10	6	8.4	10	-	-	-
Walk Time (mins)	-	-	-	-	1	-	-	-
Other Riders	-	0	-	-	-	-	-	-
Add. Travel Time (mins)	-	4	-	-	5	-	-	-
Parking Cost ($)	9	-	-	-	-	-	-	-
Your Choice								

Figure 1. An example of a stated preference question

The benefit of collecting SP data lies in its ability to provide insights into the responses to new and emerging technologies (Louviere, Hensher, & Swait, 2000). In addition, combining RP and SP data together when developing models allows the strengths of both types of data to be fully exploited while also compensating for their respective weaknesses (Sanko, 2001). For the SPRINT, the importance of the SP questions lies in their ability to capture information about trade-offs between different attributes, such as travel time, travel costs, and reliability. Although there are many benefits of collecting SP data, there is a key shortcoming that must be addressed if the data are to be used to their fullest extent. Specifically, errors can be introduced into the results if the responses differ from the choices that the respondents would actually make if presented with the same circumstances in their daily lives. As a result, the approach is taken to design SP questions has increasingly focused on making choice situations as realistic as possible (Matyas & Kamargianni, 2018).

In order to address this issue, the SP questions were designed using a pivoted approach, wherein the attributes of the SP experiment are based on the characteristics of RP trips. Improving the realism of SP questions can help improve the relevance of and extent to which respondents can understand the choice situation, which in turn can reduce the uncertainty that is captured in the responses (Rose, Bliemer, Hensher, & Collins, 2008). In order to facilitate the design of the SP questions, respondents were asked to report: a typical commuting trip and a recent non-commuting trip. The distinction between these two types of trips was made in order to help identify whether the purpose of the trip affects the trade-offs that are made in the process of choosing a mode of travel. Each respondent was asked to complete six choice experiments – three pertaining to their typical commute and three pertaining to a recent non-commuting trip. Based on the reported origin and destinations for these trips, level-of-service information was obtained using the Google Maps Directional API in order to determine the values of travel time and cost for each of the alternatives presented in each SP question. For each of these experiments, respondents were asked to indicate their confidence in their choice using a five-point Likert scale (ranging from very unconfident to very confident).

Four modes are considered to be available to all respondents regardless of the characteristics of the RP trip: public transit, exclusive ride-hailing, shared ride-hailing, and taxi. The distinction between exclusive and shared ride-hailing was made because of the differences in the characteristics of the two modes and was in part based on prior studies that have shown the potential for ride-hailing users to hold discriminatory attitudes towards their fellow passengers Moody, Middleton, & Zhao (2019). The decision to have public transit available for all respondents was stems from the design of the Toronto Transit Commission's (TTC) base-network, which ensures that "90% of the population and employment is within a 400 metre (5 minutes) walk to transit service seven days a week" (Toronto Transit Commission, 2017). In addition, four other modes were made available to respondents based on various personal, household, and trip characteristics. The criteria for the inclusion of these modes are summarized in Table 1 below.

Table 1. Inclusion criteria for various modes

Mode	Condition
Drive yourself	Respondent owns a driver's license
Driven by someone you know	The household has at least one vehicle available for personal use
Bicycling	The trip is less than 10 km in length
Walking	The trip is less than 3 km in length

Because the attributes are ultimately what characterize the alternatives, the process by which they are selected requires careful consideration. A literature review of stated preference studies pertaining to mode choice was conducted in order to key attributes. As shown in Figure 2, the majority of the reviewed studies include attributes related to out-of-vehicle travel time (OVTT), in-vehicle travel time (IVTT), and travel costs. A closer examination of the out-of-vehicle travel times used in these studies reveals that waiting time is the most common type of out-of-vehicle time used, as shown in Figure 3.

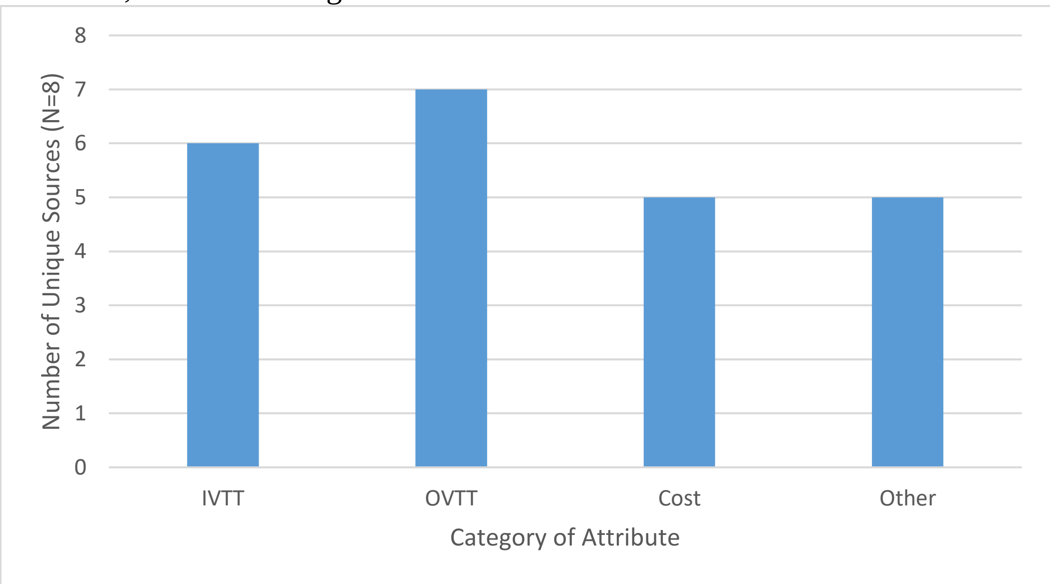

Figure 2. Types of attributes in reviewed SP studies

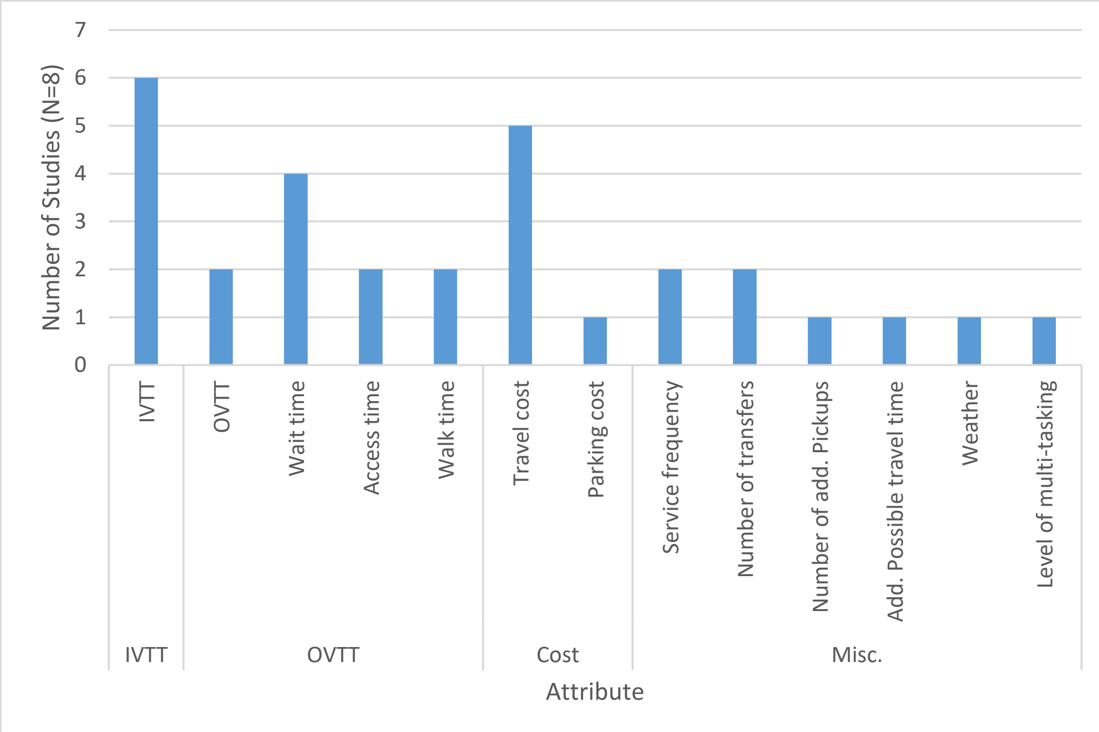

Figure 3. Attributes used in reviewed SP studies

The final set of attributes that were used to design the stated preference experiments are summarized in Table 2. *The number of other passengers in the vehicle* was included as an attribute of the shard ride-hailing alternative to help gain insights into the effects of sharing a ride with strangers on the use of shared services. The *detour time* attribute is meant to capture the additional travel time that results from the need to pick up additional riders when using a shared mode. When applied to the public transit mode, the attribute represents the additional travel time experienced by riders due to delays. The inclusion of the *level of crowding* attribute was based on the tendency for the use of ride-hailing services to be motivated by comfort and convenience (Rayle, Dai, Chan, Cervero, & Shaheen, 2016). Similarly, the *frequency of delays over five minutes* attribute was included based on the perceived unreliability of public transit services to motivate the substitution of ride-hailing for public transit service (Clewlow & Mishra, 2017).

Table 2. SP design attributes, by alternative

	Alternative							
Attribute	**Drive Yourself**	**Driven by Someone You Know**	**Public Transit**	**Exclusive Ride-hailing**	**Shared Ride-hailing**	**Taxi**	**Bicycling**	**Walking**
Travel Time	X	X	X	X	X	X	X	X
Travel Cost	X	X	X	X	X	X		
Waiting Time			X	X	X	X		

Walking Time			X					
Parking Cost	X							
Other Passengers					X			
Detour Time			X		X			
Level of Crowding			X					
Frequency of Delays over 5 ins			X					

In the design of the SP experiment, each attribute could assume one of three values, or “levels”; this number was selected to ensure attribute level balance in the experimental design. Simply put, attribute level balance refers to the case in which each attribute level appears an equal number of times Rose & Bliemer (2009). Taking the pivoted approach to experimental design can create challenges when attempting to define the levels of each attribute, due to the dependence of travel time and costs on the origin and destination of the RP trip. This issue is addressed by applying the approach outlined in Weiss, Salehin, & Habib, (2019), who developed an SP survey to understand the impacts of autonomous vehicles on mode choice in the Greater Toronto Area. The baseline values used to design the SP experiments were calculated based on a set of assumptions regarding trip distances and travel times. The values of the other two levels for each attribute were determined based on the results of a literature review. Appendix B - Assumptions and Calculations for SP Design provides a detailed summary of the process through which these values were determined and calculated.

The design of stated preference experiments involves the selection of the specific combination of attributes that were presented to the respondent. Factorial design, in which each combination of attribute levels is enumerated, represents the most basic approach to designing SP experiments. While simple, the application of factorial design means that the number of choice experiments that must be completed by the respondents rapidly increases as the number of attributes and levels increases. Additionally, the use of efficient design methods to develop SP experiments can produce better t-statistics for parameter estimates and requires both fewer experiments and smaller sample sizes (Frei, Hyland, & Mahmassani, 2017). For the SPRINT, the Bayesian D-efficient design approach was taken to design the SP experiments.

Broadly speaking, the efficient design approach to experiment design aims to both “reduce correlations in the data for estimation purposes” and to minimize the standard errors in the parameters estimated using the data. D-efficient design involves the minimization of the D-error value, which is derived from the determinant of the asymptotic variance-covariance (AVC) matrix. The definition of the AVC matrix is based on the specification and parameters of the choice model that will be estimated using the stated preference data. This inherently creates a chicken-and-egg problem because the design of the experiments is based on the parameters of the model, but the model must be estimated based on data from the experiments. This issue is addressed by using values from other studies for the experimental design process, referred to as

'priors'. Bayesian D-efficient design takes this one step further by assuming that the priors follow a specific distribution, rather than taking on a fixed value. (ChoiceMetrics, 2018)
The design of the stated preference experiments began with the application of the D-efficient design approach, using priors that were based on the parameters of the model described in (Weiss, Salehin, & Habib, 2019). This process was executed in the experiment design software Ngene (ChoiceMetrics, 2018). The values of the priors were modified to ensure that the estimate sample size requirement was comparable to the target sample size of the survey (around 1,000 completed surveys). The values of the travel time and cost priors were also modified to ensure that the value of travel time for exclusive and shared ride-hailing services was close to $30/ hr, which is in line with other studies. An experimental design was produced for each combination of feasible alternatives; consequently, a total of 16 sets of choice experiments were created, resulting in a total of 96 experimental designs (6 total choice experiments per respondent x 16 different combinations of available modes). After the completion of this process, the standard error values produced by Ngene were used to repeat the experimental design process using the Bayesian D-efficient approach. The parameters for travel time and travel cost were assumed to follow the normal distribution, whose mean value is that of the corresponding prior and whose standard error is the value produced by Ngene. This process again resulted in a total of 96 different experimental designs.

The experimental designs were formatted into the JSON file format and implemented into TRAISI. Respondents were presented with six choice experiments each of which was based on the modes that were feasible for their reported trip. An example of a stated preference question that was presented to survey respondents is shown in Figure 4 below.

Question 41: Please choose the alternative that you would prefer to use **for your typical commuting trip**.

	Drive yourself	Driven by someone you know	Public Transit	Exclusive Ride Hailing	Shared Ride Hailing	Taxi	Bicycling	Walking
Travel Time (mins) ?	6	6	29	6	7	6	6	14
Travel Cost ($) ?	$0.22	$0.11	$ 3.10	$1.94	$1.30	$7.39	-	-
Waiting Time (mins) ?	-	-	7.5	2	5	2	-	-
Walking Time (mins) ?	-	-	5	-	-	-	-	-
Parking Cost ($) ?	$ 15	-	-	-	-	-	-	-
Other Passengers ?	-	-	-	-	1	-	-	-
Delay Time (mins) ?	-	-	1	-	4	-	-	-
Level of Crowding ?	-	-	Moderately crowded (50% chance of getting a seat)	-	-	-	-	-
Frequency of Delays over 5 mins ?	-	-	Once a month	-	-	-	-	-
Your Choice:	○	●	○	○	○	○	○	○

Figure 4. Example of a Stated Preference Question in TRAISI

2.3.3. Attitudinal Questions

Attitudinal questions were included in the SPRINT to help gain insights into the role that perceptions and attitudes play in the degree to which people use ride-hailing services. In addition, this information can also help shed light on the trade-offs that respondents make when choosing a mode of travel. While travel behaviour and the mode choice process are often thought of as a function of socio-economic, household, and trip attributes, attitudinal information can equally valuable in some cases (Daly, Hess, Patruni, Potoglou, & Rohr, 2012). Based on a review of the literature, three types of attitudinal questions were included in the survey: familiarity questions, agree/disagree questions, and importance questions.

The first set of questions is meant to identify the degree to which the respondents are familiar with both shared and exclusive ride-hailing services. In addition, respondents are also asked to report the factors that influenced them to utilize a ride-hailing for the first time. The responses to these questions can be used to understand how familiarity with ride-hailing services varies based on demographics. The response options for these questions were based on those presented in (Spurlock, et al., 2019). The agree-disagree questions use a five-point Likert scale to identify the factors that may influence a respondent to choose ride-hailing over public transit services or vice-versa. These questions focused on four factors: being late for an appointment or meeting, reliability, precipitation, and safety. The 'importance' questions ask respondents to indicate the relative priority that they place on different aspects of travel when using ride-hailing and public transit services. A total of seven factors pertaining to public transit were presented to respondents in addition to 10 factors pertaining to ride-hailing services. The factors selected for the 'importance' questions were based on the factors used in Alemi, Circella, & Sperling (2017). The full list of household and socio-economic questions can be found in the *Attitudinal Questions* section of Appendix A – Survey Questionnaire.

2.3.4. Questions on the Use of Ride-hailing Services

In order to identify different types of ride-hailing users, the SPRINT asked ride-hailing users to report the frequency and purposes for which they use these services. The collection of this information can help provide insights into the role that attitudes, perceptions, and socio-economics play in the use of ride-hailing services. Aside from these questions, respondents who reported that they have used ride-hailing services at least once were asked to provide details about the most recent trip that they made using said services. Respondents were asked to report the following information, which can be used to develop mode choice models:

- The origin and destination of the trip,
- The departure time of the trip,
- The purpose of the trip,
- Whether the trip was made using shared or exclusive ride-hailing services,
- The number of persons travelling with the respondent, and
- The cost of the trip

In addition to these attributes, respondents were also asked several questions regarding their choice to use a ride-hailing service to make this trip. Following the example of Alemi, Circella,

& Sperling (2017), respondents were asked to indicate the mode that they would have used to make the trip had ride-hailing services not been available. The response options for this question included modes such as driving oneself, using public transit and taking a taxi. 'I would not have made this trip at all' was also included as a response option, as studies such as (Rayle, Dai, Chan, Cervero, & Shaheen (2016) have found that the availability of ride-hailing services has the potential to induce travel demand. The information obtained from this question will be used to identify the modes for which ride-hailing services are a substitute. Respondents were also asked to indicate the reason(s) that they decided to use ride-hailing services for the trip. The full list of household and socio-economic questions can be found in the *Information on Ride-Hailing Users* and *Information on the Most Recent Ride-Hailing Trip* sections of Appendix A – Survey Questionnaire.

The following sub-section explains the approach of data collection (survey implementation).

2.4. Survey Conduct

The SPRINT was conducted using a web-based questionnaire that was coded into the Travel Internet Survey Interface (TRAISI). The goal of the survey was to understand the effects that the introduction of ride-hailing services had on the travel behaviour of the residents of the City of Toronto and to understand the characteristics of the users of ride-hailing services. The survey was administered to the members of the Canadian Viewpoint ('CanView') consumer panel. Panel members were deemed to be eligible for the survey if their home address was within the City of Toronto. In total, 723 completed responses were obtained from a total of 913 participants.

3. SURVEY RESULTS

This section presents a summary and discussion of the results of the SPRINT. The survey results are grouped into five categories: descriptive statistics; usage of ride-hailing services; familiarity, importance, and perceptions; descriptive analysis of SP data; and model results. Based on a comparison of the socio-demographic characteristics of the sample to that from 2016, the older population are slightly underrepresented; medium and upper-medium earning households are slightly overrepresented, and the residents of North York and Toronto-East York districts are slightly overrepresented.

The findings of the survey appear to contradict some of the existing literature that suggests that ride-hailing services are not typically used for commuting trips. In terms of substitution, many respondents reported that their most recent ride-hailing trip would have been made using public transit or a taxi had ride-hailing services not been available. When asked why they used ride-hailing services for this trip, many respondents stated that their decision was influenced by faster travel times, costs, and the ease with they could pay for the trip. The results of this survey imply that there is a segment of the population that uses ride-hailing services as a substitute for public transit, in part due to the differences between the travel time, reliability, comfort, and convenience of the two modes. The findings of the survey also indicate that the factors that influence the use of ride-hailing services vary based on the purpose of the trip and the type of ride-hailing service that is being considered.

3.1. Descriptive Statistics

In order to help determine the extent to which the sample was representative of the City of Toronto, the first step of the data analysis process was to compare the distribution of various socio-economic characteristics of the sample to that of the City, using data from the 2016 Canadian Census. The distributions of the four characteristics were compared: age, gender, household size, and income.

As shown in Figure 1, the percentage of persons aged 20 to 69 is greater than that of the City of Toronto, the percentage of persons younger than 20 or older than 70 years of age is less than that of the City. The underrepresentation of these age groups is understandable, given the use of a market research panel as the sample frame and web-based tool to conduct the survey. In terms of gender, women are overrepresented in the sample while men are underrepresented. It should be noted that the 2016 Canadian Census apparently only had two response option for its gender question – male or female. The breakdown of respondents by gender is shown in Figure 6. Households with three or more persons appear to be overrepresented in the SPRINT, while single-person households are underrepresented. Interestingly, the proportion of respondents from two-person households appears to closely match that of the Census (see Figure 7). Finally, it appears that households that earn between $50,000 and $150,000 annually are overrepresented in the SPRINT, while households whose annual income is below $40,000 or greater than $150,000 are underrepresented (see Figure 8). Overall, it appears that the sample cannot be said to be completely representative of the population of the City of Toronto.

