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How has the COVID-19 pandemic affected the use of ride-sourcing services? An empirical evidence-based investigation for the Greater Toronto Area

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ABSTRACT

The ongoing COVID-19 pandemic has fundamentally changed the nature of day-to-day life in cities worldwide. In the transportation sector, COVID-19 appears to have impacted modal preferences. In particular, people seem to be less willing to use modes where they may encounter strangers (such as public transit) and modes that involve coming into contact with shared surfaces (such as ride-sourcing). Given the transformative impact that ride-sourcing services had on urban mobility before the pandemic, it is crucial to understand the effects of COVID-19 on the use of ride-sourcing moving forward. Using data from a web-based survey, this study combines descriptive analysis with the application of a two-stage ordered logit model framework to investigate the impacts of COVID-19 on the utilization of ride-sourcing services in the Greater Toronto Area, including how often ride-sourcing is used and the earliest stage of the pandemic that a person would consider using ride-sourcing. Generally speaking, the use of ride-sourcing has decreased since the start of the pandemic, however, there are also people who are using ride-sourcing more often than they did before the pandemic. The results indicate that the perception of risk, the tendency to take precautions when leaving home, and socio-economic factors influence the earliest stage of the pandemic where a person would consider using ride-sourcing. Overall, it appears that ride-sourcing usage will gradually increase as restrictions are lifted; however, it is unlikely to return to pre-pandemic levels until COVID-19 is no longer considered a public health threat.

1. Introduction

The ongoing threat posed by the novel coronavirus disease-2019 (COVID-19) has fundamentally transformed daily life in cities throughout the world. To help curb the spread of COVID-19, many jurisdictions have closed schools, placed limits on mass gatherings, instituted shelter-in-place orders, and encouraged companies to allow their employees to work remotely ([Government of Canada, 2020](#); [International Monetary Fund \(IMF\), 2020](#)). In many jurisdictions, it appears that governments are poised to ease some or all of these restrictions while COVID-19 remains a public health threat ([Tardivo et al., 2020](#)). To ensure the safety of their customers during the COVID-19 pandemic, public transit agencies and transportation network companies (TNCs) have both modified their operations.

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Specifically, transit agencies have instituted rear door boarding policies and limited vehicle occupancy to allow passengers to practice social distancing (American Public Transportation Association (APTA), 2020). TNCs, on the other hand, have suspended their shared services (such as UberPool and Lyft Shared) (Bellon, 2020), and have begun requiring that both drivers and passengers wear face coverings (Bussewitz & Koenig, 2020).

Despite these measures, it appears that COVID-19 has significantly impacted travel behaviour, particularly mode choice. Early studies into the impacts of COVID-19 on modal preferences have found a reduced willingness to use modes where there is the potential for encounters with strangers over the course of the trip. Specifically, it appears that the pandemic has resulted in an increased use of private vehicles and active modes (i.e., walking and bicycling) (Molloy, 2020a; Sung & Monschauer, 2020) and a decreased use of public transit (Bliss, 2020) and ride-sourcing services (Heater, 2020). This shift comes at a time where shared modes, including ride-sourcing and bike-sharing, continue to increase in both prevalence and utilization (Shared-Use Mobility Center, 2018). Shared modes, particularly ride-sourcing services (such as those offered by Uber and Lyft), have had a transformative impact on travel behaviour and urban mobility.

Given the impacts that the availability of ride-sourcing services has already had on travel behaviour, it is imperative to understand the short- and long-term impacts of COVID-19 on the utilization of ride-sourcing. This paper presents the results of an investigation that explored the impacts of the COVID-19 pandemic on the use of ride-sourcing in the Greater Toronto Area (GTA), using data from a web-based survey. The findings in this paper are based on a descriptive analysis of the survey responses and the estimation of two two-stage ordered logit models pertaining to the earliest stage of the pandemic that a person would consider using ride-sourcing. Due to the speed at which the COVID-19 situation continues to develop, it is essential to understand how the willingness to use ride-sourcing during the COVID-19 pandemic is impacted by attitudes and perceptions. The results of this paper aim to provide insights into the impact of COVID-19 on the use of ride-sourcing and the impacts of socio-economic and attitudinal variables on the earliest stage of the pandemic that a person would consider using ride-sourcing. These insights can be used to inform policies and decisions regarding the management of the transportation network and the operation of public transit during the COVID-19 pandemic.

The remainder of the paper is organized as follows: Section 2 presents a summary of pertinent literature. Section 3 describes the web-based survey through which the data for this study were collected. Section 4 summarizes the findings of the analysis of the questions in the survey pertaining to the use of ride-sourcing and perceptions regarding the COVID-19 pandemic. Section 5 presents the formulation and final specifications of the empirical models. Section 6 discusses the possible policy implications of the findings of empirical investigations. Finally, the paper concludes with a summary of key findings and recommendations for further research.

2. Literature review

When ride-sourcing was first introduced, it was a relatively novel mode of travel that was made possible by advancements in information and communications technology (ICT) and web-based payment methods (Asgari et al., 2018). Ride-sourcing services, sometimes referred to as on-demand ride or ride-hailing services (Alemi, Circella, & Sperling, 2018), typically allow customers to request and pay for a ride using a smartphone application. These services provide users with on-demand access to a private vehicle, creating the potential for ride-sourcing to act as an “accessibility enhancer” for people who cannot drive or who do not own a vehicle (Lavieri & Bhat, 2019). In the past several years, ride-sourcing has continued to grow in prevalence and popularity, as evidenced by the growth of both the number of users and the number of cities in which ride-sourcing is offered (Tirachini, 2019). As its utilization continues to grow, it is clear that ride-sourcing has had a transformative impact on urban mobility. Consequently, there is a growing body of literature that aims to understand the factors affecting the utilization of ride-sourcing and the impacts of these services on travel behaviour.