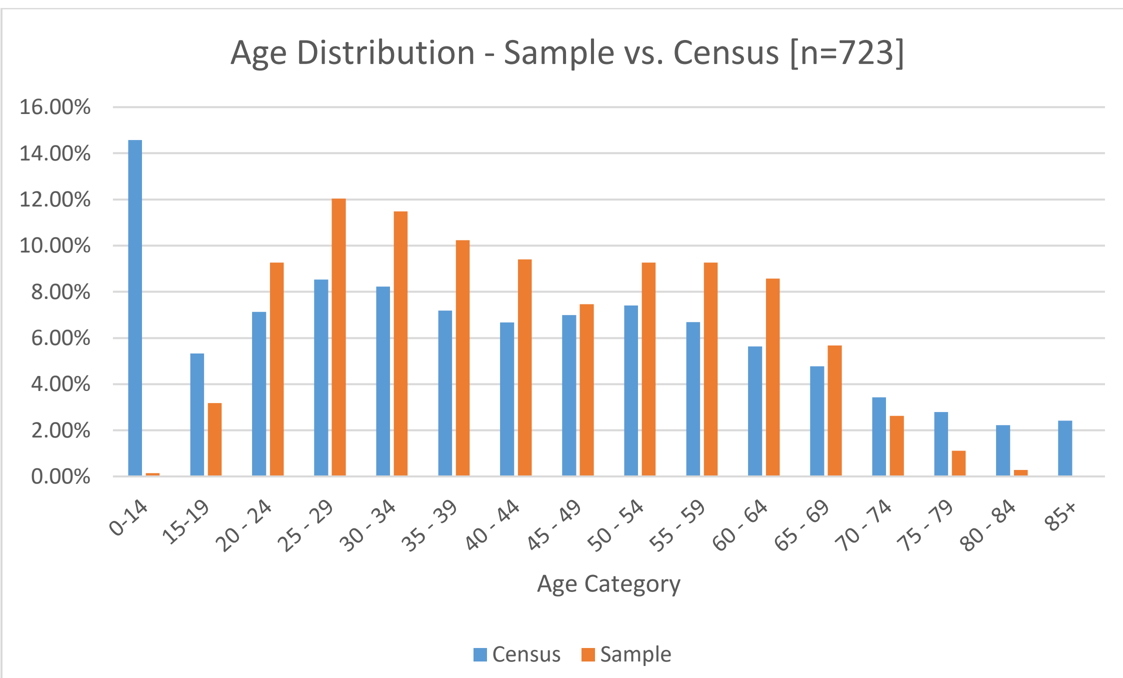

Figure 5. Distribution of the ages of respondents and the residents of Toronto

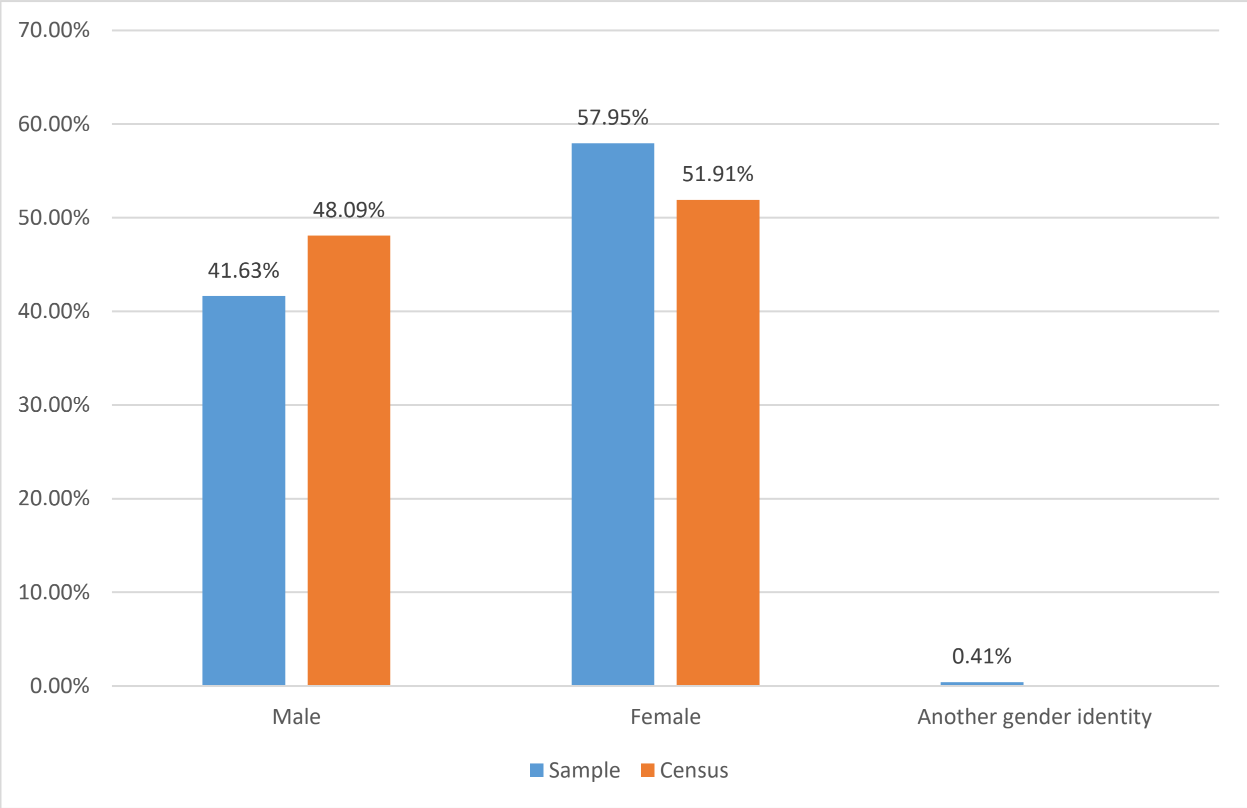

Figure 6. Distribution of respondents and Toronto residents by gender

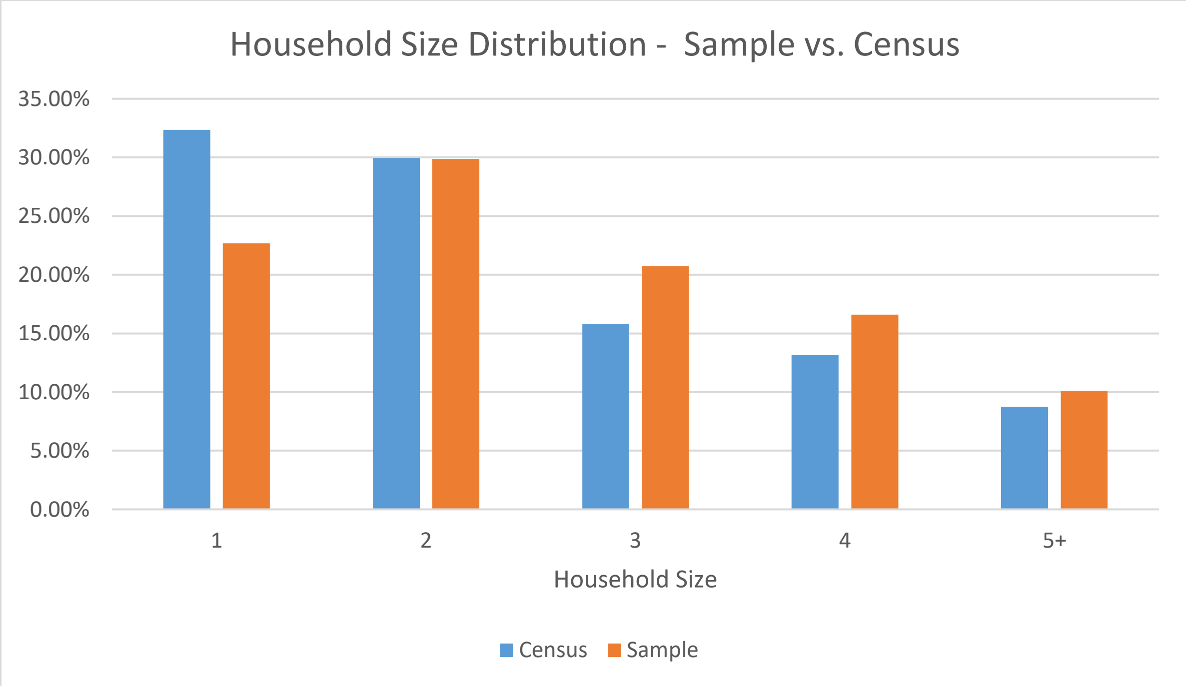

Figure 7. Distribution of household sizes for respondents and Toronto residents

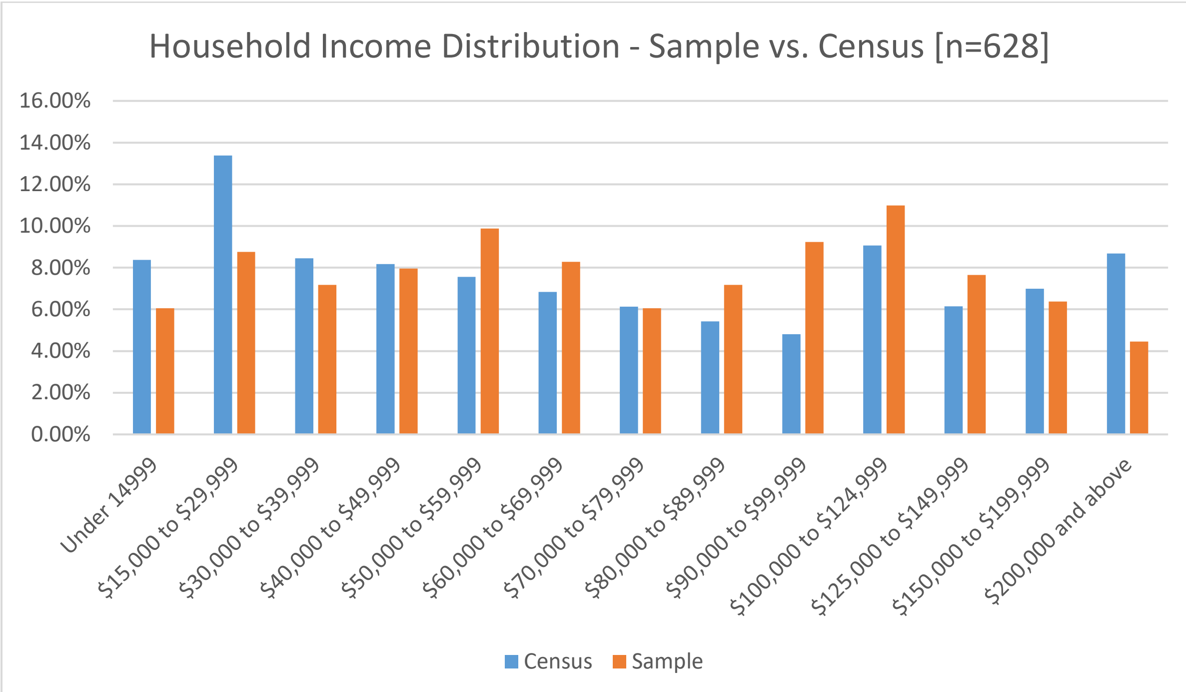

Figure 8. Distribution of household income for respondents and Toronto residents

The next stage of the data analysis process was to understand the characteristics of the individual respondents and their households. In terms of dwelling type, it appears that the majority of respondents live in single-detached houses, condominiums, or apartments (see Figure 9). As Figure 10 shows, around half of the respondents are employed full-time, while another 20% reported that they were employed on a part-time basis. In addition, around 80% of respondents reported having a driver's license, 33% reported owning a monthly or annual transit pass, while approximately 25% of respondents owned both (as seen in Figure 11). About household characteristics, summary statistics regarding vehicle ownership and employment and student status are shown in Table 3.

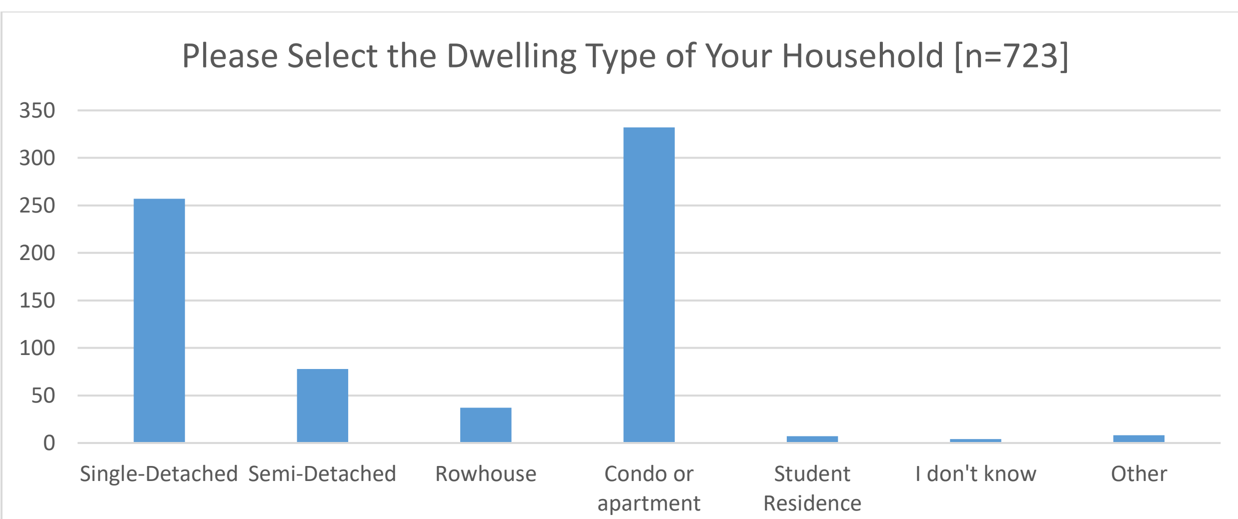

Figure 9. Number of respondents, by dwelling type

Table 3. Summary statistics of household characteristics

Statistic	Household Characteristic				
	Household Size	**No. of Vehicles**	**No. of Full-Time Workers**	**No. of Part-Time Workers**	**No. of Students**
Average	2.69	1.09	1.33	0.44	0.63
Standard Deviation	1.46	0.86	0.99	0.72	1.03
Minimum	1	0	0	0	0
1st Quartile	2	1	1	0	0
Median	2	1	1	0	0
3rd Quartile	4	2	2	1	1
Maximum	10	8	5	6	6

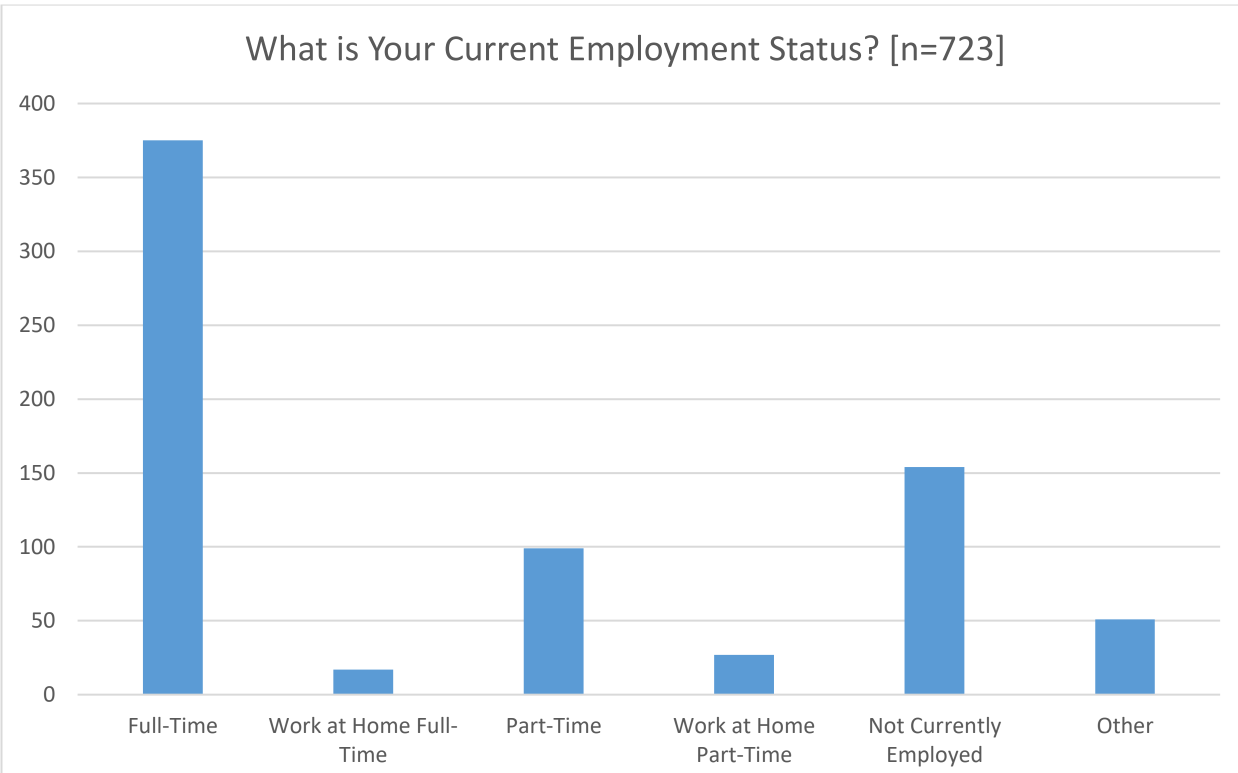

Figure 10. Distribution of the employment status of respondents

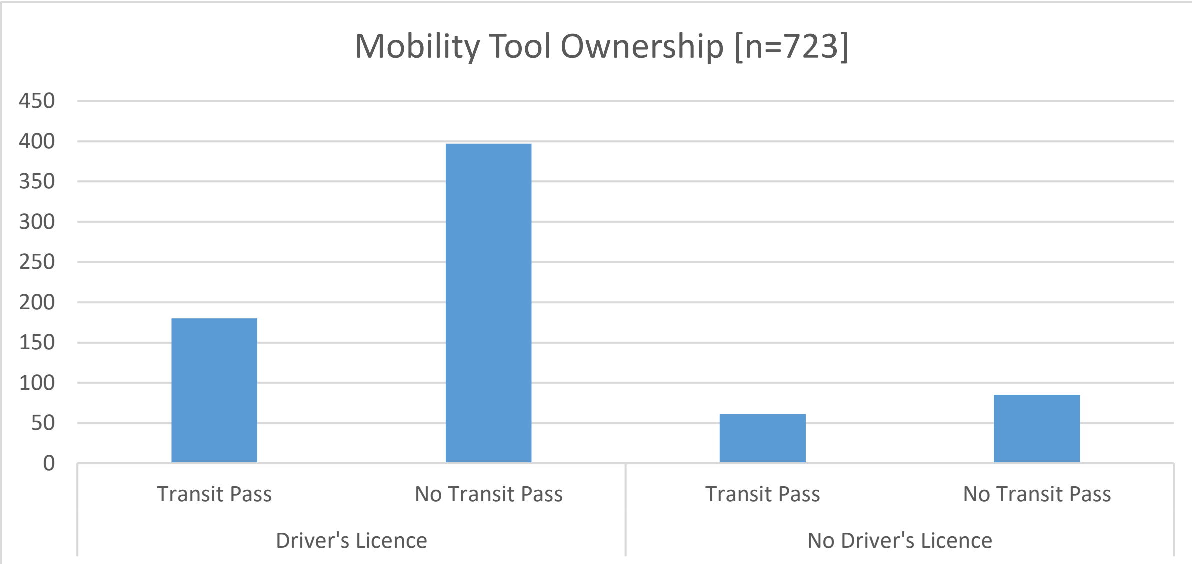

Figure 11. Summary of mobility tool ownership

In terms of the home locations, around 60% of the responses of the SPRINT were obtained from respondents who lived in Toronto-East York or North York district. This result is reasonable, given that approximately 55% of Torontonians lived in these two districts, as per the 2016 Canadian Census (City of Toronto, 2019). The number of responses received from the residents of each of Toronto's four districts is summarized in Table 4. In terms of representation, Figure 12 shows that Scarborough appears to be adequately represented, however, the residents of Etobicoke-York district are underrepresented, while the residents of North York and Toronto-East York district are somewhat overrepresented.

Table 4. Number of responses, by location

Home Location	Number of Responses
Etobicoke-York	106
North York	187
Toronto and East York	250
Scarborough	167
Outside Toronto	13

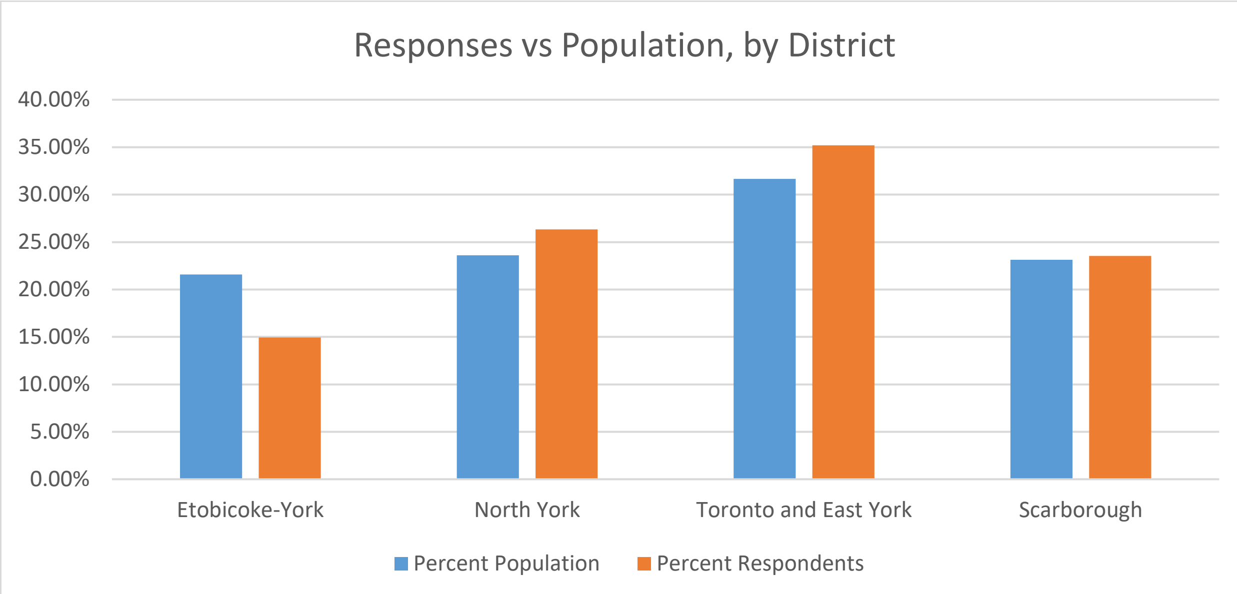

Figure 12. Distribution of population and responses, by district

3.2. Usage of Ride-hailing Services

In order to identify respondents who have used ride-hailing services at least once in their lifetime, two questions were included in the SPRINT:

1. Have you ever installed a ride-hailing application on your smartphone?
2. Have you ever used a ride-hailing service?

As shown in Table 5, around 65% of respondents reported that they have used ride-hailing services at least once, with half currently having a ride-hailing application installed on their smartphone. Interestingly, 55 respondents stated that they deleted a ride-hailing application was installed on their smartphone.

Table 5. Summary of experience of respondents using ride-hailing services

Installed a Ride-hailing App	Used a Ride-hailing Service			
	Yes, using my own account	Yes, using someone else's account	Never	Total
Yes	323	33	21	377
Yes, but I have since deleted it	26	21	8	55
Never	1	64	179	244
N/A	0	9	38	47
Total	350	127	246	723

Concerning the frequency with which the respondents use ride-hailing services, about one-quarter reported using these services more than once per week. Approximately the same percentage of respondents reported using ride-hailing services less than once per month, while around one-third of respondents use these services between one and three times per month. Overall, more than half of the respondents reported using a ride-hailing service at least once per month. See Figure 13 for further details.

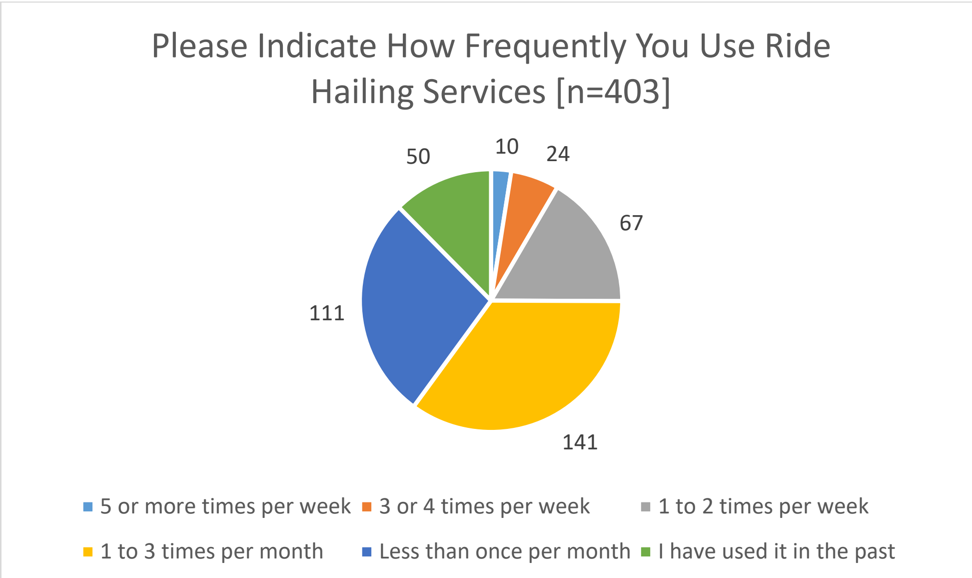

Figure 13. The frequency with which respondents reported using ride-hailing services

Respondents were also asked to indicate the types of trips for which they have used ride-hailing services in the past; the results are summarized in Figure 14. Respondents most frequently reported using ride-hailing services to travel to or from a restaurant, bar, coffee shop, a friend or relative's home, or the airport at least once. Using a ride-hailing service to reach public transit was relatively rare while using a ride-hailing service to commute to work was something that around 28% of respondents reported doing at least once. When asked to report the frequency with which they used ride-hailing services for commuting trips, about 40% reported doing so at least once per month (as shown in Figure 15). Around, the same proportion reported that they have used ride-hailing services for this purpose in the past. Overall, this result seems to indicate that ride-hailing services are regarded as a viable option for commuting, although the circumstances in which a person chooses to use these services for their commute are outside of the scope of this project. This result contradicts the findings of Shared-Use Mobility Centre (2016), who argued that ride-hailing services are seldom used for commuting. This may be because the study area was the U.S. or may possibly be indicative of an increased propensity to use ride-hailing services for commuting people become more familiar with said services.

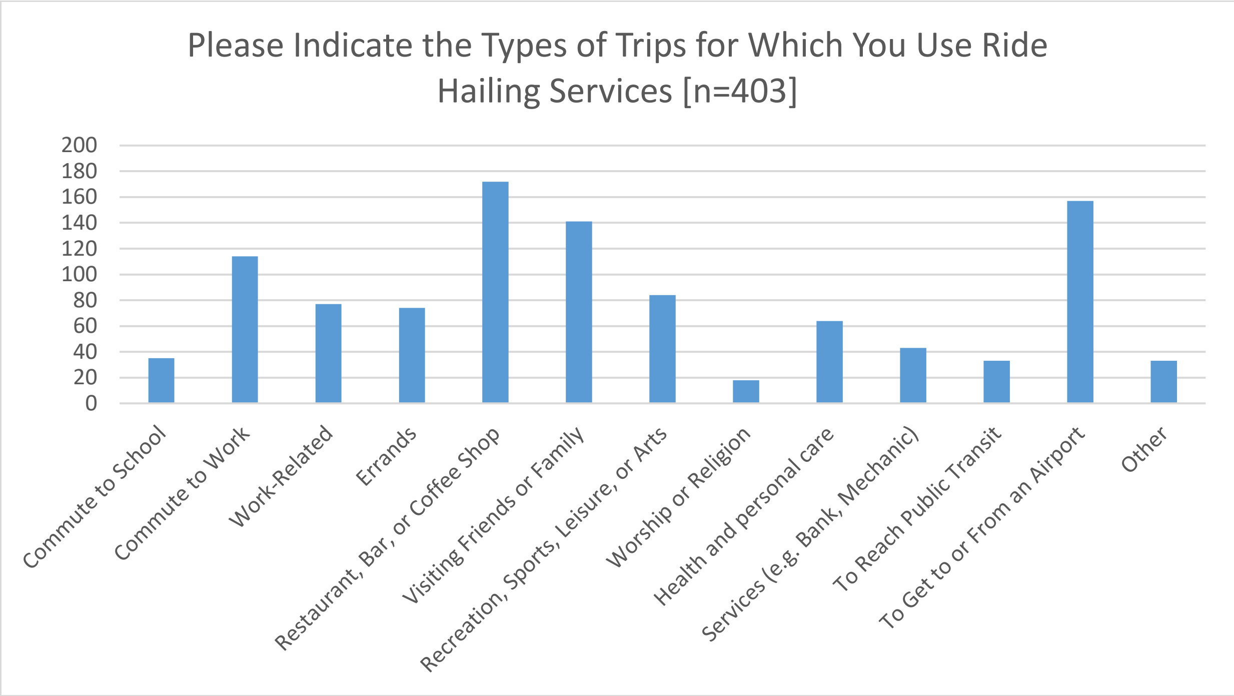

Figure 14. Trips for which respondents used ride-hailing services

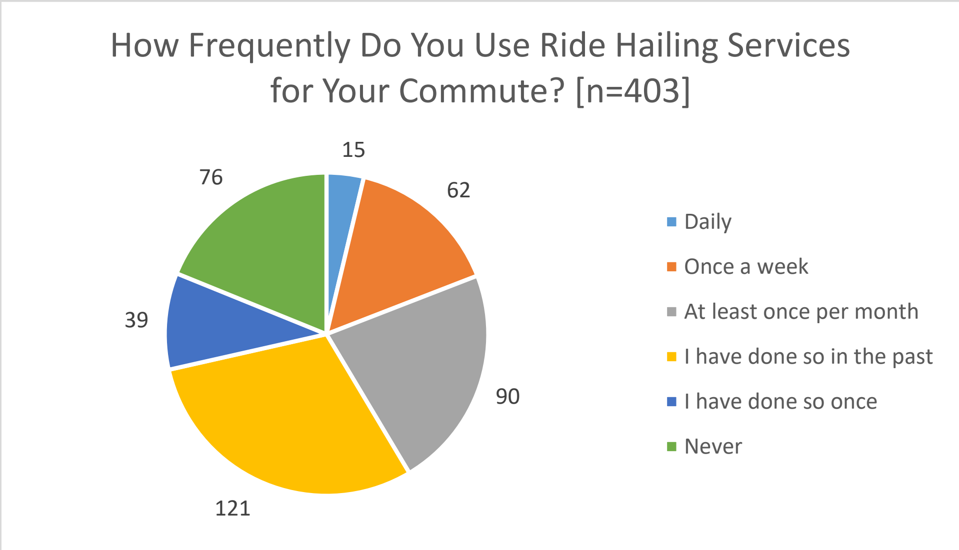

Figure 15. The frequency with which respondents use ride-hailing services to commute

Respondents who indicated that they had made at least one trip using a ride-hailing service and had installed a ride-hailing application on their smartphone were asked to provide details about their most recent trip using said service. Specifically, respondents were asked to report:

- The purpose of their trip,
- The time that the trip began,
- Whether the trip was made using exclusive or shared ride-hailing,
- The cost of the trip,

- The mode they would have used for the trip if ride-hailing services were not available,
- Whether a private automobile was available for the trip, and
- The reason(s) why they chose ride-hailing services for this trip

As Figure 16 shows, the most common trip purposes were commuting to work, going to a restaurant, bar, or coffee shop, and visiting friends or family. Many respondents also reported that their most recent ride-hailing trip was made to get to or from the airport, or to return home.

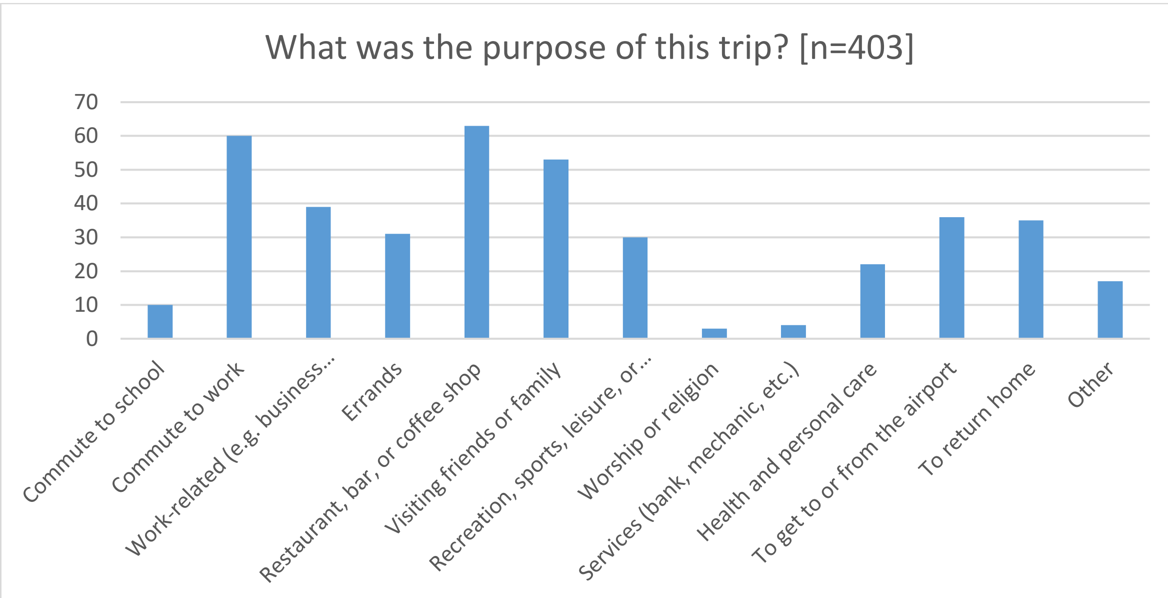

Figure 16. The purpose of the respondent's most recent ride-hailing trip

The departure times reported by the respondents were mapped to the nearest half-hour and to one of the six time periods[1] outlined by the *Service Summary* document published by the TTC for each board period. The number of trips that fall into each category is shown in Figure 17. Around two-thirds of respondents reported making their trip in the morning, afternoon, or midday periods (see Figure 18). About one-quarter of the reported trips took place during the evening period. The relatively low proportion of trips that take place in the overnight period (where transit service is at its most infrequent) may be a result of respondents being asked to report their *most recent trip*. This result may also be attributed to the fact that 70% of respondents are employed, with 50% being employed on a full-time basis.

[1] The time periods are morning peak, midday, afternoon peak, early evening, late evening, and overnight

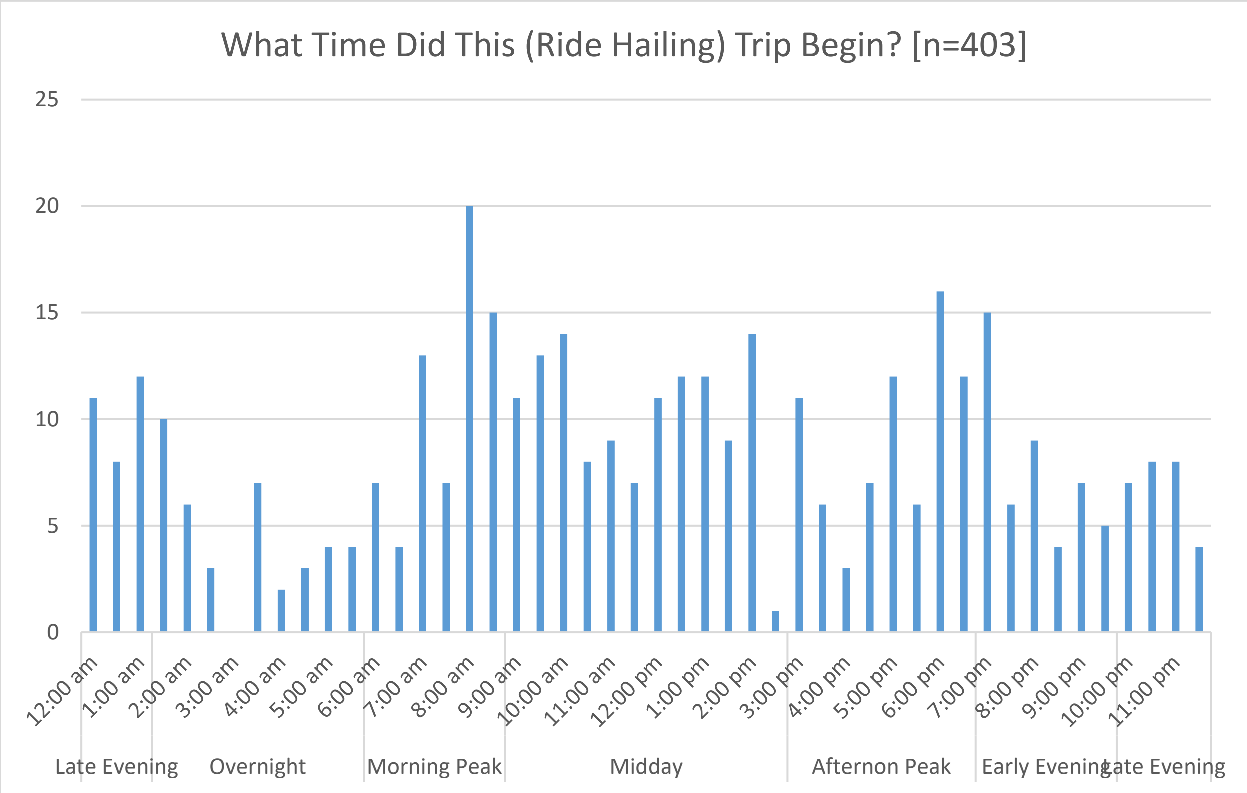

Figure 17. Distribution of departure times, by half-hour and time period

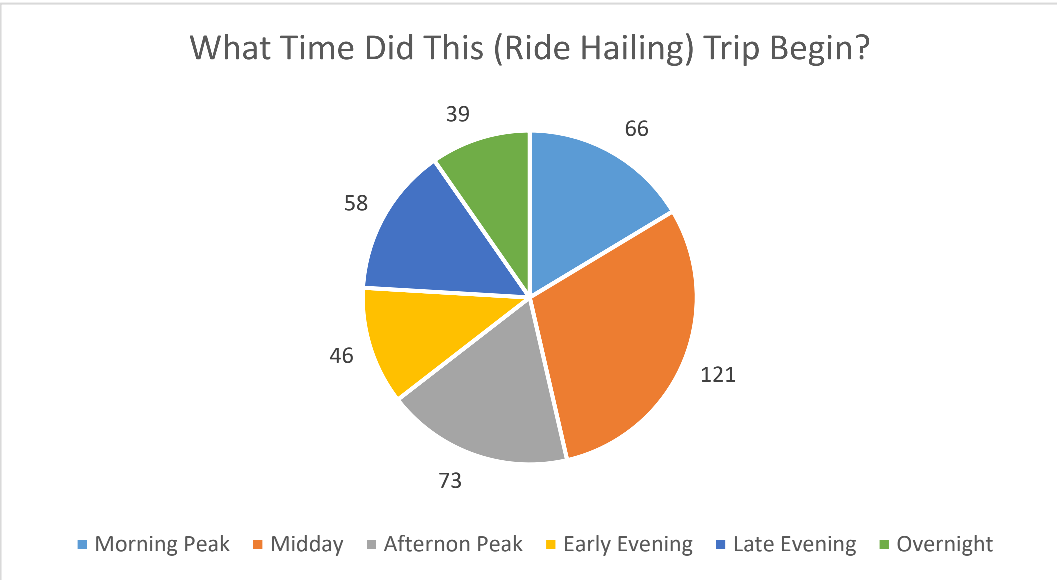

Figure 18. Distribution of reported ride-hailing trips, by period

The respondents appear to prefer exclusive ride-hailing services, as around 76% reported that their most recent ride-hailing trip was made using an exclusive service (See Figure 19).

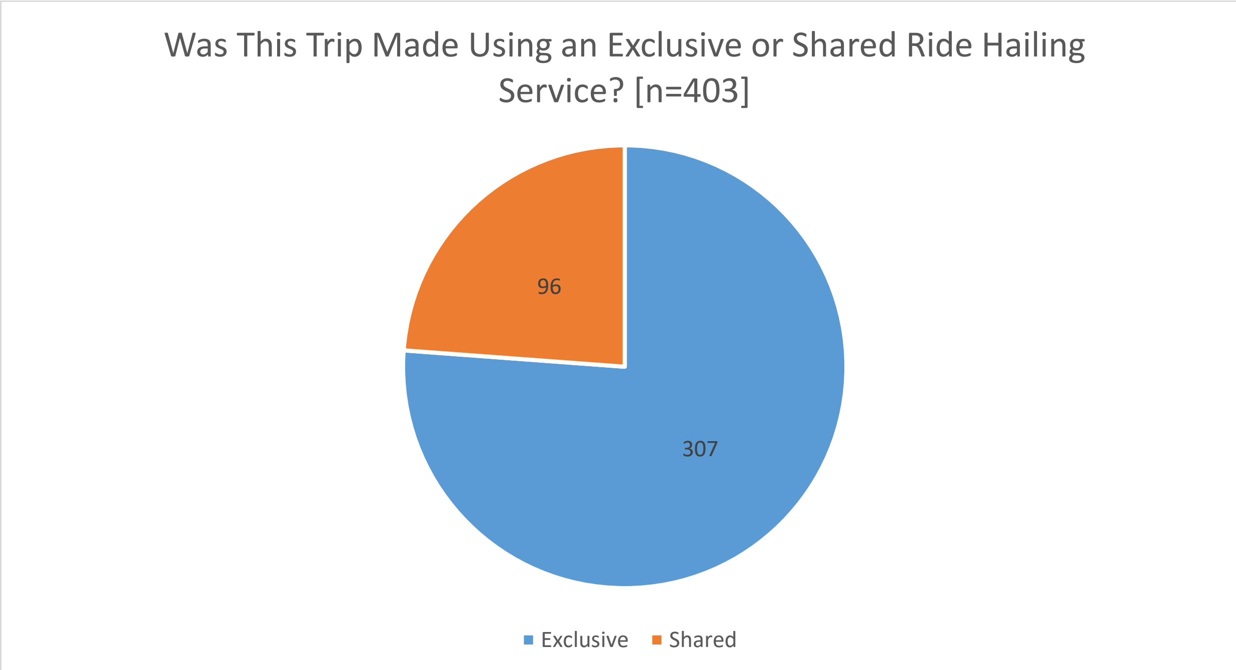

Figure 19. Utilization of exclusive vs. shared ride-hailing services (most recent trip)

As was done for the departure times, the reported cost of the reported ride-hailing trip was based on the cost of the trip in dollars. Around, three-quarters of the reported trips cost less than $30, while approximately 90% of trips cost less than $40, as shown in Figure 30.

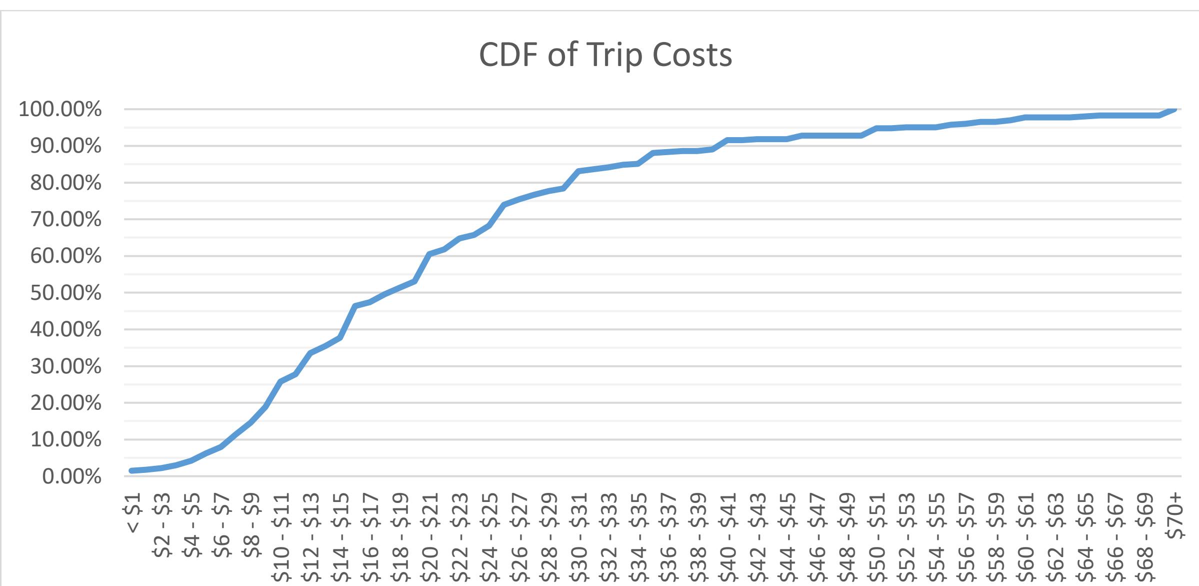

Figure 20. The cumulative distribution of the cost of the most recent ride-hailing trip

In order to help understand the effect that the introduction of ride-hailing services has had on the usage of other modes of travel, respondents were asked to indicate how they would have made their most recent ride-hailing trip had this service not been available. Broadly speaking, the results are in line with the findings of other studies. As Figure 21 shows, around half of the respondents would have made their trip using public transit had ride-hailing services not been available. About one-third of respondents indicated that they would have used a taxi to make their trip. Similar to findings of Rodier (2018), a small percentage of respondents reported that they would not have made their most recent ride-hailing trip if the service had not been available. This result is also seen when examining the responses pertaining to commuting trips (i.e. to work or school). Ride-hailing services were most frequently reported as a substitute for public transit and taxi trips by the respondents. Taken together, these results depict a trend of ride-hailing services potentially inducing additional demand for travel by private automobile. These results seem to indicate that there is at least a segment of the population that has reduced its use of public transit after the introduction of ride-hailing services. The exact extent of this reduction is outside of the scope of the survey and may warrant further investigation.

Interestingly, three respondents indicated that they would not have made their commute to work had ride-hailing services not been available. This may be indicative of the ability of ride-hailing services to improve the mobility of the residents of the areas in which they operate. The relatively small number of respondents who indicated that they would have driven themselves seems odd, given that half of the respondents indicated that a private vehicle was available for this trip.