Studies concerning ride-sourcing have covered a variety of topics, including adoption, the types of trips made using ride-sourcing, the generation of trips, and the impacts of ride-sourcing on travel behaviour. This portion of the literature review focuses on two topics – the impacts of ride-sourcing services on travel behaviour and the incorporation of attitudinal variables in econometric models of ride-sourcing utilization. For a comprehensive review of ride-sourcing studies, readers are referred to Tirachini (2019). The transformative nature of ride-sourcing primarily stems from their impacts on travel behaviour. Prior studies on the topic have found that ride-sourcing services can affect activity patterns and schedules (Alemi, Circella, Mokhtarian, et al., 2018), induce travel demand (Clewlow & Mishra, 2017) and affect the utilization of existing travel modes (Wang & Yang, 2019). In summary, it appears that ride-sourcing has affected how, when, and to a certain extent, why people travel.

Several studies have found that the availability of ride-sourcing tends to induce travel demand that would not have been realized otherwise. This is partially due to ride-sourcing being regarded as a relatively secure mode of travel, which can embolden users to participate in nighttime activities that they would not engage in otherwise (Tirachini, 2019). The relative ease with which a trip can be requested and paid for may also contribute to the potential for ride-sourcing to induce demand (Oviedo et al., 2020). Investigations into whether the availability of ride-sourcing influences travel demand are often carried out using purpose-specific surveys that include questions about how ride-sourcing trips would be made if these services were not available. For example, using data obtained from respondents in California, Rayle et al. (2016) (using data from an intercept survey in San Francisco) and Alemi, Circella, & Sperling (2018) (using data from the California Millennials Dataset) both found that roughly 8% of respondents would not have made a recent ride-sourcing trip had the service not been available.

As ride-sourcing grows in popularity and utilization, it tends to affect the usage of traditional travel modes. Broadly speaking, ride-sourcing is often found to be a substitute for public transit, taxis, and private vehicles (Tirachini, 2019), although some studies have found that ride-sourcing also replaces trips made by active modes (Lavieri & Bhat, 2019). As a competitor, ride-sourcing tends to adversely impact the taxi industry, partly due to lower costs, shorter wait times, and the ease of requesting a ride (Lavieri & Bhat, 2019;

Wang & Yang, 2019). The relationship between ride-sourcing and transit, however, is more complex. Although ride-sourcing has the potential to cannibalize ridership, several studies have found evidence of a complementary relationship between the two modes. For example, Clewlow & Mishra (2017) found that ride-sourcing may draw patronage away from bus services while complementing commuter rail services. Overall, there appears to be an imbalance in the extent to which ride-sourcing complements and is a substitute for transit (Tirachini, 2019).

Contemporary studies have tried to understand the role that attitudinal factors play in the use of ride-sourcing. Given the novelty of these services, analyzing attitudinal variables can provide valuable insights into the decision-making process (Bahamonde-Birke et al., 2017). One example of this is Alemi, Circella, Handy, et al. (2018), who incorporated attitudinal variables in their binary logit model of ride-sourcing adoption using data from the California Millennials Dataset. The authors identified three attitudinal factors (“technology-embracing”, “variety-seeking”, and “pro-environmental policies”) that helped improve the explanatory power of their model. Addressing a similar question, Acheampong et al. (2020) estimated a structural equation model to understand the factors influencing ride-sourcing adoption among residents of major cities in Ghana. The authors found that the perceived benefits and safety risks of using ride-sourcing played important roles in the decision-making process. Aside from adoption, latent attitudinal factors have been used to provide insights into the experience that a person has with ride-sourcing and the frequency with which they used ride-sourcing. Using data from the Dallas – Fort Worth area, Lavieri & Bhat (2019) estimated a Generalized Heterogenous Data Model and found that latent variables pertaining to privacy sensitivity affected the utilization of pooled services, while those who were more tech-savvy and led variety-seeking lifestyles were more likely to have experience with both private and pooled ride-sourcing. Living a variety-seeking lifestyle was also positively associated with the frequency with which a person used ride-sourcing services.

Due to its unprecedented nature, the impacts of the COVID-19 pandemic on the utilization of ride-sourcing are only beginning to be understood. Based on the danger and uncertainty surrounding COVID-19, this study focuses on perceptions of risk and safety, which are believed to have a significant impact on individual behaviours (Rossetti et al., 2018). Specifically, this study incorporates attitudinal variables into the empirical models through the use of factor scores. This paper aims to contribute to the literature by applying a two-stage ordered logit model framework to investigate the impacts of attitudinal factors on the decision to consider using ride-sourcing services during the pandemic. Given the transformative effects that ride-sourcing has had on travel behaviour, it is important to understand how the ongoing threat posed by COVID-19 will affect the utilization of ride-sourcing during the pandemic and beyond. The development of empirical models can provide insights into the influence of perceptions and socio-economic attributes on the consideration of using ride-sourcing services. Additionally, analyzing the responses provided by the respondents can provide insights into the manner in which the COVID-19 pandemic has affected the use of ride-sourcing. These insights can be used to inform transportation policies and the management of the transportation system during the COVID-19 pandemic.

3. The survey

3.1. Survey design and study area

The data for this study was collected as part of the *Study into the use of Shared Travel Modes* (SiSTM). The two primary goals of SiSTM were to investigate the impacts of the COVID-19 pandemic on the propensity to use shared travel modes (particularly ride-sourcing) and to understand the influence of attitudinal factors on said impacts. A key component of SiSTM was the administration of a survey that targeted residents of the GTA. Composed of four regional municipalities (York, Durham, Peel, and Halton) and the City of Toronto, the GTA was home to approximately 6.4 million residents, per the 2016 Canadian census (City of Toronto, 2017). The SiSTM survey was conducted in July 2020 through a web-based survey interface. The link to the survey was sent to a market research company, who invited a random sample of the members of its consumer panel who live in GTA to complete the survey. A residential location quota was utilized to ensure that the distribution of the home region of the respondents was consistent with that of the population of the GTA. Upon completion of the survey, participants were provided with non-monetary compensation by the market research company. For more information on the SiSTM survey, see Loa et al. (2020).

To support the goals of SiSTM, the survey collected a variety of information from the respondents. In order to help examine the potential short- and long-term impacts of the COVID-19 pandemic on ride-sourcing use, the study period was divided into three distinct time periods:

- **The pre-COVID period:** defined as the period of time prior to declaration of a state of emergency in Ontario (March 17, 2020),
- **The COVID recovery period:** defined as the period of time between the declaration of a state of emergency and the point in time where COVID-19 is no longer considered a public health threat, and
- **The post-COVID period:** defined as the period of time where COVID-19 is no longer considered a public health threat

Aside from socio-economic and household information, the survey also collected information on how COVID-19 has impacted the lives of the respondents and the travel mode(s) that they used prior to and during the pandemic. Respondents were also asked several questions regarding their use of ride-sourcing, including how often they used ride-sourcing before and during the pandemic, the impacts of the pandemic on their use of ride-sourcing, and the potential impacts of various health and safety measures on their willingness to use ride-sourcing. Additionally, respondents were asked to complete two sets of attitudinal questions and stated preference experiments – pertaining to the COVID recovery period and the post-COVID period. Throughout the survey, the distinction was made between exclusive ride-sourcing services (such as UberX and Lyft Classic) and shared ride-sourcing services (such as UberPool and Lyft Shared), due to the potential for the latter to match users with another customer that is travelling in the same direction

(Brown, 2020).

3.2. Sample description

The survey received 1250 responses, 1001 of which were complete. After logic checks were applied, the residential postal codes provided by the respondents were inspected to ensure that they were located in the GTA, and the responses were cleaned, a total of 920 responses remained. Key descriptive statistics are shown in Table 1. Comparisons between the distributions of home location, age, gender, and household income between the survey sample and the 2016 Canadian census are presented in Figs. 1 and 2.

In Fig. 1, it is observed that the proportion of respondents from the City of Toronto and Halton Region are representative of the study area. However, York and Peel Regions are slightly over-represented in the sample data, whereas Durham Region is under-represented. The gender distribution is fairly similar between the sample and census data, although females are slightly over-represented in the sample. With regard to age, the percentage of persons between the ages of 20 and 50 is significantly higher in the sample than in the study area. Meanwhile, people who are 65 and older are under-represented in the sample data. This is expected, given that the data were collected using a web-based survey that was administered to a consumer panel maintained by a market research company. The average age of the respondents (41.8 ± 15.4 years of age) is consistent with the average age of the target population (39.7) (Statistics Canada, 2019). Additionally, persons from households that earn between \$40,000 and \$100,000 annually appear to be over-represented in the sample, while households earning less than \$40,000 or more than \$150,000 are under-represented.

In addition to basic socio-economic characteristics, respondents were asked to report the mode(s) that they used for commuting (defined as trips to work or school) and non-commuting trips, both prior to the pandemic and during the COVID recovery period. As shown in Fig. 3, compared to before the COVID-19 pandemic, the use of private vehicles and active modes increased, while the use of ride-sourcing, public transit, and taxi services decreased. This is consistent with trends from other cities and is likely due to a decreased willingness to spend time in shared public spaces (or in vehicles with common surfaces) and the desire to practice social distancing. The greatest decrease in utilization is observed for public transit, followed by taxi and ride-sourcing services.

4. Survey data analysis

An important aspect of the SiSTM survey was to collect information that could be used to understand the impacts that the COVID-19 pandemic had on the use of ride-sourcing. To help achieve this goal, respondents were asked, among other things, about their use of ride-sourcing before the pandemic and the impacts of the pandemic on their perceptions and use of ride-sourcing. Respondents were also asked several attitudinal questions regarding their perceptions of risk, their willingness to travel during the COVID recovery period, and their willingness to return to their normal routine during the COVID recovery period. The information from these questions provides valuable insights into the extent to which the pandemic has affected ride-sourcing use. The following section presents key findings from the ride-sourcing and attitudinal questions of the SiSTM survey.

Table 1
Basic personal and household characteristics.

		Mean	Std. Dev.
	Age	41.8	15.4
	Number of household members	2.79	1.45
	Number of household vehicles	1.40	0.88
	Number of household adult bicycles	1.05	1.16
Employment status during the COVID-19 pandemic	Full-time at workplace	27.3%	
	Full-time at home	25.5%	
	Full-time, hybrid workplace (home and workplace)	4.7%	
	Part-time at workplace	5.4%	
	Part-time at home	5.9%	
	Part-time, hybrid workplace (home and workplace)	0.8%	
	Not employed	26.1%	
	Other	4.3%	
Mobility tool ownership		Yes	No
	Driver's license	87.3%	12.7%
	Access to private vehicle	88.3%	11.7%
	Transit pass	42.3%	57.7%
Student status	Full-time student	11.5%	
	Part-time student	7.7%	
	No	80.8%	
Education level	Highschool or equivalent and below	17.5%	
	Trade certificate, college diploma or university certificate	33.5%	
	Bachelor's degree or above	49.0%	
Dwelling type	Single-detached house	50.1%	
	Semi-detached house	11.0%	
	Townhouse/ Row house	10.2%	
	Apartment	28.0%	
	Other	0.7%	