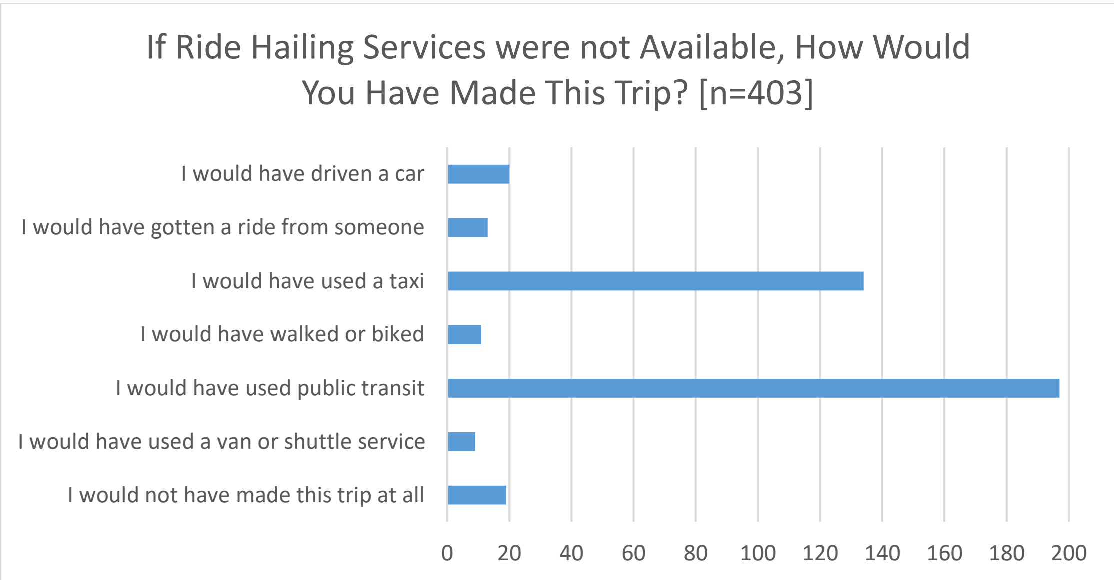

Figure 21. The “second choice” mode for the most recent ride-hailing trip

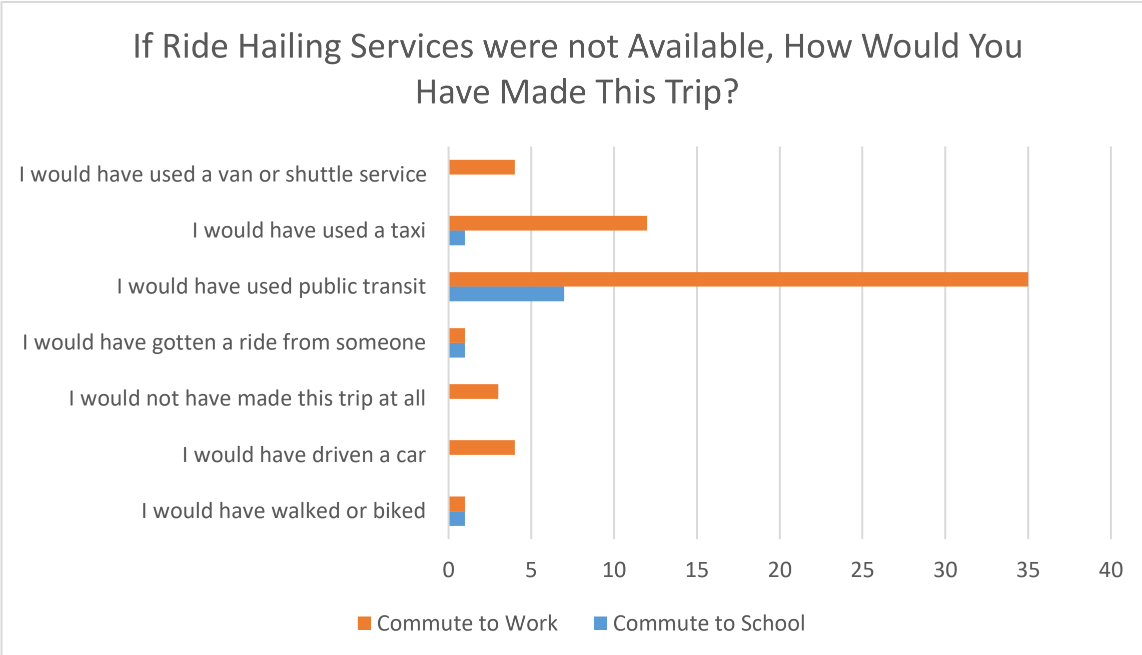

Figure 22. The "second choice" mode for the most recent commuting trip (ride-hailing)

When asked to indicate the reason(s) why they chose to use a ride-hailing service for their reported trip, many respondents stated that the faster travel time, ease of payment, and cost were contributing factors. In addition, many respondents also indicated that the comfort and ease with which a ride could be obtained influenced their decision. These results are similar to those of Alemi, Circella, & Sperling (2017), who found that the usage of ride-hailing services is driven by the attractiveness of the attributes of said services. The responses to this question are summarized in Figure 23.

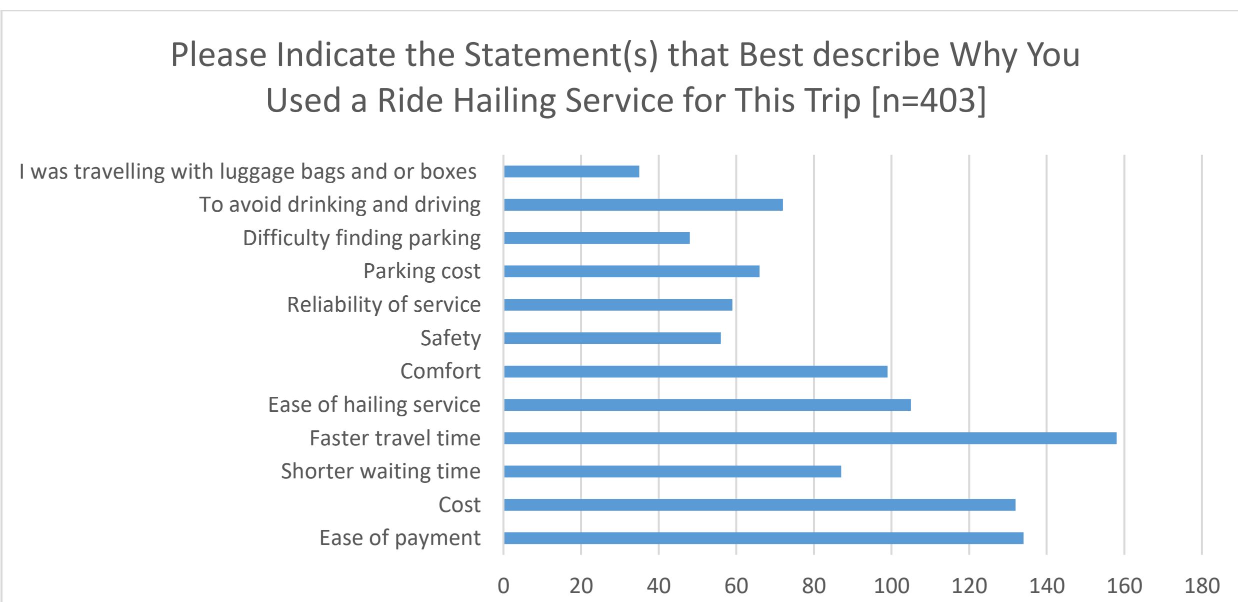

Figure 23. The reason(s) that ride-hailing was chosen for the trip

3.3. Familiarity, Importance, and Perceptions

In order to develop an understanding of how respondents regard ride-hailing and public transit services, several perceptual and attitudinal questions were included in the SPRINT. These questions asked respondents to indicate their familiarity with ride-hailing services, their perceptions of these services in comparison to public transit, and the importance that they place on different aspects of travel when they are considering using public transit and ride-hailing services.

First, respondents were asked to indicate familiarity with exclusive and shared ride-hailing services. As Figure 24 shows, respondents appear to have more experience using exclusive ride-hailing services than shared ride-hailing services. Interestingly, around 20% of respondents have not used ride-hailing services, but know of friends, co-workers, or family members that have. It may be worthwhile to conduct a survey that includes a similar question to determine whether knowing some who have used ride-hailing (or any other new mobility service) can be regarded as a leading indicator of the usage of said service. The results shown in Figure 25 appear to indicate that knowing a person who has used ride-hailing services has a non-trivial influence on the use of said services by the respondents. Over half of the respondents of the SPRINT indicated that their decision to use a ride-hailing service for the first time was influenced by the knowledge that a friend, family member, or co-worker had previously used the service.

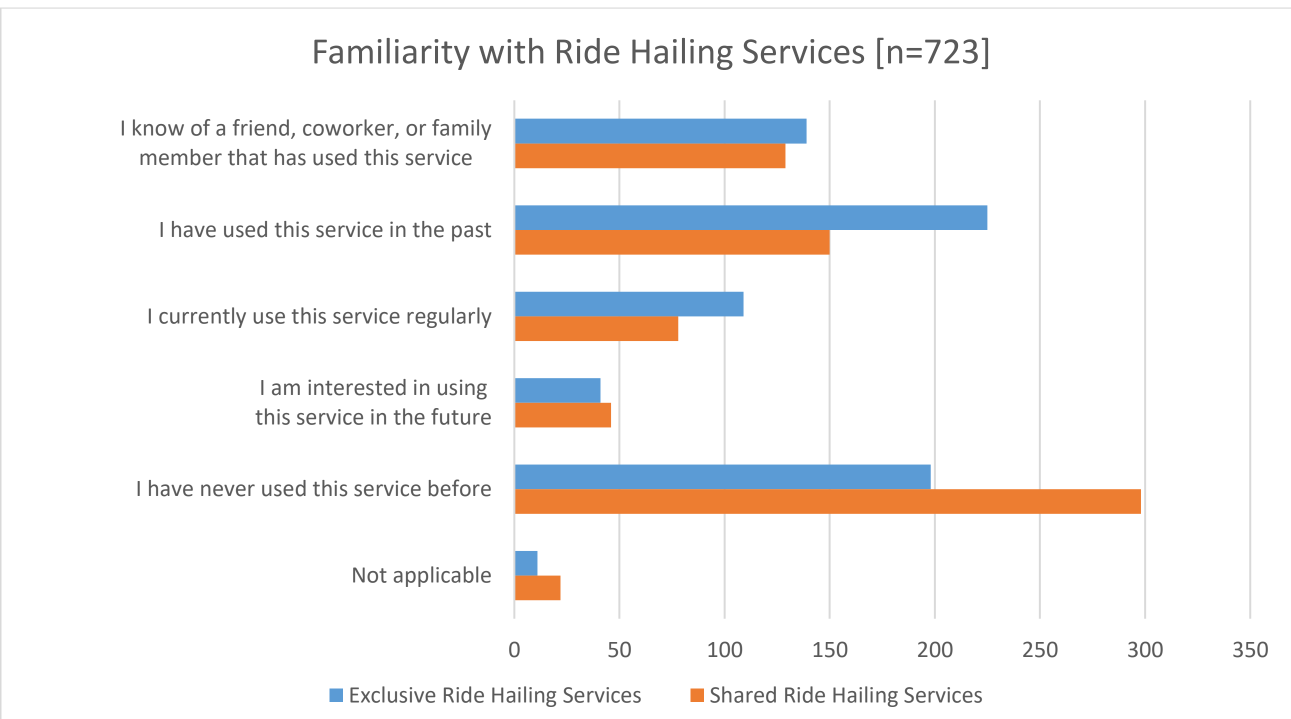

Figure 24. Familiarity with exclusive and shared ride-hailing services

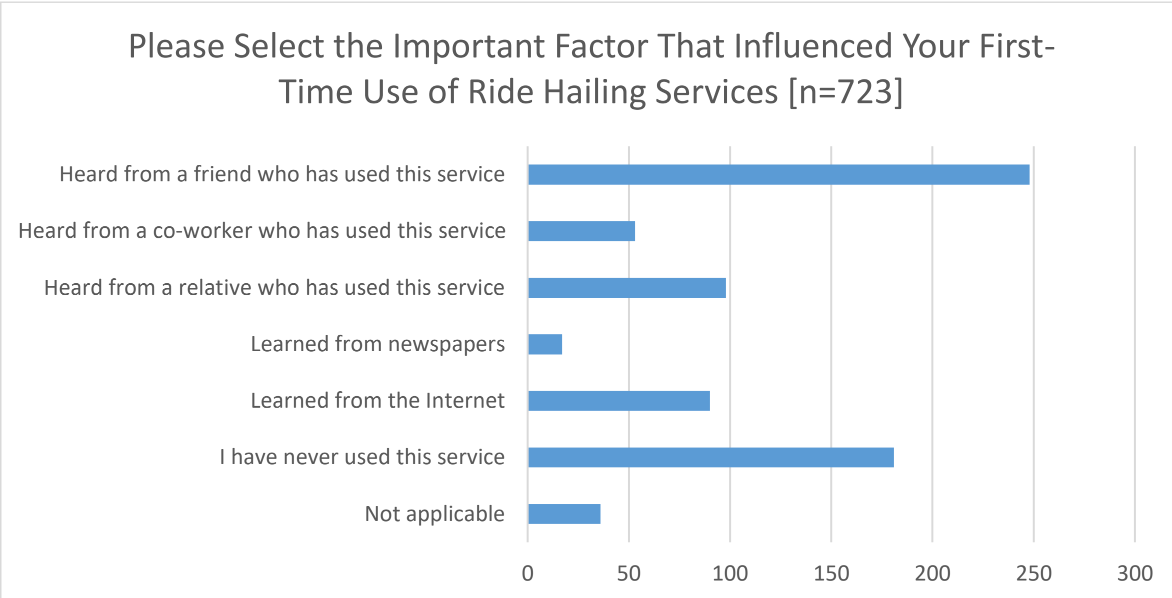

Figure 25. The factor that had the greatest impact on the first-time use of ride-hailing services

After indicating their familiarity with ride-hailing services, respondents were asked to report the importance that they place on various aspects of travel. In total, respondents were asked about the importance of seven factors related to public transit and ten factors related to ride-hailing. Responses were collected using a five-point Likert scale, ranging from unimportant to important. The results are summarized in Figures 26 and 27.

For both public transit and ride-hailing services, more than half of the respondent indicated that safety, reliability, and travel time were at least somewhat important. Around, 80% of respondents indicated that reliability and travel time were at least somewhat important factors when they are considering using public transit, while only about two-thirds of respondents felt the same way about these factors when considering using a ride-hailing service. Interestingly, difficulties finding parking, the cost of parking, and the weather was identified as at least a somewhat important factor by over half of the respondents when they are considering using public transit, however the same is not true when ride-hailing is being considered. Travel time and reliability were more commonly listed as an important factor for the use of public transit than for the use of ride-hailing services. Cost, convenience, safety, and comfort appear to be important factors when considering using a ride-hailing service to make a trip, as around 70% of respondents listed these factors as at least somewhat important (including about 50% indicating that it was an important factor). Overall, it appears that the respondents are sensitive to travel time and reliability when they are considering using public transit to make a trip, while convenience, comfort, and safety play a relatively more important role in the consideration of ride-hailing services.

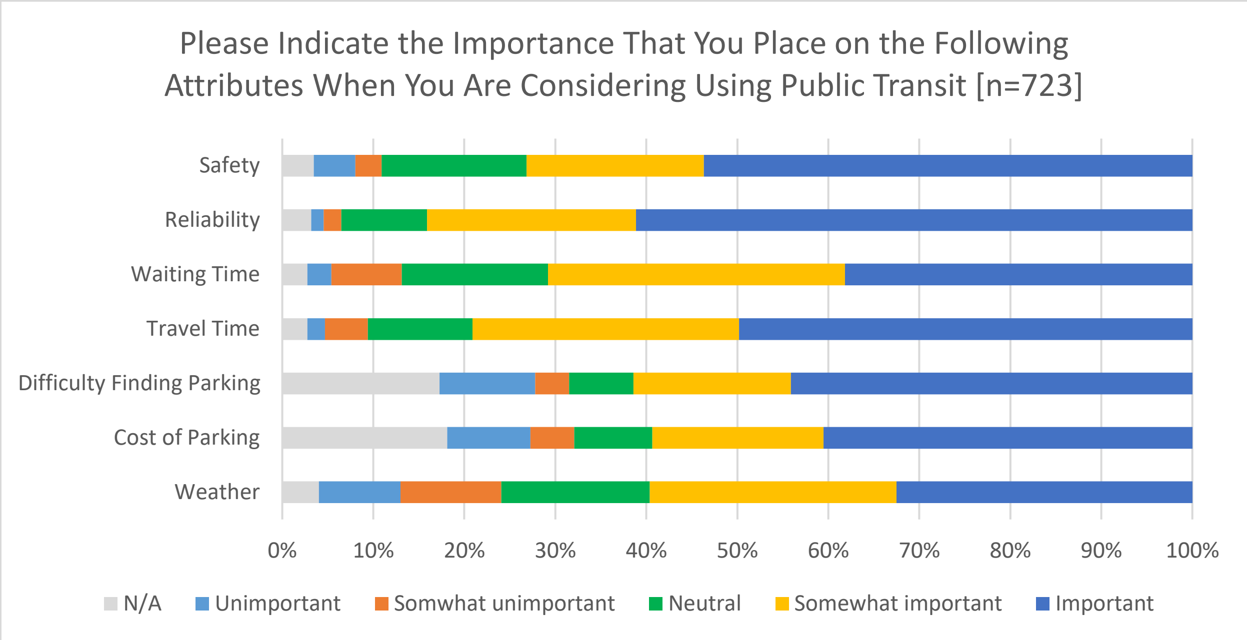

Figure 26. The importance placed on various factors when considering using public transit

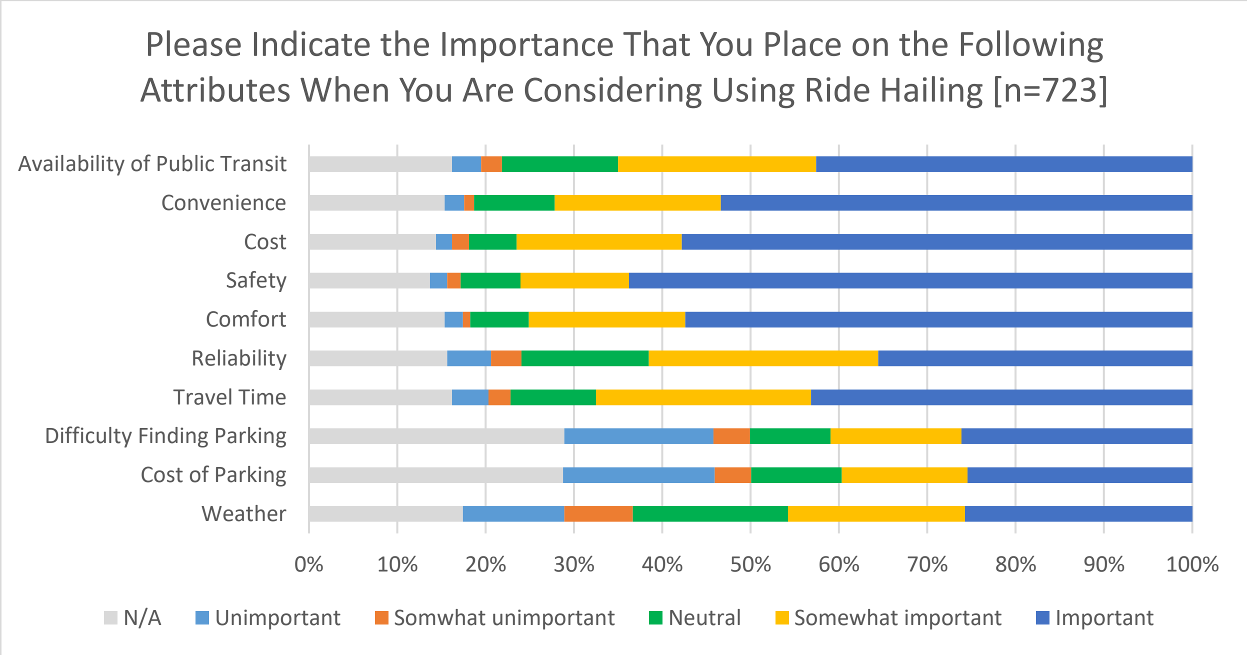

Figure 27. The importance placed on various factors when considering using public transit

Finally, respondents were asked to identify the extent to which they agreed or disagreed with four statements that compared ride-hailing and public transit services. Responses were obtained using a five-point Likert scale, with the options ranging from strongly disagree to strongly agree. The results are shown in Figure 28. The only questions for which more than half of the respondents either agree or strongly agreed pertained to the impact of urgency and tardiness on the use of ride-hailing services. The responses to this particular statement also obtained the smallest number of 'neutral' responses. This result may be indicative of the perception that ride-hailing services are faster and/ or more reliable than public transit service. The latter is echoed by the responses to the question pertaining to the reliability of the two services, where close to half of the respondents either agreed or strongly agreed that ride-hailing services are generally more reliable. One interesting result was that more respondents strongly disagreed with the statement "between 10 PM and 6 AM, I feel safer when using ride-hailing services than I do when using public transit" than strongly agreed with it. This may stem from apprehensiveness towards riding alone in a vehicle with a stranger during a time of the day where there are fewer people around to help in case something happens.

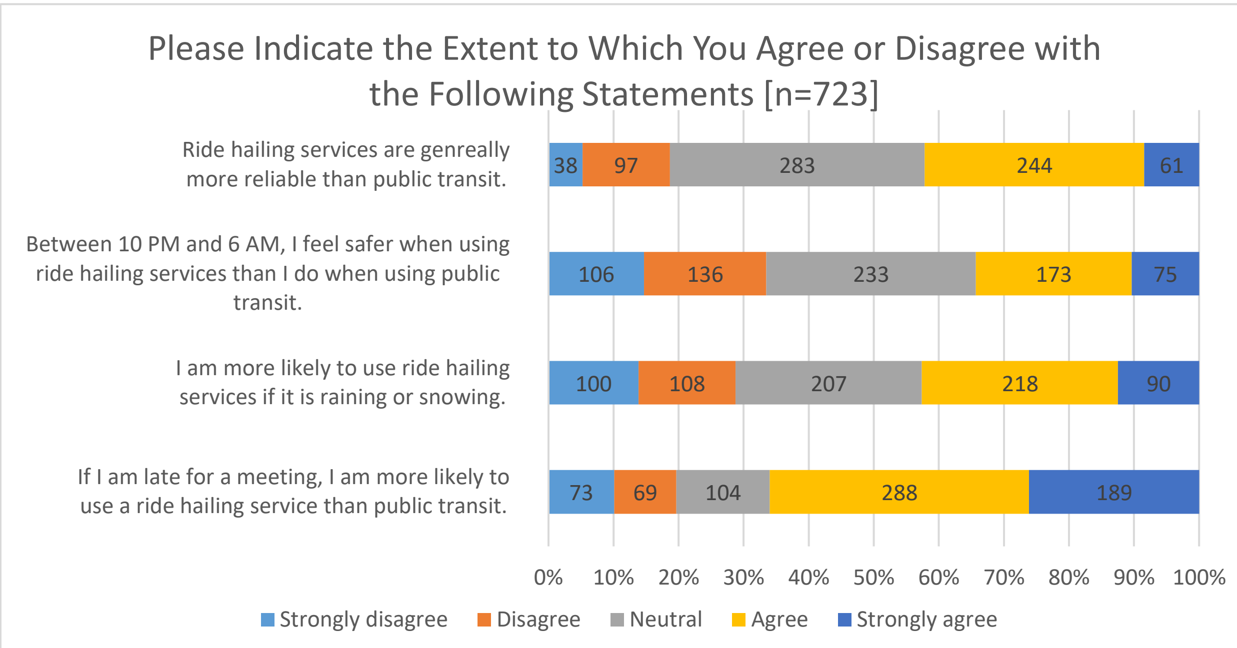

Figure 28. A summary of the responses to the agree-disagree questions in the SPRINT

3.4. Descriptive Analysis of SP Data

The first stage of analyzing the data obtained through the SP questions was to compare the responses to the SP questions to those obtained from the RP questions. Figure 29 shows the breakdown of the modes used by the respondents for a typical commuting trip and a recent non-commuting trip. For commuting trips, driving and public transit were by far the most frequently used modes. This is also true for non-commuting trips; however, walking is also much more prevalent compared to modes used for commuting trips. Because the attributes of the SP experiments were influenced by the characteristics of the reported commuting and non-commuting trip, it is interesting to compare the reported mode to the mode chosen in the SP question.