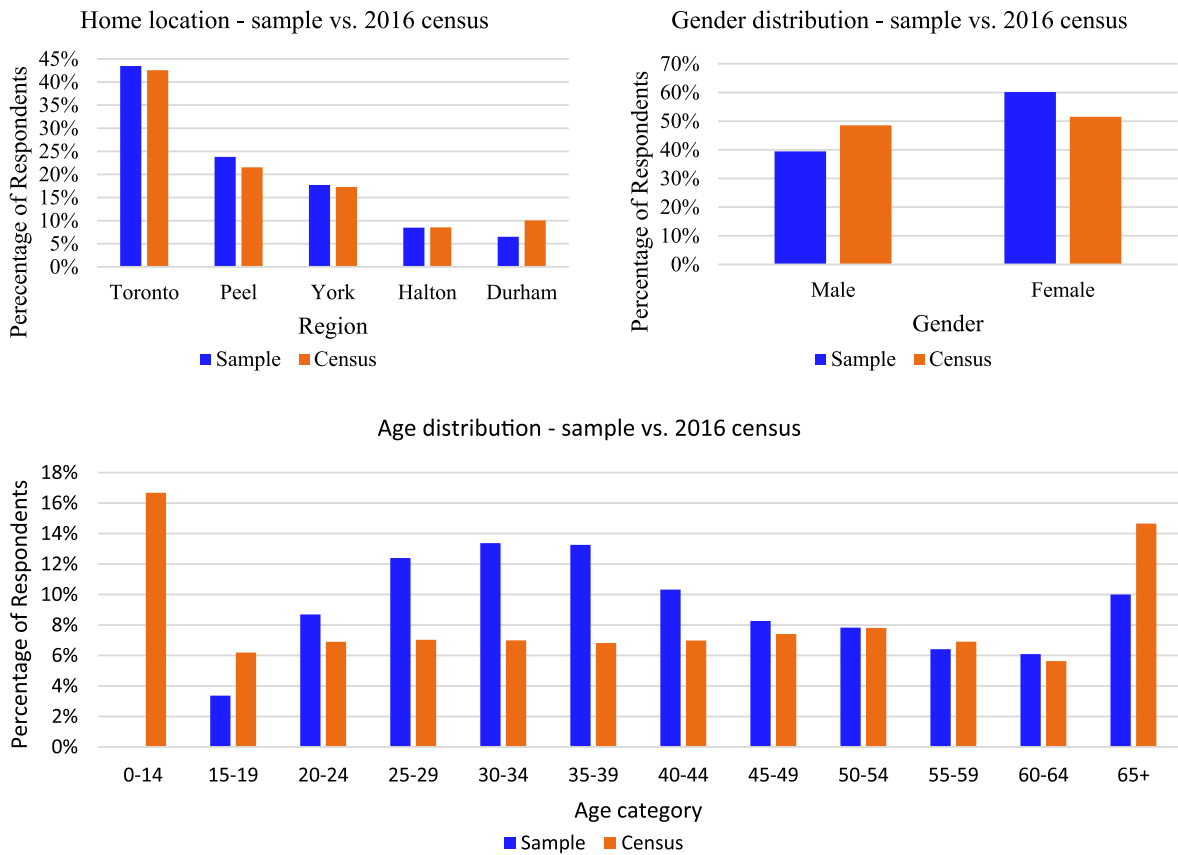


Fig. 1. Comparison of home location, gender, and age – sample vs. census.

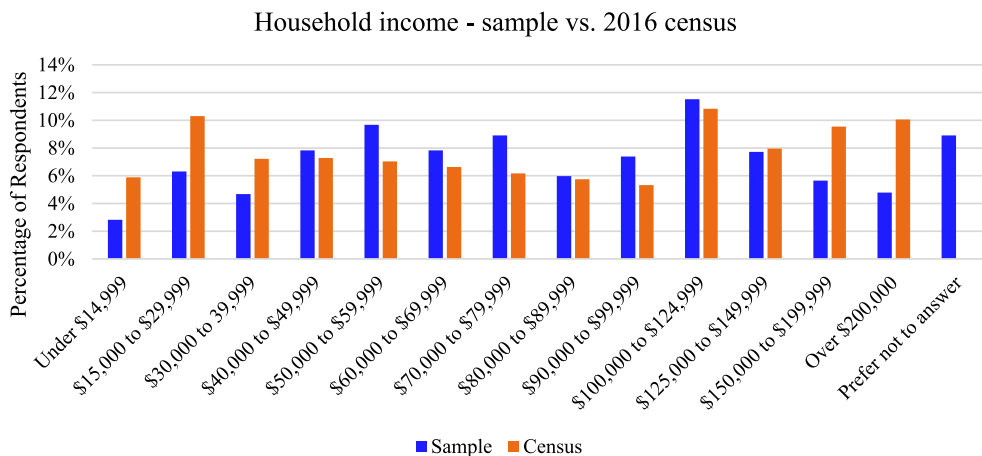


Fig. 2. Comparison of household income – sample vs. census.

4.1. Ride-sourcing use before the COVID-19 pandemic

As expected, a greater proportion of respondents had experience using exclusive ride-sourcing (54%) compared to shared ride-sourcing (43%) prior to the pandemic. Most respondents with ride-sourcing experience prior to the pandemic used these services relatively infrequently. However, 20% of respondents reported using exclusive ride-sourcing at least once per month, while 18% reported using shared ride-sourcing at the same frequency. As shown in Fig. 4, respondents primarily used ride-sourcing for commuting to work, visiting friends or family, and visiting restaurants, bars, and coffee shops.