To facilitate this comparison, the trips for which respondents reported using the park-and-ride and 'other' modes were first removed due to these two options not being considered in the SP experiments. 192 of the 4,338 total responses obtained by the six SP questions were removed for this reason. For both commuting and non-commuting trips, more than half of the SP questions solicited a response that was different from the mode reported by the respondent in the corresponding RP question. Around one in eight responses to an SP question resulted in a respondent leaving their reported mode for ride-hailing, while less than 6% of questions resulted in a respondent leaving ride-hailing for another mode. The results are summarized in Table 6. Upon further examination, this shift towards ride-hailing in the SP questions is primarily drawing trips that were made by transit, as shown in Table 7. Particularly for commuting trips, around 60% of trips that were replaced by ride-hailing were originally made by public transit. This trend is less pronounced for non-commuting trips. Although the greatest number of new ride-hailing trips were originally made by public transit, ride-hailing was also used for many trips that were originally made by driving or walking. This result mirrors the results of Alemi, Circella, Handy, & Mokhtarian (2018), who found that using ride-hailing services tends to be associated with a reduction in the frequency with which a person drives, uses public transit, and uses active modes.

Table 6. Summary statistics comparing the mode reported for the RP and SP questions

Commute Trips			**Non-Commute Trips**		
Total Scenarios	*2073*	*100.00%*	*Total Scenarios*	*2073*	*100.00%*
Switch Mode	1243	59.96%	Switch Mode	1308	63.10%
Switch from RH	22	1.06%	Switch from RH	120	5.79%
Switch to RH	254	12.25%	Switch to RH	271	13.07%
No Switch	830	40.04%	No Switch	765	36.90%

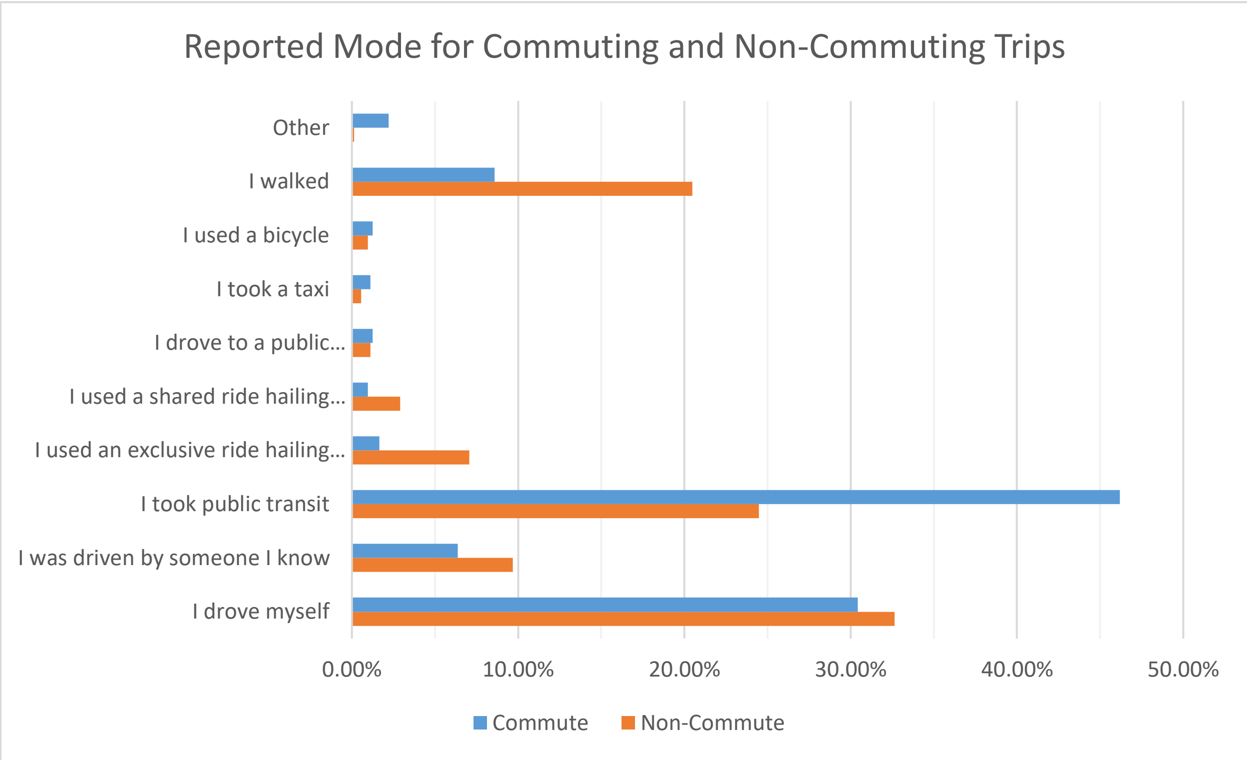

Figure 29. Usage of modes for commuting and non-commuting trips

Table 7. Modes replaced by ride-hailing, by purpose

RP Mode	Commute	Non-Commute
Drive yourself	62	74
Driven by Someone You Know	21	27
Public Transit	152	94
Taxi	2	2
Bicycle	0	4
Walking	17	70
Total	254	271

Upon comparison, it appears that the modal shares for the non-commuting trip SP question closely match the shares obtained from the corresponding RP question (see Figure 30). The same cannot be said for the modal shares of commuting trips, which appear to shift away from driving oneself and public transit to carpooling, ride-hailing, and bicycling. The factors that influenced this shift were investigated in further detail.

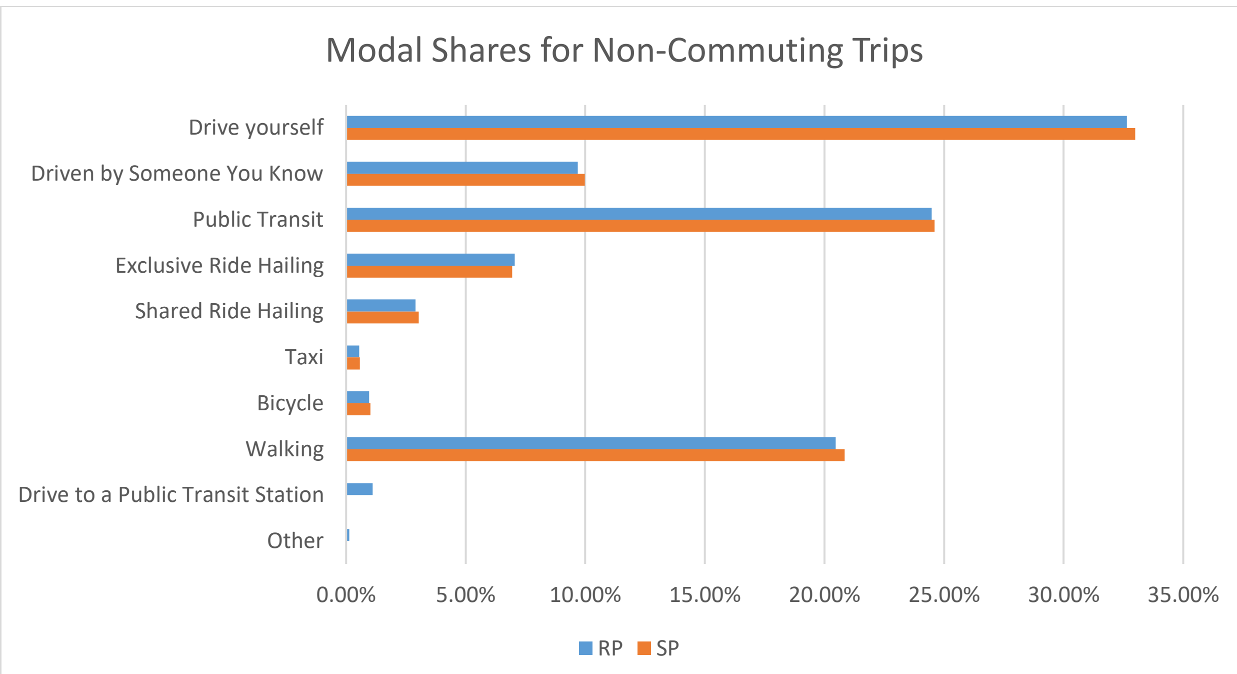

Figure 30. Comparison of modal shares for non-commuting trips

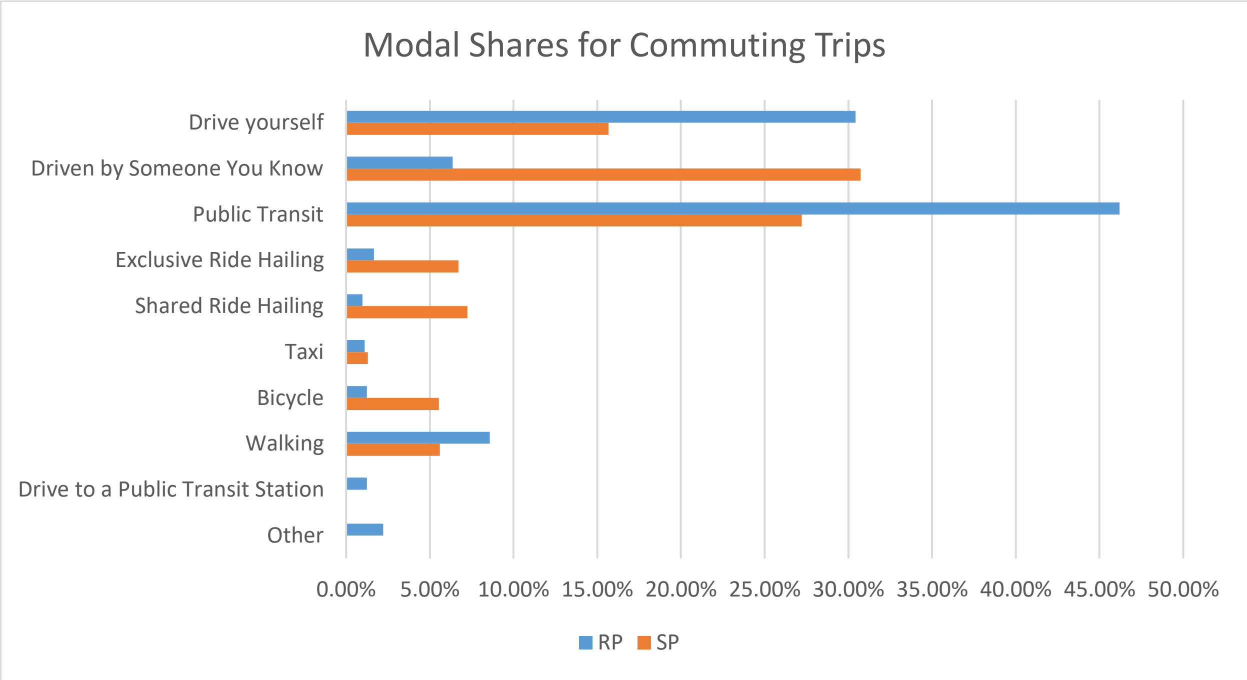

Figure 31. Comparison of modal shares for commuting trips

Figures 32 to 34 compare the commuting mode used by the respondent to the mode that was selected in each SP scenario through the use of Sankey diagrams. Although the frequency with which each mode was chosen varies from one scenario to the next, it is clear that the increase in the share of respondents who selected the *Driven by Someone You Know* alternative is due to a decrease in the number of respondents selecting the *Drive Yourself* and *Public Transit* modes. In terms of switching modes, it appears that an equal number of respondents switched from the *Drive Yourself* and *Public Transit* modes to the *Driven by Someone You Know* mode. The same appears to be true among respondents who switched to the *Exclusive Ride-Hailing* mode. For the *Shared Ride-Hailing* mode, the majority of the respondents who switched to this mode reported using *Public Transit* for their typical commuting trip.

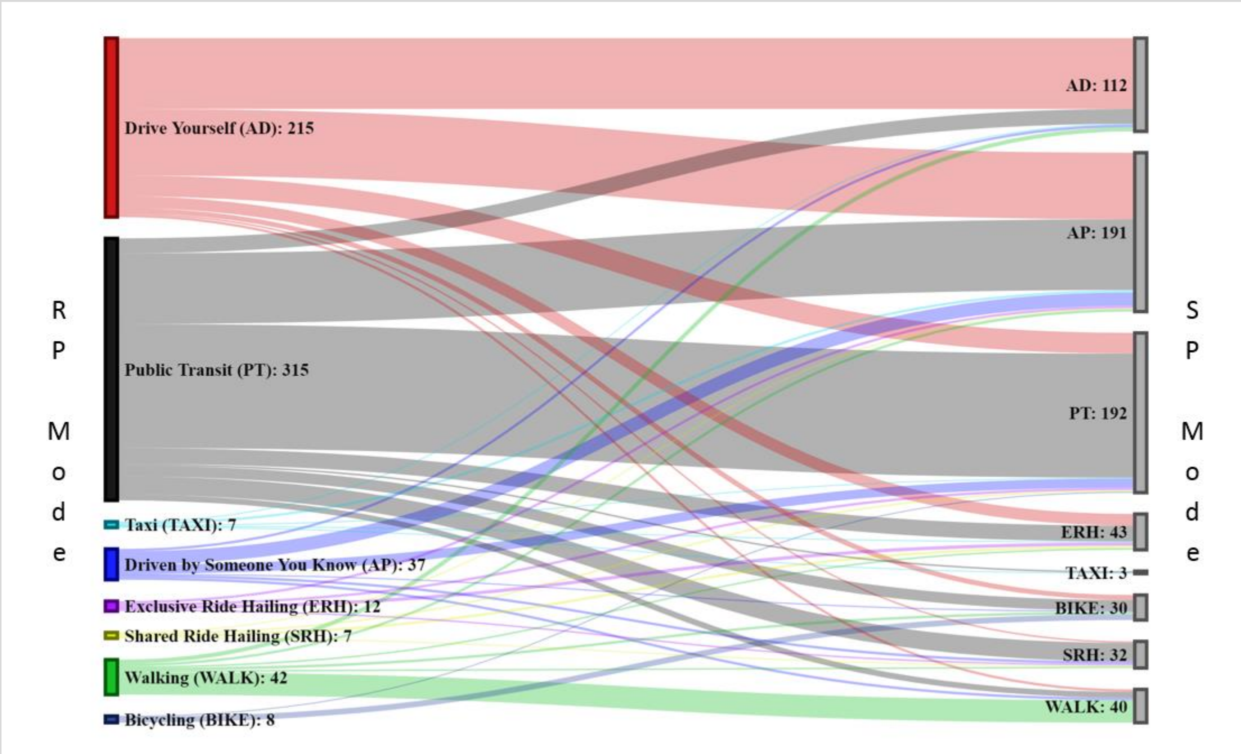

Figure 32. Comparison of RP and SP commuting mode, SP scenario 1

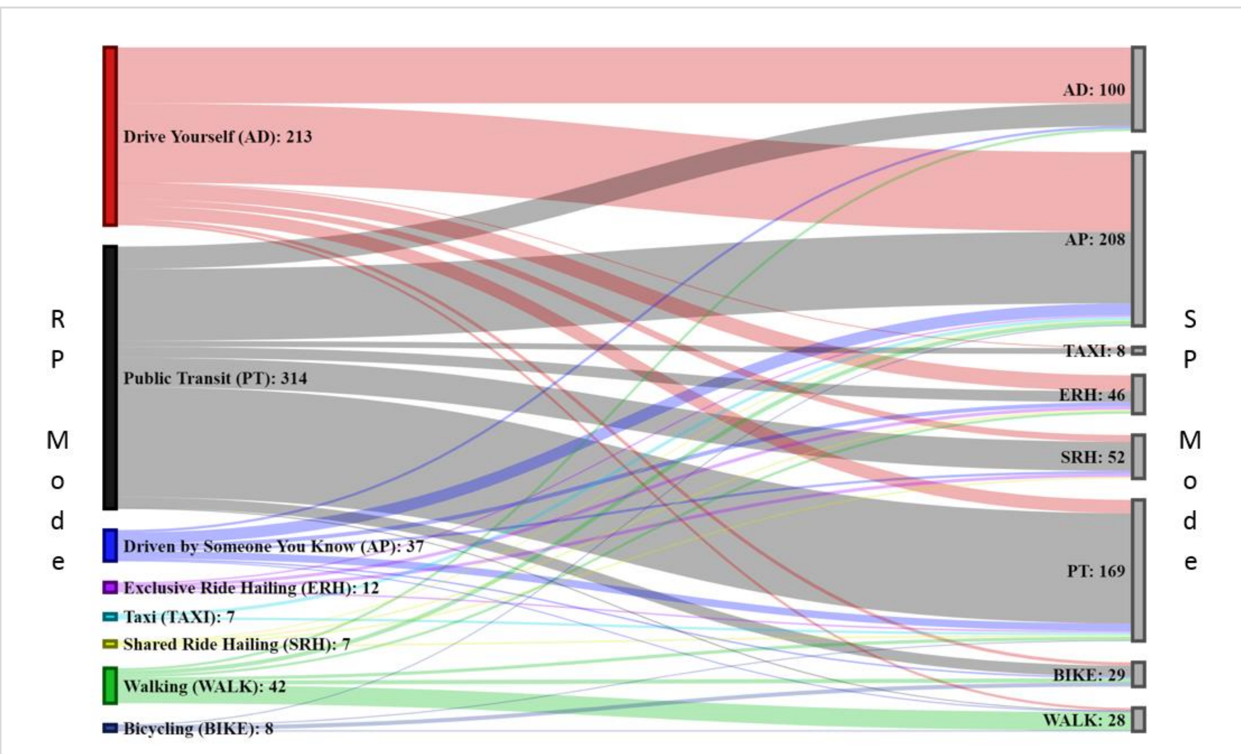

Figure 33. Comparison of RP and SP commuting mode, SP scenario 2

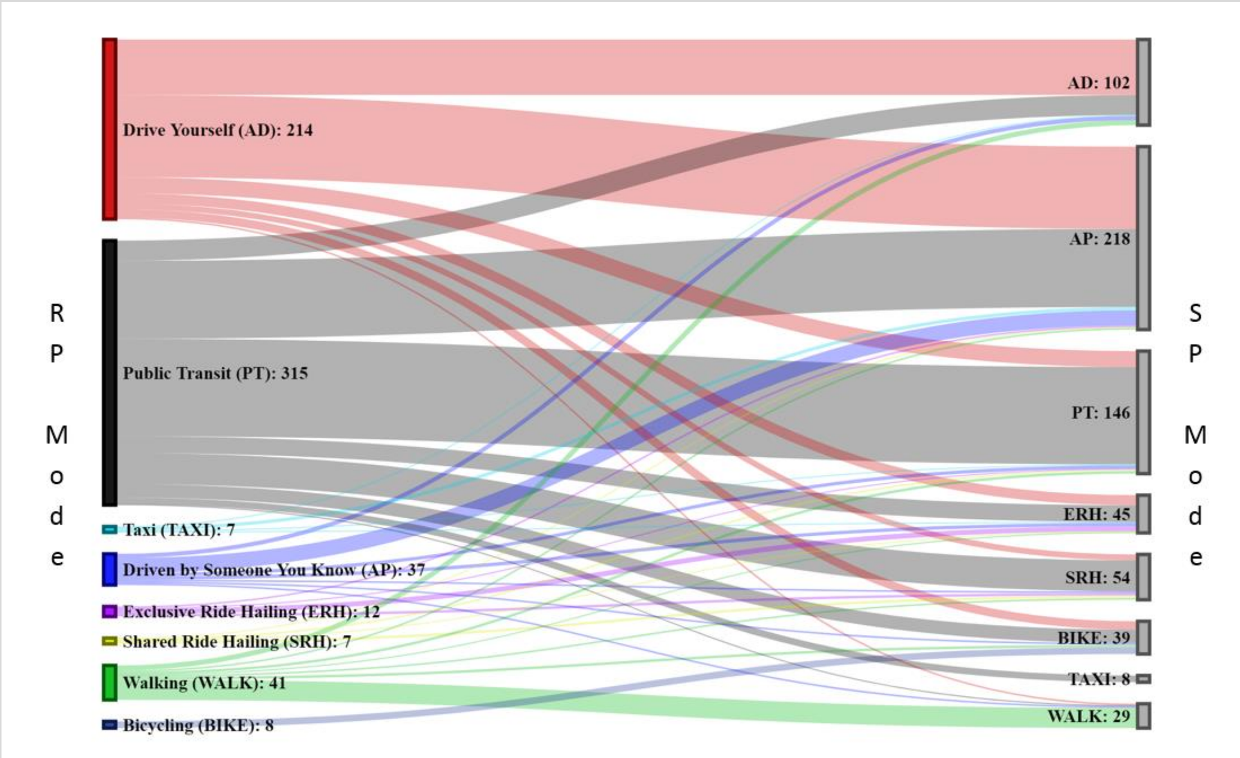

Figure 34. Comparison of RP and SP commuting mode, SP scenario 3

In order to account for the role that the experimental design played in the decision to switch modes, the attributes of the typical commuting mode (i.e. the "RP mode") were compared to the attributes of the mode that was chosen in the SP experiment (i.e. the "SP mode"). This comparison focused on instances where respondents switched from the *Drive Yourself* or *Public Transit* modes to the *Driven by Someone You Know, Exclusive Ride-Hailing, Shared Ride-Hailing*, or *Bicycling* modes.

The first comparison was between the in-vehicle travel time of the RP and SP modes. Instances where respondents switched from the *Drive Yourself* to the *Driven by Someone You Know, and the Exclusive* or *Shared Ride-Hailing* modes were omitted for this comparison, as the in-vehicle travel time values were set to be equal. As shown in Figure 35, the majority of the SP modes had a lower in-vehicle travel time than the RP mode (as evidenced by the fact that they lie below the red line). Notable exceptions to this trend include a subset of respondents who switched from *Drive Yourself* to *Bicycling* and from *Public Transit* to *Driven by Someone You Know*.