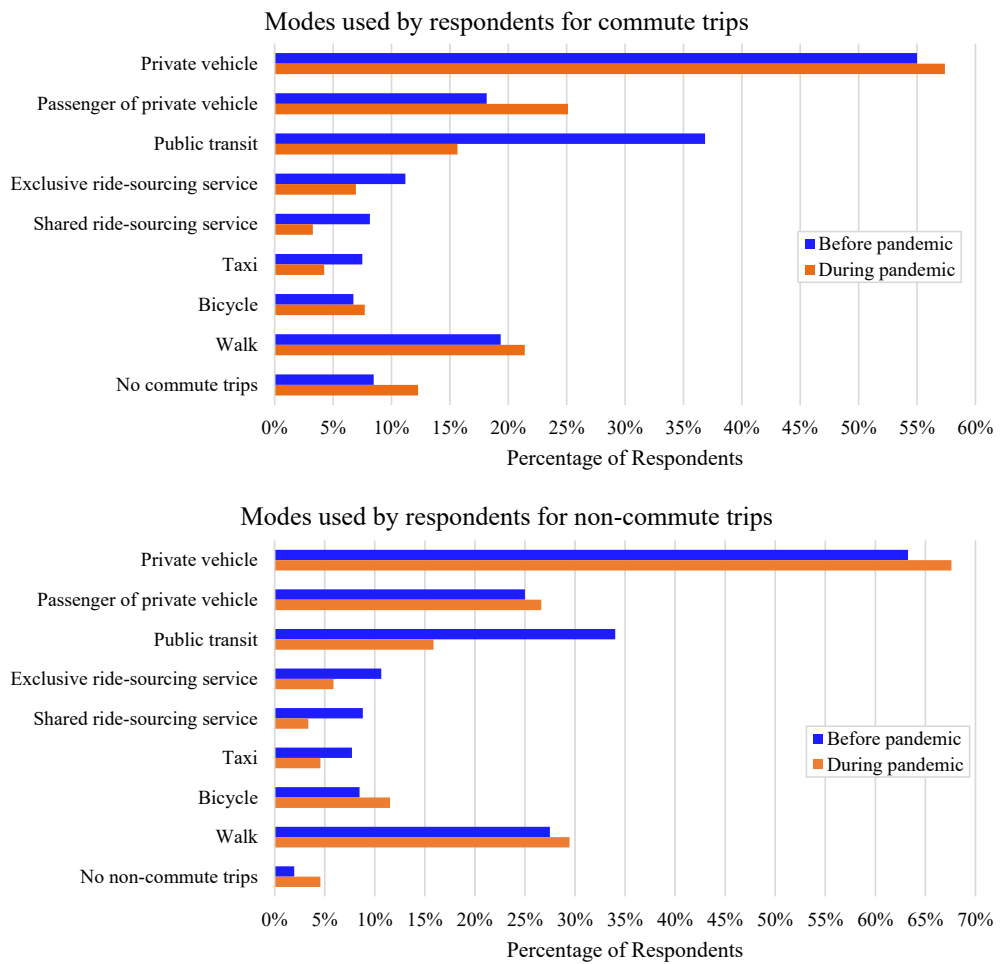


Fig. 3. Distribution of modes used by respondents for commuting and non-commuting trips.

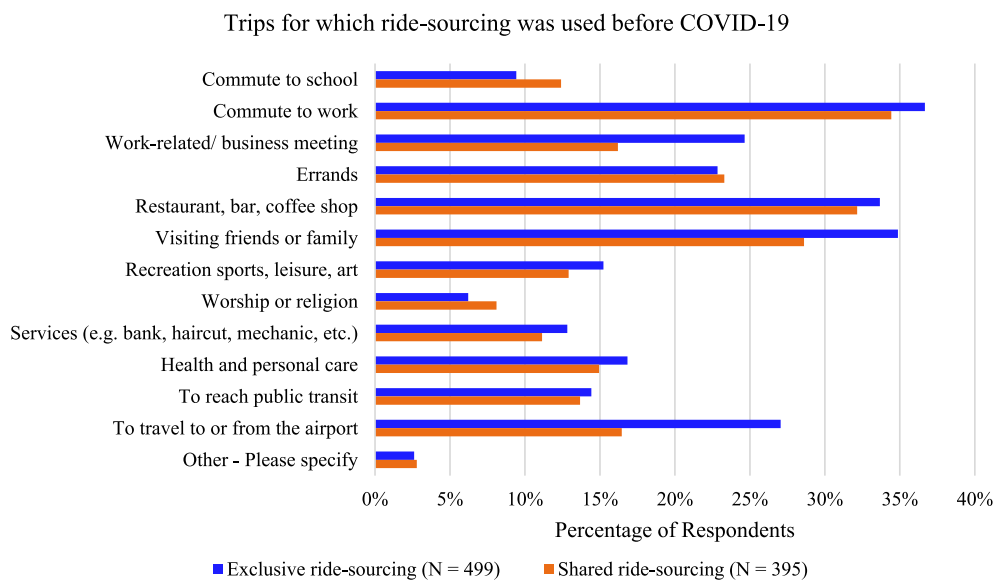


Fig. 4. Purposes of trips made using ride-sourcing, before the pandemic.

4.2. Impacts of the pandemic on ride-sourcing use

As shown in Fig. 5, the respondents appear to be using exclusive ride-sourcing less frequently than they did prior to the pandemic. This was the case for 33% of respondents, while 11% reported that they were using exclusive ride-sourcing more frequently and 56% reported no change (see Loa et al. (2021) for a more detailed discussion of the changes in ride-sourcing frequency). As part of the survey, respondents were asked to provide the reason(s) why their use of ride-sourcing changed. When asked why they are using exclusive ride-sourcing more often, roughly 30% of respondents indicated that public transit had become too unreliable, while 29% said that they were unable or unwilling to use public transit. This highlights the need for transit agencies to be mindful of both the frequency and reliability of the service that they provide. This could also suggest that transit ridership may be slow to return to pre-pandemic levels, even once COVID-19 is no longer considered a public health threat. Moreover, roughly 25% of those who increased their use of exclusive ride-sourcing did so because of a desire to avoid crowded vehicles or crowded areas. Among those who reported using exclusive ride-sourcing less often, over half did so because they were travelling less. Other reasons for this change include health concerns (47%), the desire to avoid shared spaces and surfaces (42%), and concerns about the cleanliness of the vehicles and the ability to practice social distancing (32% each). As long as these concerns exist, TNCs may face challenges when trying to attract customers to their services while COVID-19 is still considered a public health threat.

Based on the potential for COVID-19 to be transmitted person-to-person, respondents were asked about the impacts that the implementation of health and safety (H&S) measures would have on their willingness to use ride-sourcing during the COVID recovery period. 35% of respondents indicated that H&S measures would increase their willingness to use ride-sourcing during this period; the most popular measures were making masks mandatory for both passengers and drivers, having hand sanitizer and disinfectant wipes available in vehicles, and disinfecting vehicles after each trip. Interestingly, 80% of respondents said that they would like to see H&S measures implemented in ride-sourcing vehicles in the post-COVID period. This disparity can be attributed to respondents who are unwilling to use ride-sourcing during the COVID recovery period but who are willing to use ride-sourcing in the post-COVID period. Among these respondents, the most popular measures were having hand sanitizer available in vehicles, having a mandatory mask policy for drivers and passengers, and disinfecting vehicles after each trip. These results are likely a reflection of the apprehension of the respondents towards being in shared spaces and coming into contact with shared surfaces at the time of the survey.

As part of the survey, respondents were asked whether they would continue to use ride-sourcing after the COVID-19 pandemic and whether the frequency with which they use ride-sourcing would change once the pandemic is over. Among respondents who had ride-sourcing experience, 64% said that they would use exclusive ride-sourcing after the pandemic, while only 42% said the same about shared ride-sourcing. These respondents were asked to anticipate how often they will use ride-sourcing after the pandemic, compared to how often they used ride-sourcing before the pandemic. While the majority of respondents did not believe that the frequency with which they use ride-sourcing would change, 24% said that they would use exclusive ride-sourcing less often, and 18% said the same about their use of shared ride-sourcing. Fig. 6 summarizes the mode(s) that the respondents believe that they would use instead of ride-sourcing. The majority of these respondents indicated that they would use private vehicles (either as a driver or passenger), while a small portion also said that they would not make some of their ride-sourcing trips.

As these results have shown, COVID-19 has adversely affected the willingness to use ride-sourcing. As various jurisdictions take a phased approach to lifting restrictions that were implemented to slow the spread of COVID-19, the question of when people will start to consider using ride-sourcing remains. In the SiSTM survey, respondents were asked to indicate the earliest point in time that they would consider using exclusive and shared ride-sourcing. The options presented to the respondents were partially based on the framework for lifting restrictions that was developed by the Government of Ontario (Government of Ontario, 2020). The response options for these questions were as follows:

1. During stage 1 (select businesses that can maintain physical distancing re-open, non-urgent surgeries resume)

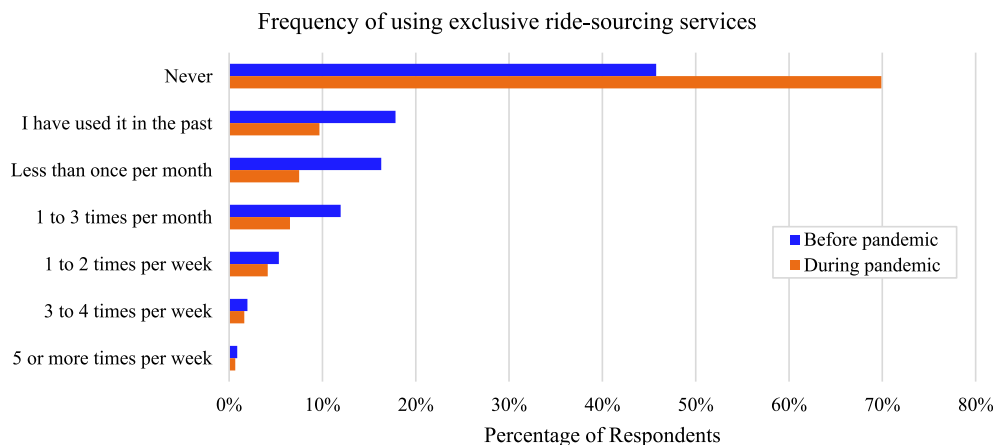


Fig. 5. Comparison of exclusive ride-sourcing frequency, before and during the pandemic.

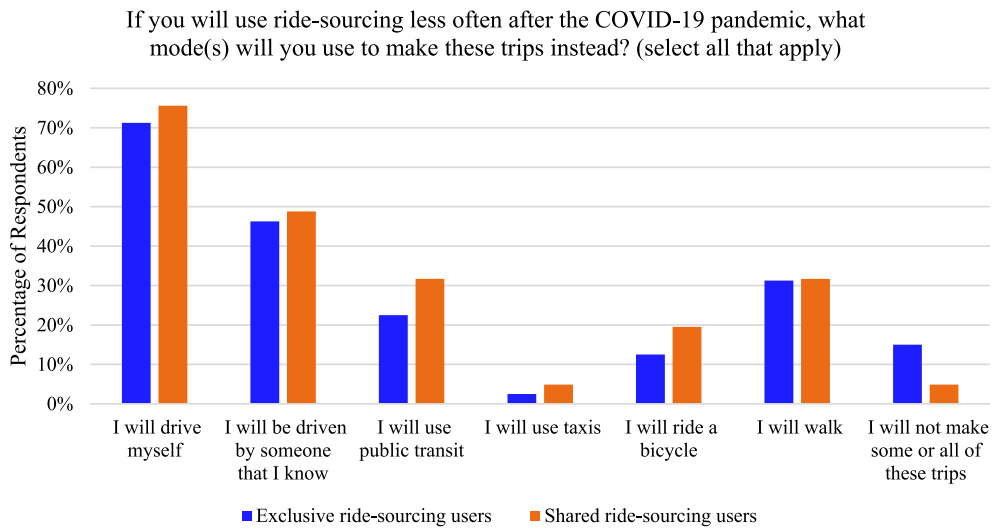


Fig. 6. Modes that would be used by respondents who will reduce their use of ride-sourcing after the COVID-19 pandemic.