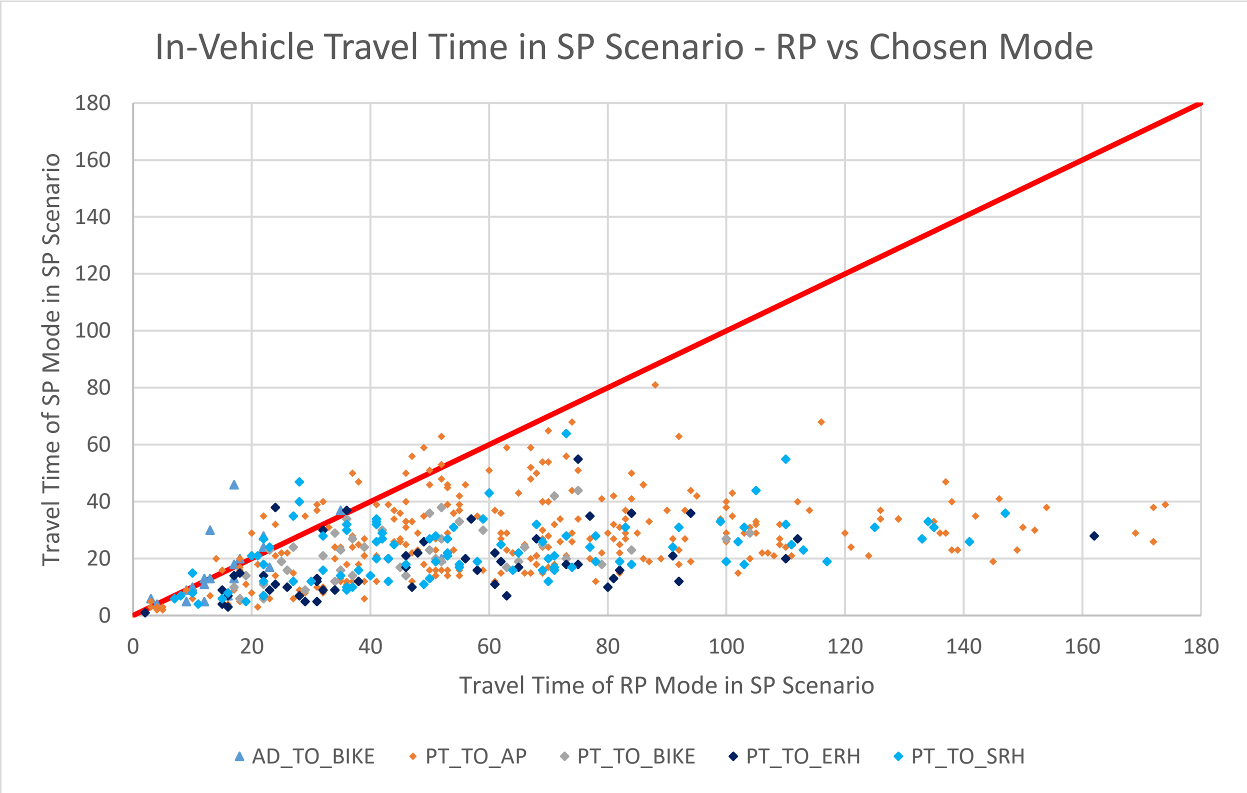

Figure 35. In-vehicle travel time in SP scenario – RP vs SP mode

Next, a similar comparison was made for the total travel time for the RP and SP modes. For the Drive *Yourself*, *Driven by Someone You Know*, *Bicycling*, and *Walking* modes, the total travel time is equal to the in-vehicle travel time. For *Public Transit*, total travel time is the sum of the in-vehicle travel, walking, waiting, and delay time. For *Exclusive Ride-Hailing* and *Taxi*, the total travel time is the sum of the in-vehicle travel and waiting time. The total travel time for *Shared Ride-Hailing* is similar to that of *Exclusive Ride-Hailing*, with the addition of delay time. The results shown in Figure 36 appear to imply that respondents who switched from the *Public Transit* mode were influenced by the total travel time associated with using said mode. Regardless of whether respondents switched to carpooling or ride-hailing, the total travel time of the SP mode was consistently lower than that of the SP mode. Interestingly, respondents who switched from driving to ride-hailing or bicycling did so in spite of the fact that these modes had higher travel times. The switch to ride-hailing services may be indicative of a willingness of drivers to pay for additional comfort or convenience.

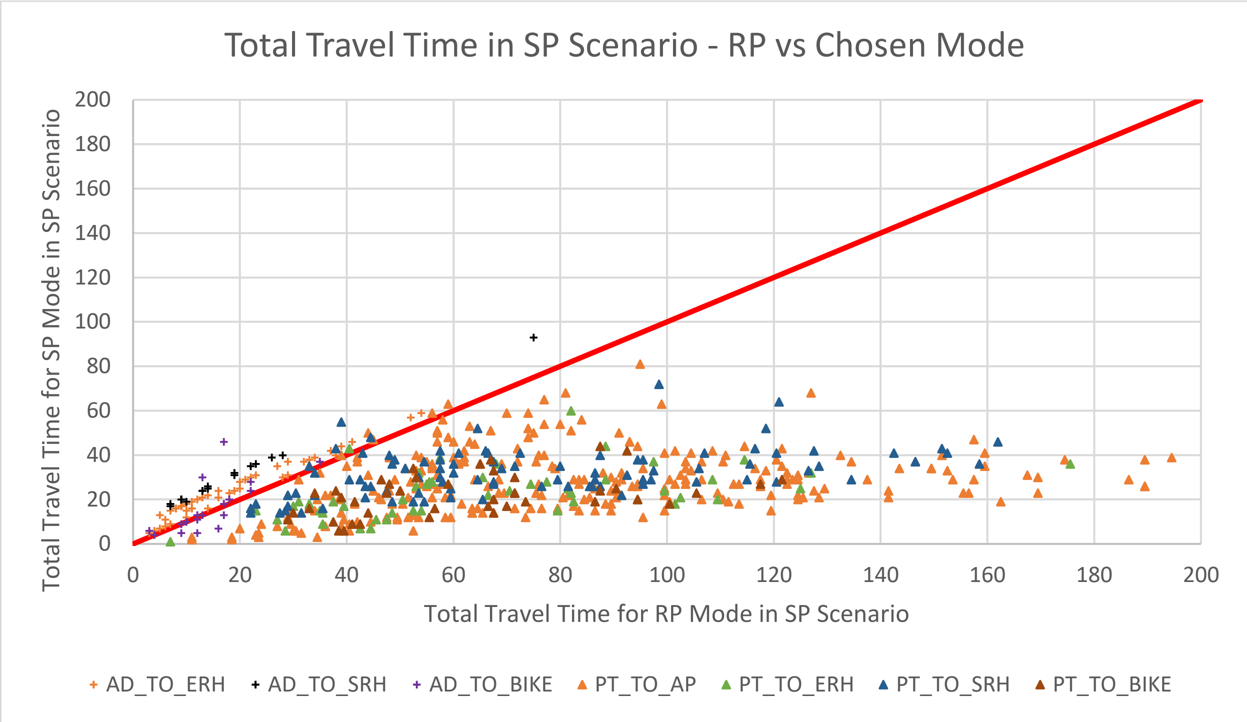

Figure 36. Total travel time in SP scenario – RP vs SP mode

Finally, the travel costs of the RP and SP modes were compared. As shown in Figure 37, it appears that the decision to switch from the *Drive Yourself* to the *Driven by Someone You Know* mode appears to also have been influenced by cost. Given that both the in-vehicle and total travel times were are equal for the two modes in each SP scenario, it appears that costs (both in terms of travel and parking costs) are the primary driver to this particular switch. With regards to shifts from public transit to ride-hailing services in the SP scenarios, it appears that this subset of respondents is willing to make a trade-off between higher costs for shorter travel times. In cases where drivers switch to ride-hailing, is appears that these respondents are willing to accept both higher total travel times, albeit equal in-vehicle travel times, and comparable or higher travel costs. For this subset of respondents, it appears that the switch to ride-hailing services could potentially be motivated by the more attractive aspects of these services, such as convenience and comfort. The willingness to pay more for faster travel times or increased convenience or comfort should be taken with a grain of salt, as respondents were asked to choose the alternative that they would prefer for a typical commuting trip. The questions did not indicate whether this trip would be made with regularity, introducing the potential that respondents may select costlier modes for a one-off trip that they would not use if they had to incur these costs on a daily basis.

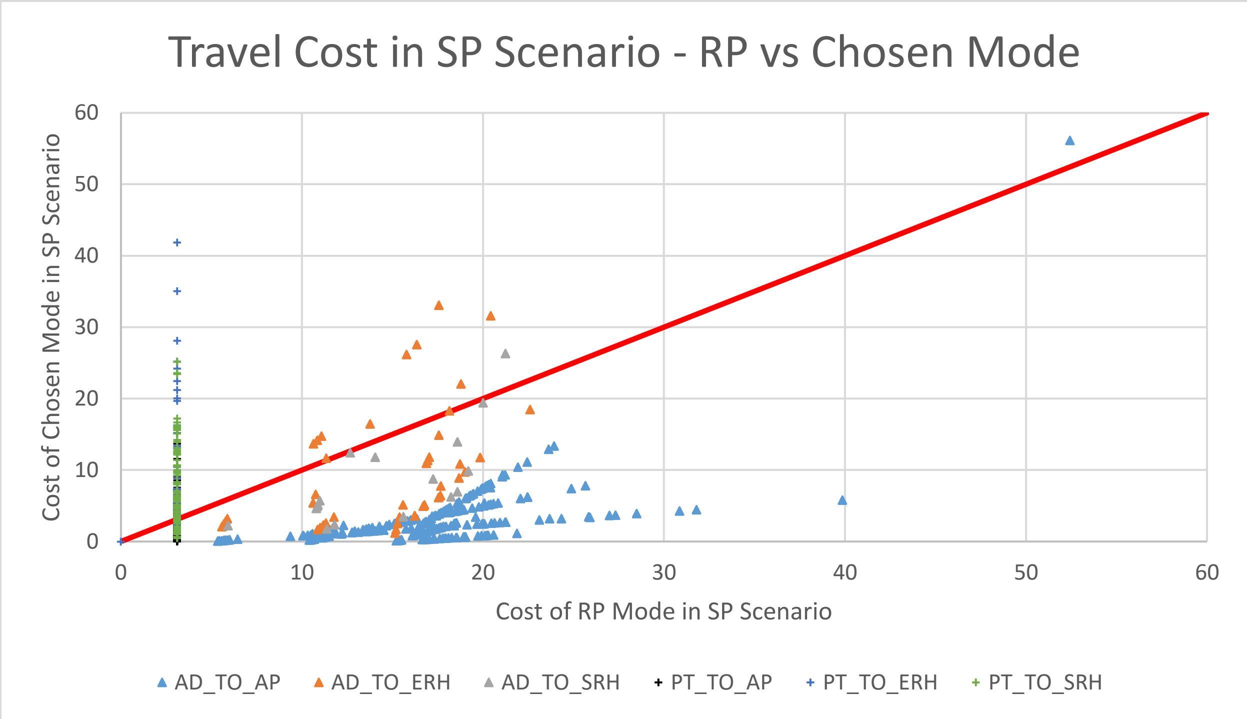

Figure 37. Travel cost in SP scenario – RP vs SP mode

Overall, it appears that the differences between the modal shares for commuting trips in the RP and SP questions can primarily be attributed to travel time and travel costs. The comparison between the attributes of the RP and SP modes reveals that there appears to be a process of trade-offs between travel times and travel costs, with some respondents being willing to pay more for shorter travel times.

3.5. Model Results

The responses to the revealed preference and stated preference questions were analyzed using the multinomial logit (MNL) model. Broadly speaking, the MNL model is used to analyze the influences that variables such as personal attributes, household characteristics, and the attributes of the alternatives have on the selection of a particular attribute. This specific approach to discrete choice analysis is predicated on the assumption that each choice maker aims to maximize the utility that they derive from the selected alternative (Ben-Akiva & Lerman, 1985). The power of the MNL model lies in its closed form and the efficient manner in which the model parameters can be estimated. Key shortcomings of the model include its ability to only represent systematic variations in taste and the presence of the proportional substitution property (Train, 2009). In spite of these issues, the MNL model can provide valuable insights into the impacts of different variables on the propensity to select a given alternative.

The MNL model is built upon the application of random utility-maximizing theory and assumes that the probability that person n chooses alternative i is a function of the utility that they derive from making this choice (U_{in}). This utility can be subdivided into a systematic and random component, denoted as V_{in} and ε_{in}, respectively. The systematic component of utility is the portion of the utility that is the product of observable characteristics, such as socio-economic, household, and trip characteristics. Conversely, the random component of utility is influenced by unobservable characteristics. Consequently, the individual values of the random components cannot be measured, however assumptions can be made about the distribution of these values. The formulation of the MNL model is the consequence of assuming that the random component of utility follows the Type I Extreme Value Distribution, also known as the Gumbel distribution. For the MNL model, the probability that person n chooses alternative *i* is given by (Ben-Akiva & Lerman, 1985):

$$P_n(i) = \frac{\exp(\mu V_{in})}{\sum_{j=1}^{J} \exp(\mu V_{jn})}$$

Two mode choice models were estimated using the responses to the stated preference questions – one for commuting trips and one for non-commuting trips. In order to help ensure that the responses to the SP questions were reasonably reflective of the choice that a respondent would make in reality, observations where the respondent indicated that they were unconfident or somewhat unconfident in their choice were omitted. For this reason, 15 observations were excluded from the commuting mode choice model, while 21 observations were omitted from the non-commuting model. The level of confidence that respondents had in their choices in each SP scenario is shown in Figure 38.

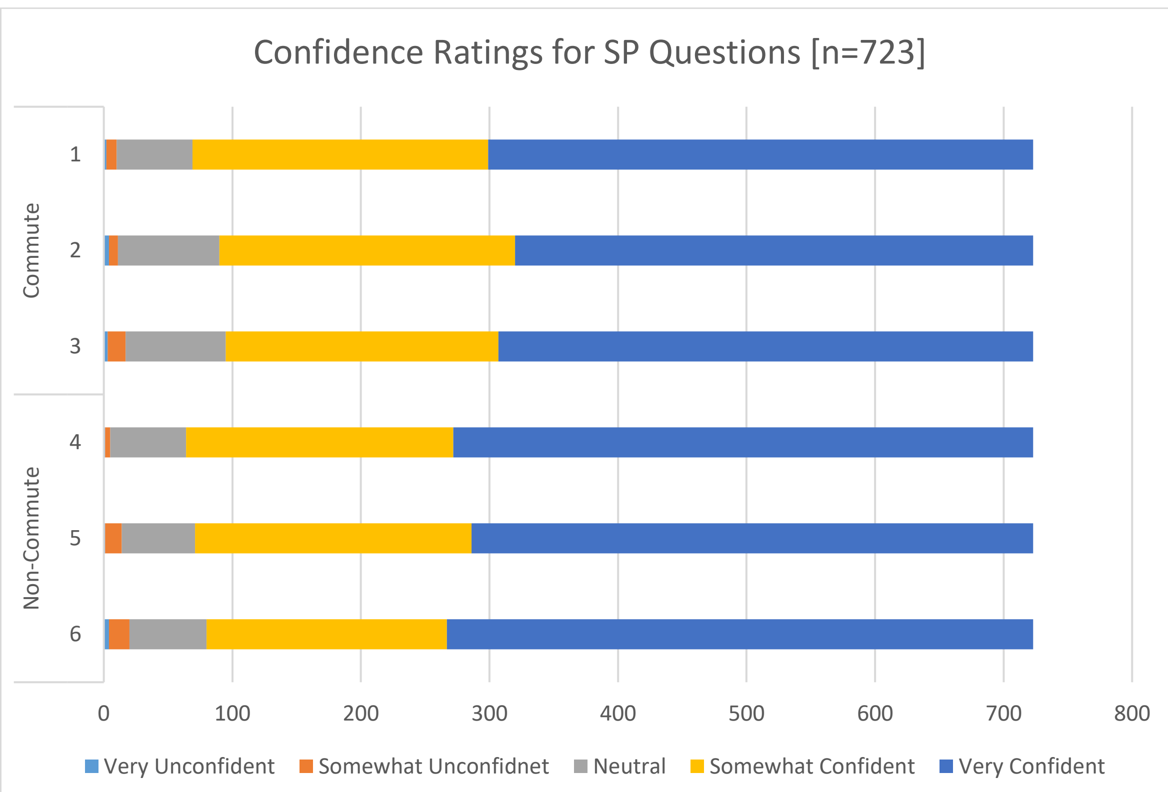

Figure 38. Aggregate shares for confidence ratings, by SP scenario

The parameters of the two models are summarized in Table 8. The adjusted rho-squared value the mode choice models for the commuting and non-commuting SP experiments was 0.2260 and 0.1908, respectively. These values, which are “measures [of] how well the models fit the [corresponding] data [sets]” (Train, 2009), are indicative of relatively good fits. The parameters that were included in the final model were selected based on their explanatory power, the sign of the coefficient, and the value of the t-statistic. There were a few cases where a parameter is kept in the model despite the t-statistic indicating that it is not statistically significant. These parameters were kept in order to help provide further insights into the mode choice process.

For both commuting and non-commuting trips, travel time and cost have the expected negative sign. For commuting trips, the ownership of a monthly or annual transit pass increases the likelihood that a person will use public transit or exclusive ride-hailing services. This result may indicate the existence of a complementary relationship between public transit and ride-hailing services. Also for commuting trips, belonging to a household that earned more than $100,000 in the past year was associated with a decrease in the likelihood of using public transit and exclusive ride-hailing services. As expected, the likelihood of using public transit and exclusive ride-hailing services decreases as the number of household vehicles increases. Interestingly, age appears to play a key role in the utilization of ride-hailing and taxi services for commuting trips. The results indicate that older respondents are more likely to use taxi services and less likely to use ride-hailing services. This may be indicative of a generational gap in preferences for ride-hailing and taxi services, which is in line with the results of prior studies of the use of ride-hailing services. Comfort also seems to play a role in the decision to use public transit for commuting trips, with crowding having a detrimental impact. Conversely, this does not appear to be the case for shared ride-hailing services, as the number of fellow passengers having a positive, albeit insignificant, impact on the propensity to use this service.

The results of the mode choice model for non-commuting trips are fairly similar to those of the mod choice model for commuting trips, with a few key exceptions. Most notably, age does not have a significant impact on the use of ride-hailing and taxi services, however it does appear to have an impact on the likelihood that a person will drive. An increase in age was associated with an increased propensity to drive oneself when completing a non-commuting trip. This appears to be somewhat consistent with the global trend of younger seniors being more likely to own a driver’s licence and to make more trips using their own vehicles than their predecessors Rosenbloom (2001). Gender also appears to impact the use of exclusive ride-hailing and public transit services, with female travellers being less likely to use public transit and more likely to use exclusive ride-hailing services. With regards to reliability, the occurrence of delays of over five minutes at least once per month has a negative impact on the likelihood of using public transit.

Table 8. Summary of model results

Variable Description	Commuting		Non-Commuting	
	Estimate	t-Stat	Estimate	t-Stat
Drive Yourself				
Alternative-Specific Constant	3.1304	2.3793	1.3394	2.0282
Travel Time (hr)	-1.5895	-2.8388	-1.5774	-3.0946
Parking Cost	-0.0245	-0.9122	-	-
Age	-	-	0.0251	3.2597
Driven by Someone You Know				
Alternative-Specific Constant	3.4123	2.6645	3.4671	6.4126
Travel Time (hr)	-0.6196	-1.3620	-1.4331	-2.7909
Cost	-0.0874	-2.4416	-	-
Public Transit				
Alternative-Specific Constant	3.4029	2.6235	2.5342	4.2014
Travel Time (hr)	-0.5606	-3.5571	-0.3772	-1.8325
Moderately or Highly Crowding (Dummy)	-0.2677	-1.3718	-0.3054	-1.4249
Owns Transit Pass (Dummy)	0.6695	3.4121	0.5787	2.7655
Number of Household Vehicles	-0.3689	-2.8307	-	-
Household Income >$100k (Dummy)	-0.2624	-1.0820	-	-
Delay > 5 mins at Least Once per Month (Dummy)	-	-	-0.0446	-0.2055
Gender = Female (Dummy)	-	-	-0.2585	-1.2107
Exclusive Ride Hailing				
Alternative-Specific Constant	3.0525	2.1882	1.9552	2.9953
Travel Time (hr)	-0.2291	-0.2044	-0.2682	-0.2304
Cost	-0.0623	-2.2950	-0.0481	-1.8521
Owns Transit Pass (Dummy)	0.5178	1.5791	-	-
Number of Household Vehicles	-0.4187	-1.6986	-0.2225	-1.2159
Household Income >$100k (Dummy)	-0.7261	-1.4266	-	-
Age	-0.0150	-1.2482	-	-
Possesses Driver's Licence (Dummy)	-	-	-0.1821	-0.5641
Gender = Female (Dummy)	-	-	0.3928	1.2811
Shared Ride Hailing				
Alternative-Specific Constant	3.2573	2.3227	2.3118	3.8734
Travel Time (hr)	-1.1060	-1.0277	-2.1749	-2.1246
Cost	-0.1163	-2.9231	-0.0466	-1.5225
Number of Other Passengers	0.0152	0.0826	0.0018	0.0104
Age	-0.0161	-1.4468	-	-
Taxi				
Travel Time (hr)	-0.0962	-0.0393	-0.1513	-0.0854

Cost	-0.0635	-1.1807	-0.0271	-0.7898
Age	0.0219	0.9636	-	-
Bicycling and Walking				
Travel Time (hr)	-3.3879	-4.3319	-3.7238	-5.1765
Alternative-Specific Constant (Bicycle)	2.7347	2.0975	2.2407	3.9710
Alternative-Specific Constant (Walking)	4.3439	3.3354	4.1109	7.2504
Overall Goodness of Fit				
Rho-Squared	0.2337		0.1972	
Adjusted Rho-Squared	0.2260		0.1908	

In order to identify the impact that a change in travel time or cost would have on the market share of public transit, exclusive ride-hailing, and shared ride-hailing, the direct elasticity was plotted for commuting and non-commuting trips. Because the magnitude of direct elasticity depends on the specific value of an attribute, a set of elasticities using hypothetical attribute values are shown below to allow for a more direct comparison, as shown in Figures 39 to 43.

For commuting trips, the direct elasticity of travel time for public transit, exclusive ride-hailing, and shared ride-hailing services are distinct from one another, as shown in Figure 39. The results shown in this figure imply that the market share of exclusive ride-hailing services is relatively less sensitive to increases in travel time compared to public transit and shared ride-hailing. Conversely, the direct elasticity of travel times for non-commuting trips is similar for public transit and exclusive ride-hailing services, which are distinct from that of shared ride-hailing services (as shown in Figure 40). In order to provide a more direct comparison between the direct elasticity of travel time for commuting and non-commuting trips, these values are plotted in Figure 41. It appears that the market shares of both exclusive and shared ride-hailing trips are more sensitive to increases in travel time when the trip is made for a non-commuting purpose. Conversely, the market share of public transit is more sensitive to increases in travel time for commuting trips than for non-commuting trips.

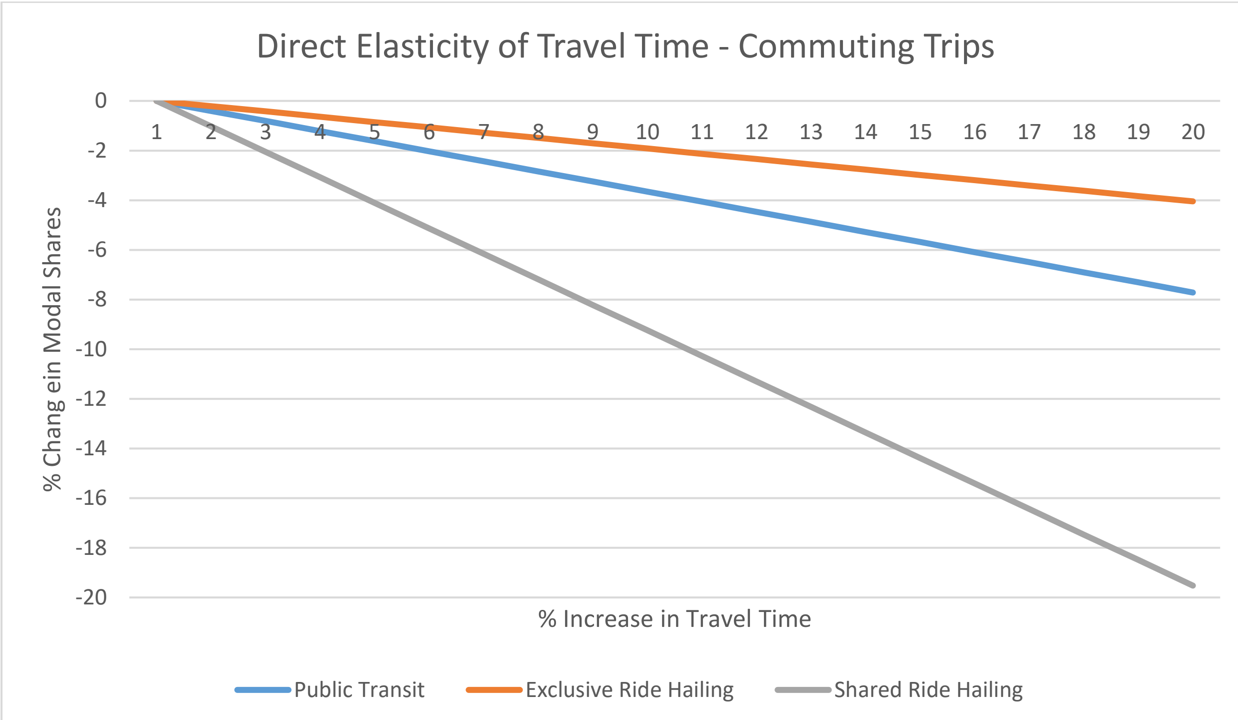

Figure 39. Direct elasticity of travel time for commuting trips

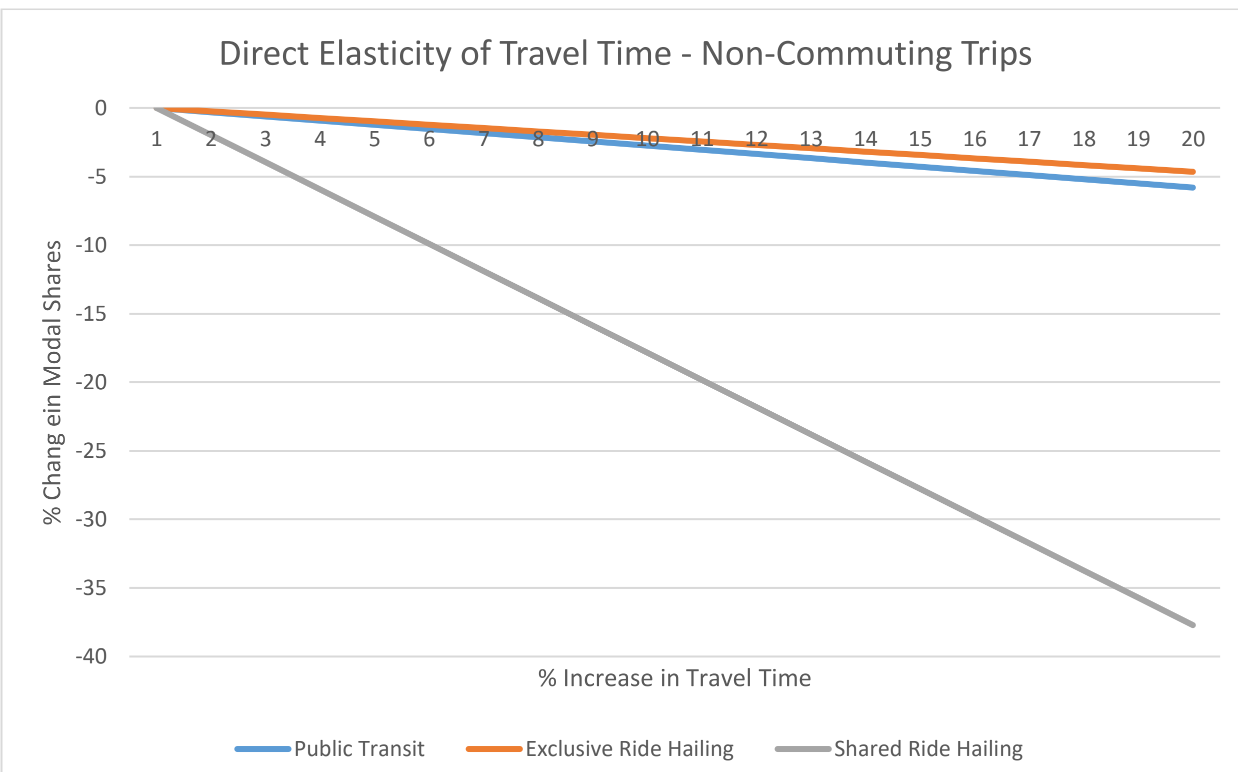

Figure 40. Direct elasticity of travel time for non-commuting trips

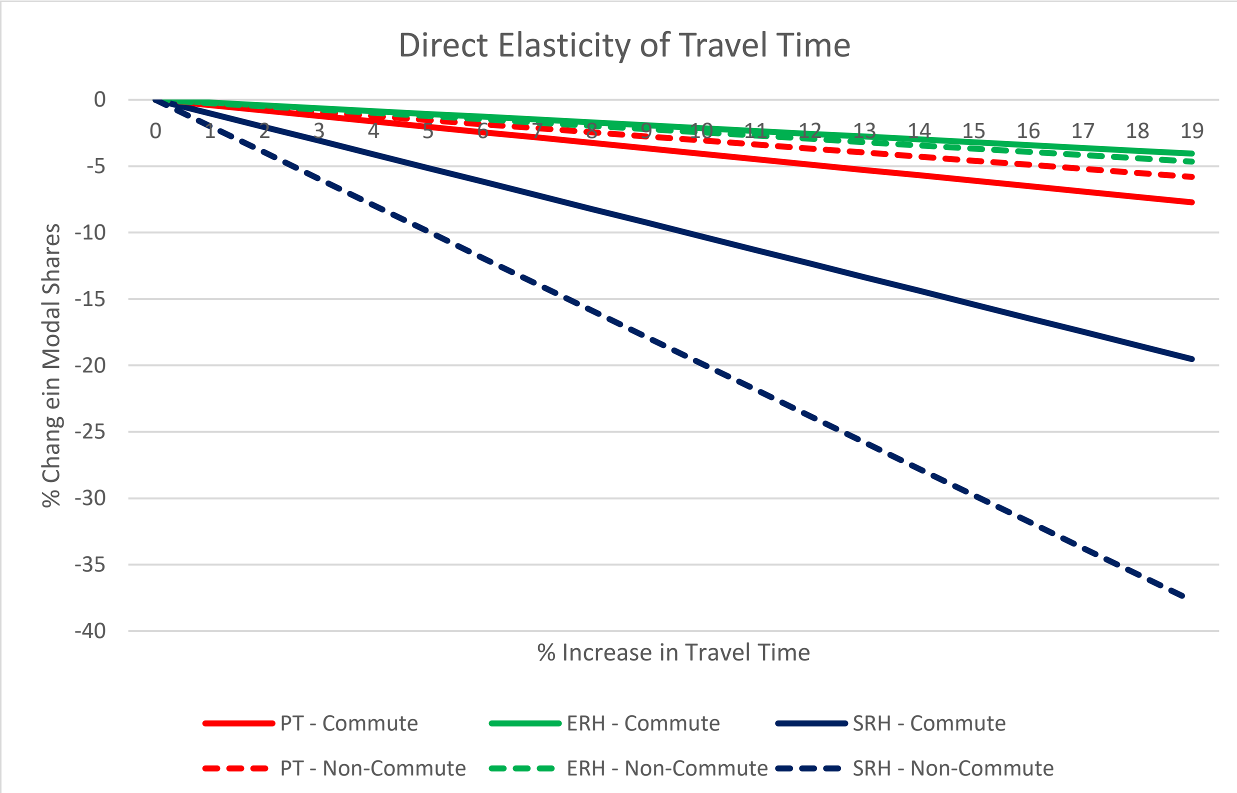

Figure 41. Direct elasticity of travel time for commuting and non-commuting trips

When considering the effect of increases in travel costs, it appears that the market share of exclusive ride-hailing services is much more sensitive than that of shared ride-hailing services for commuting trips, as shown in Figure 42. This result seems to indicate that the propensity for using exclusive ride-hailing services would be more adversely impacted by an increase in costs than shared ride-hailing services. As Figure 43 shows, this is not the case for non-commuting trips, where the direct elasticity of travel costs is fairly similar for the two types of ride-hailing services. Unlike the direct elasticity of travel time, it appears that travel costs have a more detrimental impact on the market shares of the two ride-hailing services when the trip is made for commuting purposes (see Figure 44).

Taken together, these results highlight the potential need to consider shared and exclusive ride-hailing services separately from a policy analysis standpoint, rather than as a single homogenous service. Additionally, this may be indicative of a need to segment ride-hailing users based on whether they tend to use exclusive or shared services more frequently.

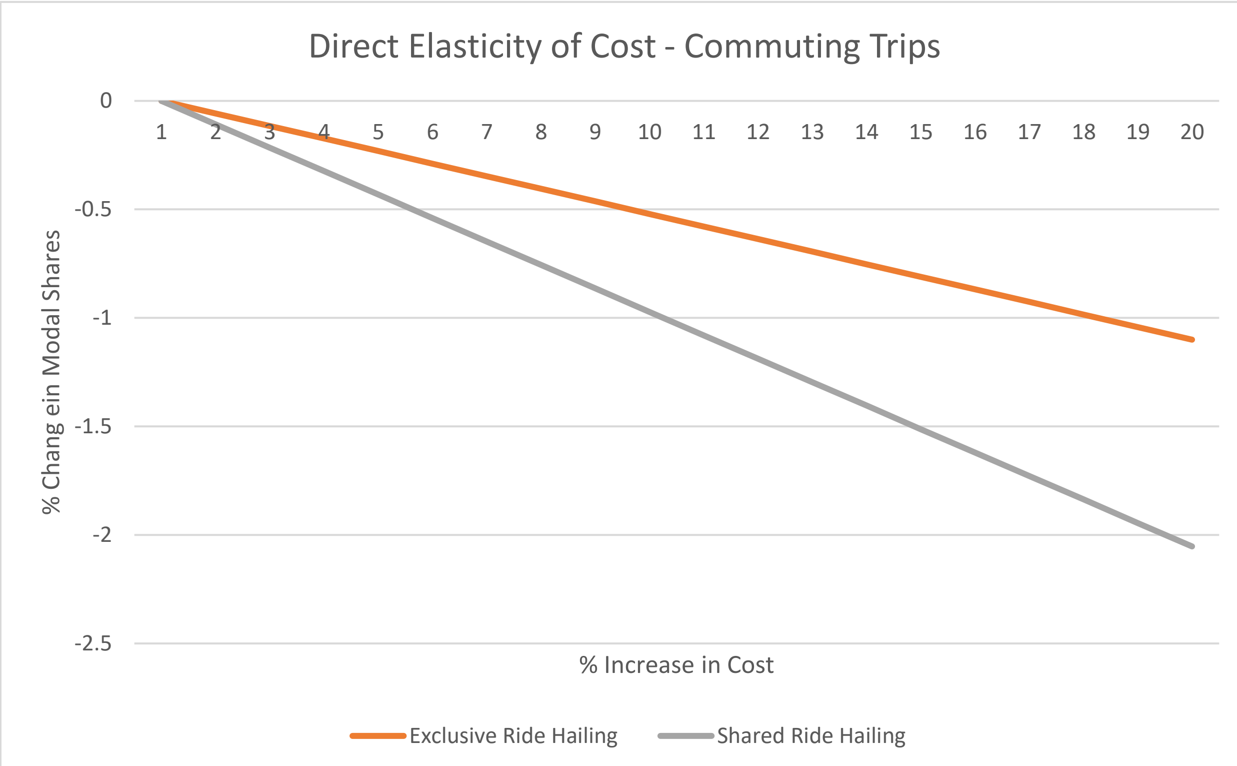

Figure 42. Direct elasticity of travel cost for commuting trips

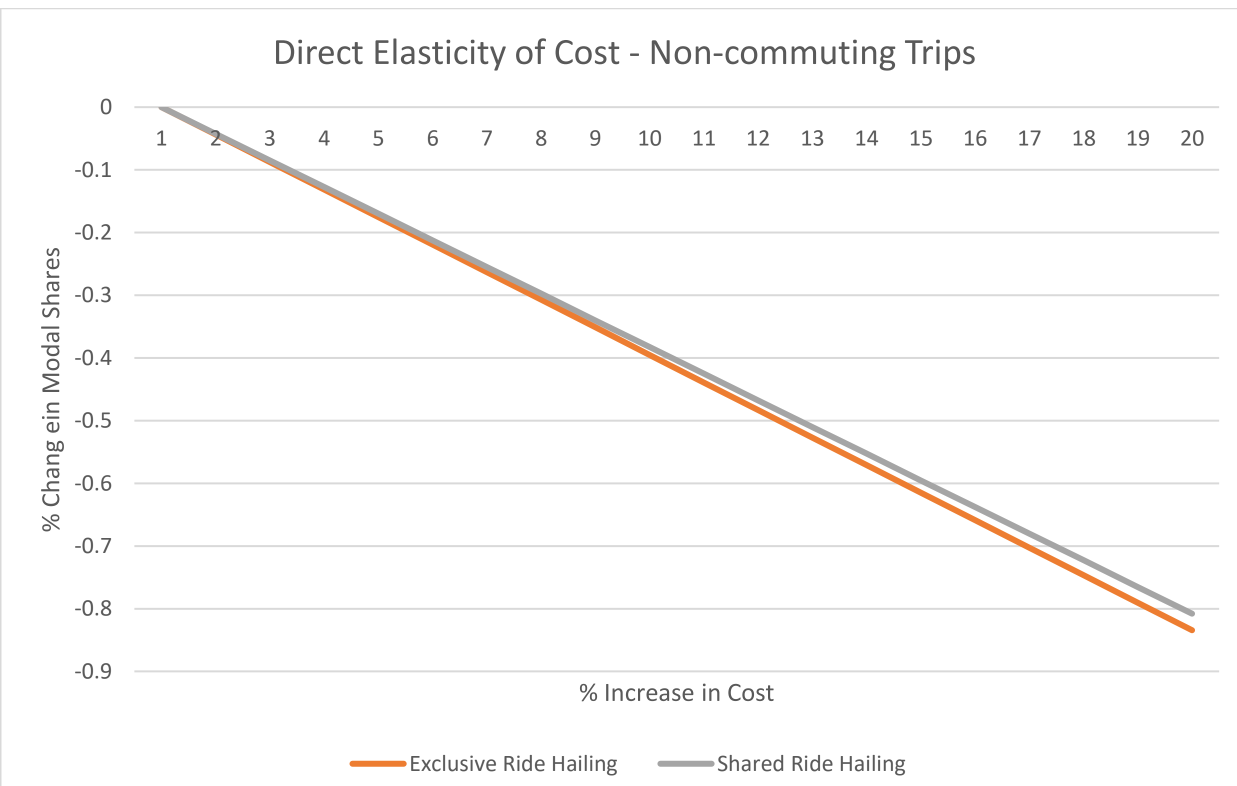

Figure 43. Direct elasticity of travel cost for non-commuting trips

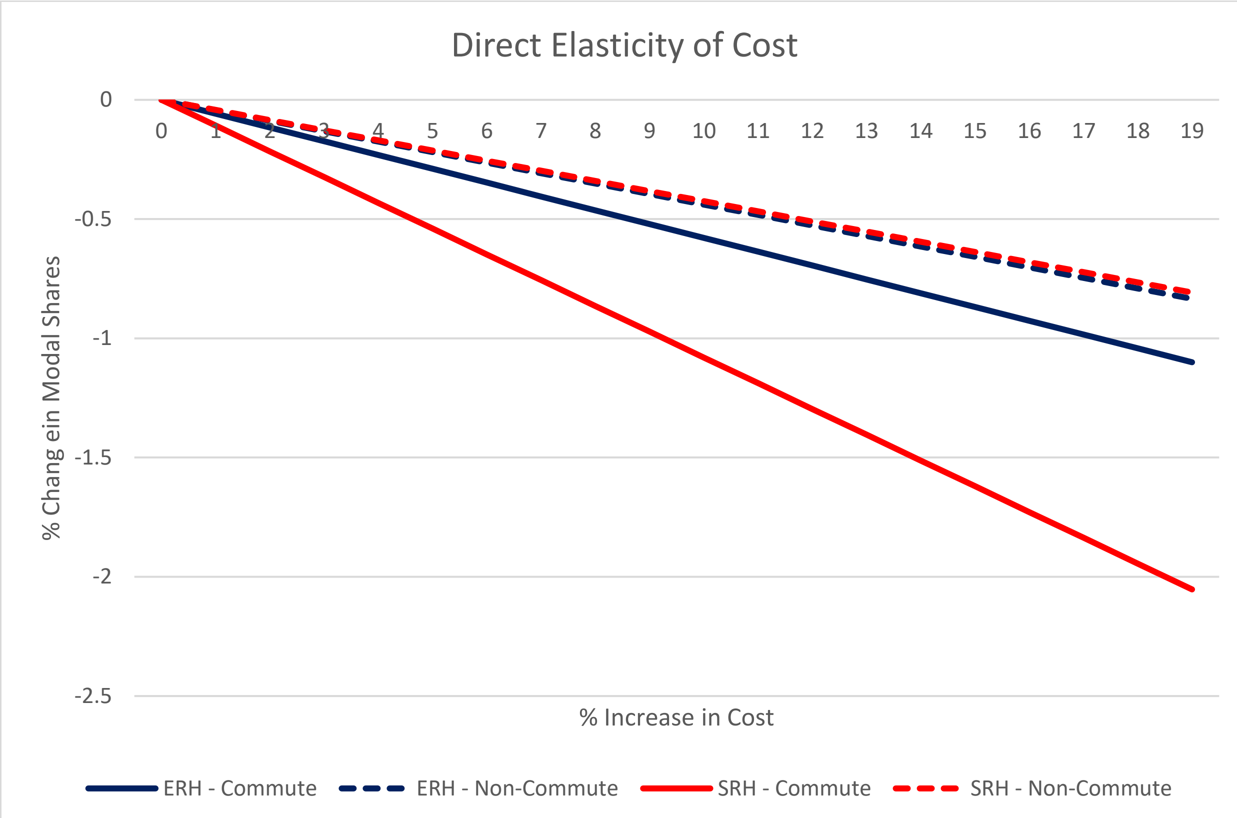

Figure 44. Direct elasticity of cost for commuting and non-commuting trips

4. CONCLUSIONS

This report presents the findings of a survey that aimed to identify the factors that influence the decision to use or not use ride-hailing services. The survey collected both revealed and stated preference data about mode choice behaviour. It used a pivoted approach to the design of the stated preference experiments, where the attributes presented to respondents in the SP questions were based on the characteristics of their reported trips. Respondents were asked to complete a total of six stated preference experiments, three pertaining to a typical commuting trip and three pertaining to a recent non-commuting trip. This approach was taken to help improve the realism of the SP experiments.

A random sample of 723 residents of the City of Toronto provided data through the survey. In terms of their use of ride-hailing services, around 56% of respondents reported that they had used a ride-hailing service at least once. Of this 50%, about half of these respondents reported using ride-hailing services at least once per month, typically to visit restaurants, bars, and coffee shops, to visit friends or family, and to get to or from an airport. Contrary to some of the findings in the literature, around one-third of respondents reported using ride-hailing services at least once per month for their commute. The findings indicate that some respondents have used ride-hailing services as a substitute for public transit.

When comparing the factors that play an important role when deciding to use public transit and ride-hailing services, travel time and reliability tend to be more important for the former than the latter. The respondents placed greater importance on convenience, comfort, safety, and convenience when considering using ride-hailing services. In addition, about two-thirds of respondents indicated that they were more likely to choose ride-hailing services than public transit if they are running late for an appointment or meeting. These results present both a challenge and an opportunity for public transit agencies and policy makers. One the one hand, the use of ride-hailing services are partially influenced by the characteristics of the services themselves. On the other hand, it is clear that above all else, the respondents valued travel time and reliability when they are considering using public transit – two things that to a certain extent can be controlled through operations and planning.

The results of the modelling exercises indicate that the factors that influence the use of public transit and ride-hailing services vary based on the purpose of the trip. While travel time and cost remain important regardless of trip purpose, the extent to these factors affects the propensity to use these modes still varies. In addition, the results of the modelling exercise seem to suggest that treating "ride-hailing users" as a homogenous segment of travellers may need to be reconsidered. The extent to which various aspects of travel influence the use of shared and exclusive ride-hailing services appears to differ between the two services, even for the same trip purpose. The data obtained through the survey represent the first stage of a process that will ultimately enhance the understanding factors that influence the use of ride-hailing services in the City of Toronto.

This report presents a descriptive analysis of the whole dataset and the results of a discrete choice model of mode choice (using the stated preference data only). Because of the tight time constraint, further modelling exercise was not possible. However, the collected dataset will provide unique information set for further research on capturing the competition between ride-hailing services and other urban modes through the use of more advanced econometric modelling approach and by harnessing both revealed and stated preference information.

Acknowledgments & Disclaimer

This report was prepared as part of the project *UTTRI Technical Support for the City of Toronto Vehicle for Hire Bylaw Review*, funded by the City of Toronto. The findings and opinions expressed in this report are those of the authors alone and do not necessarily reflect those of the City of Toronto.

References

Alemi, F., Circella, G., & Sperling, D. (2017). Adoption of Uber and Lyft, Factors Limiting and/or Encouraging Their Use and Impacts on Other Travel Modes among Millennials and Gen Xers in California. *97th Annual Meeting of the Transportation Research Board.* Washington, D.C.

Alemi, F., Circella, G., Handy, S., & Mokhtarian, P. (2018). What Influences Travelers to use Uber? Exploring the Factors Affecting the Adoption of On-Demand Ride Services in California. *Travel Behaviour and Society, 13,* 88 - 104.

Arentze, T., & Molin, E. (2013). Travellers' Preferences in Multimodal Networks – Design and Results of a Comprehensive Series of Choice Experiments. *Transportation Research Part A, 58*, 15 - 28.

Ben-Akiva, M., & Lerman, S. (1985). Discrete Choice Analysis: Theory and Application to Travel Demand. In M. Ben-Akiva, & S. Lerman, *Discrete Choice Analysis: Theory and Application to Travel Demand* (pp. 1 - 374). Boston: MIT Press.

Bhat, C., & Sardesai, R. (2006). The Impact of Stop-Making and Travel Time Reliability on Commute Mode Choice. *Transportation Research Part B, 40,* 709 - 730.

Bohannon, R. (1997). Comfortable and Maximum Walking speed of Adults Aged 20 - 79 Years - reference Values and Determinants. *Age and Ageing, 26*, 15 - 19.

ChoiceMetrics. (2018). *Ngene 1.2 User Manual & Reference Guide.* ChoiceMetrics.