2. During stage 2 (small public gatherings allowed; more workplaces re-open, physical distancing still required)
3. During stage 3 (all workplaces re-open, but physical distancing continues)
4. When a vaccine is discovered but is still being distributed
5. After I have been vaccinated, but before enough people have been vaccinated to formally end the crisis
6. After COVID-19 is no longer considered a public health threat due to mass vaccination
7. I will never use this service again

As shown in Fig. 7, over a quarter of the respondents indicated that they would not consider using ride-sourcing until the post-COVID period. In addition, the gradual lifting of restrictions appears to have a positive influence on the willingness to consider using ride-sourcing. This may be due to the impacts that the lifting of restrictions has on the perception of risk, or it could be the result of the need for some respondents to return to work as more businesses are allowed to re-open.

4.3. Attitudes and perceptions

In order to understand the impacts of attitudes and perceptions on the use of ride-sourcing during the COVID recovery period, respondents were asked several questions regarding their perceptions of risk, their willingness to spend time travelling, and their desire to return to their normal routines. These questions utilized a five-point Likert scale, with response options ranging from *strongly*

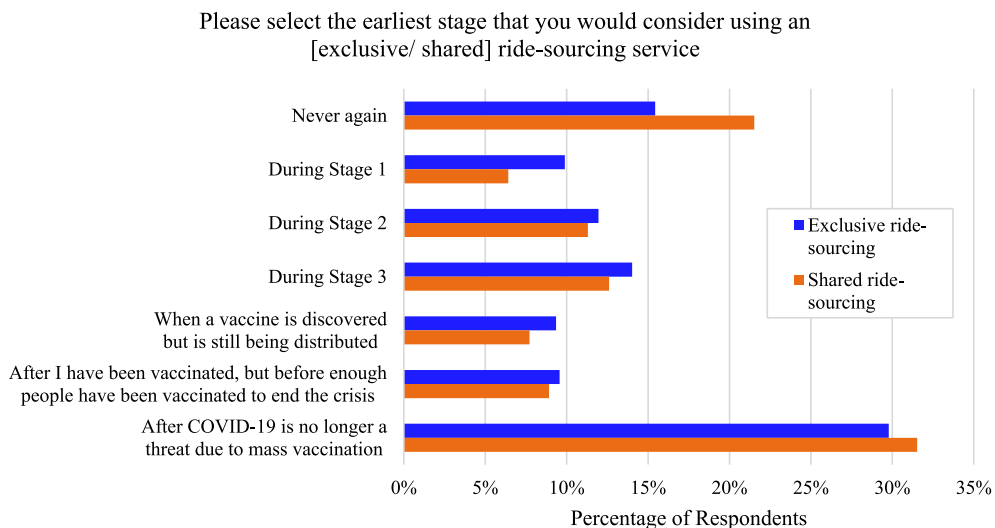


Fig. 7. Earliest stage where a respondent would consider using ride-sourcing.

disagree to strongly agree. The attitudinal questions asked respondents to indicate the extent to which they agreed with a series of statements pertaining to the period of time where COVID-19 is considered a public health threat (i.e., the COVID recovery period). The responses to these questions are summarized in Fig. 8. Broadly speaking, the majority of the respondents believe that there is increased risk associated with using modes that have common surfaces, including ride-sourcing and taxis. This is also reflected in the fact that less than one-quarter of respondents agreed that they would feel safe using a ride-sourcing or taxi service. In addition, the respondents appear to be less willing to travel and prefer to stay away from strangers when they do travel.

Using the responses to the attitudinal questions, factor analysis was applied to identify latent attitudinal factors. The “appropriate” number of latent attitudinal factors was determined through the use of parallel analysis, which compares the eigenvalues derived from the indicator variables (i.e., the responses to the attitudinal questions) to those derived from random data (Brown, 2006). Based on the results of the parallel analysis, exploratory factor analysis (EFA) was used to identify the relationships between the indicator variables and the latent attitudinal factors. The EFA was executed using the maximum likelihood approach, with the Promax transformation being applied to make the results easier to interpret. Factor loadings whose magnitudes were less than 0.4 were omitted. The factor analysis produced three latent attitudinal factors:

- **Factor 1:** Belief that the pandemic has increased the risk associated with using shared modes
- **Factor 2:** Comfort with resuming pre-pandemic travel during the pandemic
- **Factor 3:** Aversion towards travel due to the pandemic

The relationships between the attitudinal statements and the latent attitudinal factors are shown in Table 2. Once the latent attitudinal factors were defined, the Bartlett factor scores were calculated for each factor, based on the responses provided by each respondent. This allowed the attitudinal factors to be incorporated into the empirical model.