City of Toronto. (2019, January 17). *Ward Profiles*. Retrieved from Toronto: https://www.toronto.ca/city-government/data-research-maps/neighbourhoods-communities/ward-profiles/

Clewlow, R., & Mishra, G. (2017). *Disruptive Transportation – The Adoption, Utilization, and Impacts of Ride-Hailing in the United States.* Davis: UC Davis Institute of Transportation Studies.

Co-op Cabs. (2016, November). *What are the Standard Rates to Hire a Taxi in Toronto?* (Co-op Cabs) Retrieved March 29, 2019, from https://co-opcabs.com/what-are-the-standard-rates-to-hire-a-taxi-in-toronto/

Daly, A., Hess, S., Patruni, B., Potoglou, D., & Rohr, C. (2012). Using Ordered Attitudinal Indicators in a Latent Variable Choice Model - A Study of the Impact of Security on Rail Travel Behaviour. *Transportation*, 267 - 297.

Danaf, M., Atasoy, B., de Azevedo, C., Ding-Mastera, J., Abou-Zeid, M., Cox, N., . . . Ben-Akiva, M. (2019). Context-Aware Stated Preferences with Smartphone-based Travel Surveys. *Journal of Choice Modelling, 31,* 35 - 50.

DMG. (2018).

El-Geneidy, A., Krizek, K., & Iacono, M. (2007). Predicting bicycle travel speeds along different facilities using GPS data: A proof of concept model. *Proceedings of the 86th annual meeting of the transportation research board, compendium of papers.* Washington, D.C.

Frei, C., Hyland, M., & Mahmassani, H. (2017). Flexing Service Schedules: Assessing the Potential for Demand-Adaptive Hybrid Transit via a Stated Preference Approach. *Transportation Research PArt C, 76*, 71 - 89.

Idris, A., Habib, K., & Shalaby, A. (2014). Dissecting the Role of Transit Service Attributes in Attracting Commuters – Lessons from a Comprehensive Revealed Preference-Stated Preference Study on Commuting Mode-Switching Behaviour in Toronto, Ontario, Canada. *Transportation Research Record, 2*(2415), 107 - 117.

Louviere, J., Hensher, D., & Swait, J. (2000). *Stated Choice Methods: Analysis and Applications.* Cambridge: Cambridge Univeristy Press.

Matyas, M., & Kamargianni, M. (2018). Survey Design for Exploring Demand for Mobility as a Service Plans. *Transportation*.

McMaster Institute for Transportation and Logistics. (2015). *Congestion Trends in the City of Toronto.* Hamilton: McMaster Institute for Transportation and Logistics.

Moody, J., Middleton, S., & Zhao, J. (2019). Rider-to-Rider Discriminatory Attitudes and Ridesharing Behaviour. *Transportation Research PArt F, 62*, 258 - 273.

R.A. Malatest and Associates. (2018). *Transportation Tomorrow Survey 2016: Design and Conduct of the Survey.* Toronto: R.A. Malatest and Associates.

Rayle, L., Dai, D., Chan, N., Cervero, R., & Shaheen, S. (2016). Just a Better Taxi? A Survey-based Comparison of Taxis, Transit, and Ridesourcing Services in San Francisco. *Transport Policy, 45*, 168 - 178 .

Rodier, C. (2018). *The Effects of Ride Hailing Services on Travel and Associated Greenhouse Gas Emissions.* Davis: National Center for Sustainable Transportation.

Rose, J., & Bliemer, M. (2009). Constructing Efficient Stated Choice Experimental Designs. *Transport Reviews*, 587 - 617.

Rose, J., Bliemer, M., Hensher, D., & Collins, A. (2008). Designing efficient Stated Choice Experiments in the Presence of Reference Alternatives. *Transportation Research Part B*, 395 - 406.

Rosenbloom, S. (2001). Sustainability and Automobility Among the Elderly: An International Assessment. *Transportation*, 375 - 408.

Sanko, N. (2001). Guidelines for Stated Preference Experiment Design. *Master of Business Adminstration diss.* Ecole Nationale des Ponts et Chaussées.

Shared-Use Mobility Centre. (2016). *Shared Mobility and The Transformation of Public Transit.* Chicago: Shared-Use Mobility Centre.

Spurlock, C., Sears, J., Wong-Parodi, G., Walker, V., Jin, L., Taylor, M., . . . Todd, A. (2019). Describing the Users – Understanding Adoption of and Interest in Shared, Electrified, and Automated Transportation in the San Francisco Bay Area. *Transportation Research Part D*.

TomTom. (2017). *TomTom Traffic Index: Measuring Congestion Index Worlwide*. (TomTom) Retrieved April 7, 2019, from https://www.tomtom.com/en_gb/trafficindex/city/toronto

Toronto Transit Commission. (2017). *Service Standards and Decision Rules for Planning Transit Service.* Toronto: Toronto Transit Commission (TTC).

Toronto Transit Commission. (2019, January 20). *Prices*. (Toronto Transit Commission) Retrieved March 25, 2019, from http://ttc.ca/Fares_and_passes/Prices/Prices.jsp

Train, K. (2009). Discrete Choice Methods with Simulation. In K. Train, *Discrete Choice Methods with Simulation* (pp. 34 - 75). New York City: Cambride University Press.

Weiss, A., Salehin, M., & Habib, K. (2019). A Joint RP-off-SP Survey to Understand the Impacts of Autonomous Vehicle on Travel Mode Choices in the Greater Toronto Area. *Paper Presented at the 98th Annual Meeting of the Transportation Research Board.* Washington, D.C.

Yan, X., Levine, J., & Zhao, X. (2018). Integrating Ridesourcing Services with Public Transit – An Evaluation of Traveler Responses Combining Revealed and Stated Preference Data. *Transportation Research Part C*.

APPENDIX A – SURVEY QUESTIONNAIRE

<u>Household Attributes:</u>

1. Please identify the current address of your household by clicking on the map and/ or using the search function below.
   Question Type: Map-based interface
2. Please select the dwelling type of your household.
   Question Type: Radio button (choose one)
   Response Options: Single-detached; semi-detached; row house; condo; apartment; student residence; other
3. How many members/ residents (including yourself) are in your household?
   Question Type: Numerical
4. How many vehicles does your household have available for personal use?
   Question Type: Numerical
5. How many household members/ residents (including yourself) are full-time workers?
   Question Type: Numerical
6. How many household members/ residents (including yourself) are part-time workers?
   Question Type: Numerical
7. How many household members/ residents (including yourself) are students?
   Question Type: Numerical
8. Please indicate the total earnings of the members of your household (including yourself).
   Question Type: Radio button (choose one)
   Response Options: under $14,999; $15,000 - $29,999; $30,000 - $39,999; $40,000 - $49,999; $50,000 - $59,999; $60,000 - $69,999; $70,000 - $79,999; $80,000 - $89,999; $90,000 - $99,999; $100,000 - $124,999; $125,000 - $149,999; $150,000 - $199,999; $200,000 and above; decline/ don’t know

<u>Personal Attributes:</u>

1. What is your age?
   Question Type: Numerical
2. What is your gender?
   Question Type: Radio button (choose one)
   Response Options: Male; female; other [textbox]; prefer not to answer
3. Do you have a driver’s license?
   Question Type: Radio button (choose one)
   Response Options: Yes; no
4. Do you own a transit pass? Note: A Presto card without a monthly or annual metropass is not considered a transit pass.
   Question Type: Radio button (choose one)
   Response Options: Yes; no
5. What is your current employment status?
   Question Type: Radio button (choose one)
   Response Options: Full-time; work at home full-time; part-time; work at home part-time; not employed; other
6. Are you currently a student?

Question Type: Radio button (choose one)
Response Options: Yes; no

7. Have you ever installed a ride-hailing (e.g. Uber, Lyft) application on your smartphone?
   Question Type: Radio button (choose one)
   Response Options: Yes; yes but I have since deleted it; never; I do not own a smartphone
8. Have you ever used a ride-hailing service (e.g. Uber, Lyft)?
   Question Type: Radio button (choose one)
   Response Options: Yes, using my own account; yes, using someone else's account; never

<u>Information on Ride-Hailing Users:</u>

1. Please indicate how frequently you use ride-hailing services (e.g. Uber, Lyft, etc.)
   Question Type: Radio button (choose one)
   Response Options: I have used it in the past; less than once per month; 1-3 times per month; 1-2 times per week; 3-4 times per week; 5 or more times per week
2. Please indicate the types of trips for which you use ride-hailing services (e.g. Uber, Lyft, etc.)
   Question Type: Check box (choose all that apply)
   Response Options: Commute to school; commute to work; work-related/ business meeting; schooling and errands; restaurant, bar, coffee; visiting friends, family; recreation, sports, leisure, arts; worship, religion; services (bank, haircut, mechanic, etc.); health and personal care; to reach public transit; other (please specify)

<u>Information on the Most Recent Ride-Hailing Trip:</u>

1. Please use the map below to indicate the start and end point of the most recent trip you made using a ride-hailing service.
   Question Type: Map-based interface
2. What time did this trip begin?
   Question Type: Numerical, time
3. What was the purpose of this trip?
   Question Type: Radio button (choose one)
   Response Options: Commute to school; commute to work; work-related/ business meeting; schooling and errands; restaurant, bar, coffee; visiting friends, family; recreation, sports, leisure, arts; worship, religion; services (bank, haircut, mechanic, etc.); health and personal care; to reach public transit; other (please specify)
   Follow-Up Question: If the commute trip: do you use ride-hailing services to make this trip on a regular basis?
4. Was this trip made using an exclusive or shared ride-hailing service?
   Question Type: Radio button (choose one)
   Response Options: Exclusive; shared
5. How many persons (excluding the driver) made this trip with you?
   Question Type: Numerical

6. How much did this trip cost you?
   Question Type: Numerical
7. If ride-hailing were not available, how would you have made this trip?
   Question Type: Radio button (choose one)
   Response Options: I would not have made this trip at all; I would have used a van or shuttle service; I would have used public transit; I would have walked or biked; I would have used a taxi; I would have gotten a ride from someone; I would have driven a car (if the respondent has a driver's license)
8. Was a private automobile available for this trip?
   Question Type: Conditional, radio button (choose one); *<respondent must have a driver's license and household must have at least one private auto>*
9. Please indicate the statement(s) that best describe why you used a ride-hailing service for this trip.
   Question Type: Check box (choose all that apply)
   Response Options: Ease of payment; cost; shorter wait time; faster travel time; ease of hailing service; comfort; safety; reliability of service; parking cost; difficulty finding parking; to avoid drinking and driving

<u>Information on a Typical Commuting Trip:</u>

1. Please use the map below to indicate the start and end point of a typical commuting trip (i.e. to work or school).
   Question Type: Map-based interface
2. What time did this trip begin?
   Question Type: Numerical, time
3. How did you make this trip?
   Question Type: Radio button (choose one)
   Response Options: Drive own car; drive car share car; driven by someone I know; exclusive ride-hailing service; shared ride-hailing service; public transit; drove to public transit station; taxi; I used my own bike; used a shared bike; I walked
4. How did you pay for this trip?
   Question Type: Conditional, radio button (choose one); *<only for transit trips>*
   Response Options: Transit pass; another pass; cash; token; Presto card; other
5. How much did the trip cost you?
   Question Type: Conditional, numerical; *<only for a taxi, ride-hailing, and transit trips>*
6. How much did you pay for parking?
   Question Type: Conditional; numerical *<must report driving for the trip>*
7. How long did you have to wait?
   Question Type: Conditional; numerical *<only for taxi and ride-hailing>*

<u>Information on the Most Recent Non-Commuting Trip:</u>

1. Please use the map below to indicate the start and end point of your most recent non-commuting trip (i.e. trips to places other than work or school).
   Question Type: Map-based interface

2. What time did this trip begin?
   Question Type: Numerical, time
3. What was the purpose of this trip?
   Question Type: Radio button (choose one)
   Response Options: Restaurant, bar, coffee; visiting friends, family; recreation, sports, leisure, arts; worship, religion; services (bank, haircut, mechanic, etc.); health and personal care; other (please specify)
4. How did you make this trip?
   Question Type: Radio button (choose one)
   Response Options: Drive own car; drive car share car; driven by someone I know; exclusive ride-hailing service; shared ride-hailing service; public transit; drove to public transit station; taxi; used my own bike; used a shared bike; I walked
5. How did you pay for this trip?
   Question Type: Conditional, radio button (choose one); *<only for transit trips>*
   Response Options: Transit pass; another pass; cash; token; Presto card; other
6. How much did the trip cost you?
   Question Type: Conditional, numerical; *<only for a taxi, ride-hailing, and transit trips>*
7. How much did you pay for parking?
   Question Type: Conditional; numerical *<must report driving for the trip>*
8. How long did you have to wait?
   Question Type: Conditional; numerical *<only for taxi and ride-hailing>*

<u>Attitudinal Questions:</u>
Familiarity Questions:

1. Please select the response that best reflects your familiarity with exclusive ride-hailing services such as UberX and Lyft Classic.
   Question Type: Radio button (choose one)
   Response Options: I know of a friend, co-worker, or family member that has used this service; I have used this service; I currently use this service regularly; I am interested in using this service in the future; I have never used this service before; not applicable
2. Please select the response that best reflects your familiarity with shared ride-hailing services such as UberPool and Lyft Line.
   Question Type: Radio button (choose one)
   Response Options: I know of a friend, co-worker, or family member that has used this service; I have used this service; I currently use this service regularly; I am interested in using this service in the future; I have never used this service before; not applicable
3. Please select the important factor that influenced your first-time use of ride-hailing services (Uber, Lyft).
   Question Type: Check box (choose all that apply)
   Response Options: Heard from a friend who used, Heard from a co-worker who used, Heard from a relative who used; learned from television/radio; learned from newspapers; learned from the internet; not applicable

Importance Questions:

1. Please indicate the importance that you place on the following attributes when using or you are considering using public transit. Factors: weather, cost of parking, difficulty finding parking, travel time, waiting time, reliability, safety.
   Question Type: Matrix of radio buttons (choose one for each row)
   Response Options: Unimportant; somewhat unimportant; neutral; somewhat important; and important
2. Please indicate the importance that you place on the following attributes when using or you are considering using a ride-hailing service. Factors: weather, cost of parking, difficulty finding parking, travel time, reliability, comfort, safety, cost, convenience, availability of transit service.
   Question Type: Matrix of radio buttons (choose one for each row)
   Response Options: Unimportant; somewhat unimportant; neutral; somewhat important; and important

Agree/Disagree Questions:

1. If I am late for an appointment or meeting, I am more likely to use a ride-hailing service than public transit.
   Question Type: Radio button (choose one)
   Response Options: Strongly disagree; disagree; neutral; agree; strongly agree
2. Ride-hailing services are generally more reliable than public transit
   Question Type: Radio button (choose one)
   Response Options: Strongly disagree; disagree; neutral; agree; strongly agree
3. I am more likely to use ride-hailing services when it is raining or snowing.
   Question Type: Radio button (choose one)
   Response Options: Strongly disagree; disagree; neutral; agree; strongly agree
4. Between 10 pm and 6 am, I feel safer when using a ride-hailing service than I do when using public transit
   Question Type: Radio button (choose one)
   Response Options: Strongly disagree; disagree; neutral; agree; strongly agree

APPENDIX B – ASSUMPTIONS AND CALCULATIONS FOR SP DESIGN

<u>Assumptions:</u>
Trip Distance [taken from (Weiss, Salehin, & Habib, 2019)]:
- **Motorized modes:** 15 km
- **Non-motorized modes:** 3 km

Base Values for Travel Speeds:
- **Motorized modes:** 45 km/h
- **Biking:** 18 km/h
- **Walking:** 5 km/h
- **Transit:** 40 km/h
- **Walking:** 3 km/h

<u>Attribute Levels – Travel Times:</u>
Private Auto Modes (incl. taxi and ride-hailing):

Level	Value (mins)	Rationale
1.0	20	Baseline value, calculated based on 45 km/h travel speed
1.3	26	Based on the travel time index for Toronto in 2016 reported in (TomTom, 2017) - 30%
1.7	35.2	Based on the buffer time index for Toronto in 2014 reported in (McMaster Institute for Transportation and Logistics, 2015) - 30%

N.B. The travel time for shared ride-hailing services is assumed to be 13% longer than that of exclusive ride-hailing services, based on the median ratio of the travel times of shared to exclusive ride-hailing services

Bicycling:

The upper and lower levels were calculated based on the results obtained by (El-Geneidy, Krizek, & Iacono, 2007), who found that the coefficient of variation of bicycle speeds in their study was around 28%. ± 25% was used to ensure that the values were round numbers.

Level	Value (mins)	Rationale
0.75	7.5	75% of the baseline
1.0	10	Calculated based on the 18 km/h speed used in (Weiss, Salehin, & Habib, 2019)
1.25	12.5	125% of the baseline value

Walking:

The upper and lower levels were calculated based on the results of (Bohannon, 1997), who found that the coefficient of variation of waling speed varied from 0.65 to 0.17. ± 20% was used for convenience.

Level	Value (mins)	Rationale
0.8	28.8	80% of the baseline
1.0	36	Calculated based on the 5 km/h baseline speed
1.20	43.2	120% of the baseline value

Public Transit:

Attribute levels for travel times using public transit vary among different studies, as shown in the table below. Based on these values, 1.5 and 2.0 were chosen as attribute levels.

Levels	Source
[0.5,1.0,1.5]	(Frei, Hyland, & Mahmassani, 2017)
[0.9,1.5,1.75]	(Idris, Habib, & Shalaby, 2014)
[0.7, 0.85, 0.95, 1, 1.05, 1.15, 1.20, 1.5]	(Danaf, et al., 2019)
[0.7, 0.75, 0.8, 1.2, 1.25 1.3]	(Arentze & Molin, 2013)

Level	Value (mins)	Rationale
1.0	23	80% of the baseline
1.5	34.5	Calculated based on the 5 km/h baseline speed
2.0	46	120% of the baseline value

<u>Attribute Levels – Travel Cost:</u>
Exclusive and Shared Ride-hailing :

The base price of an exclusive ride-hailing trip was based on the $0.18/min and $0.81/km value cited in (Weiss, Salehin, & Habib, 2019). Based on the distance and travel time of the hypothetical trip, this works out to $1.05/km. The price of shared ride-hailing services were assumed to be two-thirds of the price of exclusive services, based on looking up the prices of different trips in the Uber app. The upper threshold of 1.5 was based on (Frei, Hyland, & Mahmassani, 2017). The intermediate value of 1.25 is based on the potential for surge pricing, which would increase the cost of using ride-hailing services beyond the baseline value.

Level	Value ($)	Rationale
1.0	15.75 or 10.50	Calculated based on baseline cost
1.25	19.96 or 13.13	Chosen based on the potential for surge pricing
1.5	23.63 or 15.75	Based on the value used in (Frei, Hyland, & Mahmassani, 2017)

Drive Yourself:

The baseline cost of driving is taken as $0.36/km, as reported in (Weiss, Salehin, & Habib, 2019). The three levels were chosen based on the level of driving costs used in (Frei, Hyland, & Mahmassani, 2017).

Level	Value ($)	Rationale
0.5	2.7	Based on values used in (Frei, Hyland, & Mahmassani, 2017)
1.0	5.4	
1.5	8.1	

Driven by Someone You Know:

In (Bhat & Sardesai, 2006), the ratio of the cost of a shared ride to that of driving alone can take on four levels: 40%, 50% 60%, and 70%. 50% was chosen as the baseline value for simplicity. The upper and lower levels were set at ± 20%, due to 40 is 20% less than 50 and 60 being 20% greater than 50.

Level	Value ($)	Rationale
0.8	2.2	80% of the baseline
1.0	2.7	Selected as the baseline value, based on (Bhat & Sardesai, 2006)
1.2	3.2	120% of the baseline value

Taxi:

The baseline value for the cost of a taxi ride was based on the pricing scheme reported in (Co-op Cabs, 2016):
Fare = $4 + 1.75/km + 0.5/ min waiting

The approach to defining the upper and lower levels was the same as the approach used for the *Driven by Someone You Know* mode.

Level	Value ($)	Rationale
0.8	24.20	80% of the baseline
1.0	30.25	Selected as the baseline value, based on (Co-op Cabs, 2016)
1.2	36.30	120% of the baseline value

Public Transit:

Set to $3.10, the current adult fare for the TTC when using a Presto card (Toronto Transit Commission, 2019).

Attribute Levels – Waiting Times:
Public Transit:

For higher-frequency transit services, and assuming random arrivals at stops and stations, the waiting time is assumed to be 50% of the route headway. From the Service Design Guidelines set out by the TTC, the minimum headways for different types of services are 6, 10, 15, and 30 mins (Toronto Transit Commission, 2017). Based on this standard, values of 2.5, 5, and 7.5 minutes are used.

Ride-hailing and Taxi:

Values of 2, 5, and 8 minutes were assumed, based on the values used in (Weiss, Salehin, & Habib, 2019).

Attribute Levels – Walking Times:
Public Transit:

The baseline value of 5 minutes was taken from the Service Design Guidelines set out by the TTC, who design the "base network" to ensure that 90% of population and employment are within a 5-minute walk of a transit stop (Toronto Transit Commission, 2017). For minutes were added and subtracted to create the largest possible gap between the lower and baseline values. Thus, values of 1, 5, and 9 minutes were used.

Attribute Levels – Parking Costs:
Drive Yourself:

The levels for this attribute were based on the levels used for the travel costs for the *Drive Yourself* mode. Consequently, 0.5, 1.0, and 1.5 were used as levels.

Attribute Levels – Other Passengers:
Shared Ride-hailing :

Based on the standard five-seat car that is used for Uber X and Lyft Classic trips, four possible levels are possible. Due to the desire to maintain attribute level balance, only three levels are used. In order to account for cases where a trip with a shared ride-hailing service does not require additional passengers to be picked up, values of 0, 1, and 2 additional passengers were used.

Attribute Levels – Detour Time:
Shared Ride-hailing :

The values used in the SP experiment design of (Weiss, Salehin, & Habib, 2019) were combined with the approach using by (Yan, Levine, & Zhao, 2018). The detour time was dependent on the number of additional passengers, with each additional passenger resulting in four minutes of detour time.

Public Transit:

The choice of values for the additional travel times experienced by riders was based on the on-time performance standards published by the TTC in (Toronto Transit Commission, 2017). Using the headway deviation standards set out in the design standards, values of 1, 5, and 9 minutes were used.

<u>Attribute Levels – Level of Crowding</u>
Public Transit:

Three levels of crowding were chosen, in order to capture the value that respondents place on comfort and the ability to find a seat after boarding the transit vehicle. The levels are:

- No crowding (can always get a seat),
- Moderately crowded (50% chance of getting a seat), and
- Highly crowded (25% chance of getting a seat)

<u>Attribute Levels – Frequency of Delays over 5 minutes:</u>
Public Transit:

Three levels were chosen for this attribute, which is meant to represent different levels of perceived reliability. The levels are:

- Delays are rare,
- Once a week, and
- Once a month