Respondents' Attitudes Pertaining to the COVID-19 Recovery Period

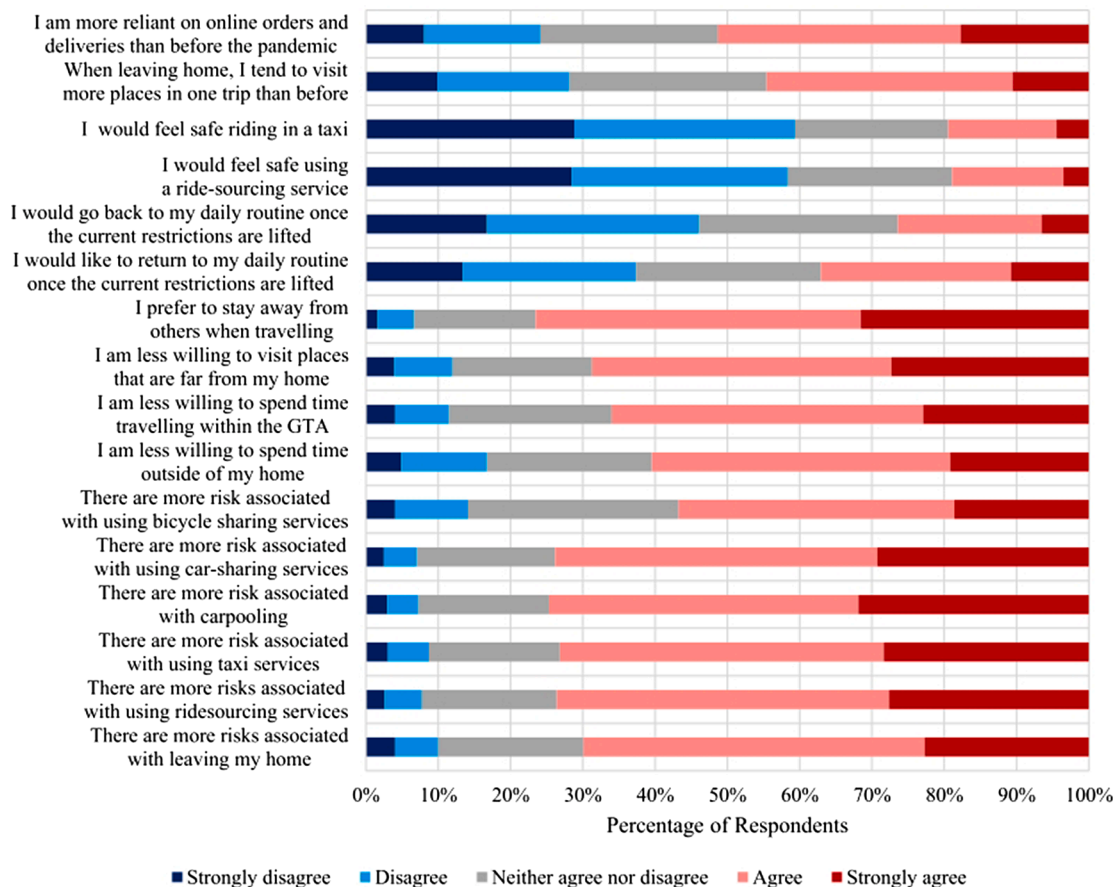


Fig. 8. Responses to attitudinal questions pertaining to the COVID recovery period (i.e., while COVID-19 is still considered a public health threat).

Table 2
Definition of the latent attitudinal factors and the corresponding attitudinal statements.

Factors and Relevant Attitudinal Statements	Factor Loading
Belief that the pandemic has increased the risk associated with using shared modes	
I believe there are more risks associated with leaving my home than before the pandemic.	0.539
I believe there is more risk associated with using ridesourcing services than before the pandemic.	0.889
I believe there is more risk associated with using taxi services than before the pandemic.	0.972
I believe there is more risk associated with carpooling than before the pandemic.	0.858
I believe there is more risk associated with using car-sharing services (e.g., Zipcar, Communauto) than before the pandemic.	0.800
I believe there is more risk associated with using bicycle-sharing services than before the pandemic.	0.574
Comfort with resuming pre-pandemic travel during the pandemic	
I would like to return to my daily routine once the current restrictions are lifted, even while COVID-19 is still considered a public health threat.	0.611
I will go back to my daily routine once the current restrictions are lifted, even while COVID-19 is still considered a public health threat.	0.692
I would feel safe using a ride-sourcing service while COVID-19 is still considered a public health threat.	0.881
I would feel safe riding in a taxi while COVID-19 is still considered a public health threat.	0.862
Aversion towards travel due to the pandemic	
I am less willing to spend time outside of my home than I was before the pandemic.	0.707
I am less willing to spend time travelling within the Greater Toronto Area than I was before the pandemic.	0.882
I am less willing to visit places that are far from my home than I was before the pandemic.	0.842
I prefer to stay away from others when I am travelling.	0.532

5. Empirical model

5.1. Model formulation

A direct reflection of the impacts of COVID-19 on the use of ride-sourcing services is the earliest point in time that customers would consider using ride-sourcing during the COVID recovery period. To investigate the factors that influence this decision, two-stage ordered logit (2SOL) models are developed for exclusive ride-sourcing and shared ride-sourcing services, using the responses shown in Fig. 7. The 2SOL model applied in this study is comprised of two components – a binary logit model and an ordered logit model. The binary logit model captures the factors influencing the likelihood of an individual indicating that they will never use ride-sourcing again. The ordered logit model is then used to examine the earliest stage of the COVID recovery period that a person would consider using either exclusive or shared ride-sourcing. This is represented using milestones in the COVID recovery period, including the gradual lifting of restrictions and the development of a vaccine (as outlined in Section 4.2).

The formulation of the econometric model is as follows. Let y_i represent the earliest stage of the COVID recovery period that individual i would consider using an exclusive or shared ride-sourcing service. The value of y_i can range from *I will never use this service again* ($j = 0$) to *After COVID-19 is no longer considered a public health threat due to mass vaccination* ($j = 6$). The first stage of the modelling framework determines the factors that influence the decision to never use exclusive or shared ride-sourcing services again (i.e., $y_i = 0$). Let the utility associated with individual i choosing to never use exclusive or shared ride-sourcing again be represented by U_i ; this utility can be decomposed into a systematic component (represented by V_i) and an unobserved component (represented by ε_i), where (Train, 2009):

$$U_i = V_i + \varepsilon_i \tag{1}$$

In the binary logit model, ε_i is assumed to follow the logistic distribution. The systematic component of U_i can be modelled as a function of socio-economic attributes, household characteristics, and latent attitudinal factors:

$$V_i = \Gamma' z_i \tag{2}$$

where Γ is a vector of parameters and z_i is a vector of explanatory variables for individual i . The probability of individual i choosing to never use an exclusive or shared ride-sourcing service again is given by (Train, 2009):

$$P(y_i = 0) = \frac{\exp(V_i)}{1 + \exp(V_i)} = \frac{\exp(\Gamma' z_i)}{1 + \exp(\Gamma' z_i)} \tag{3}$$

$$P(y \neq 0) = 1 - P(y_i = 0) \tag{4}$$

The second stage of the modelling framework examines the factors that influence the earliest stage of the COVID recovery period that an individual would consider using ride-sourcing. In the second stage of the model, the value of y_i can range from *During stage 1* ($j = 1$) to *After COVID-19 is no longer considered a public health threat due to mass vaccination* ($j = 6$). Because the outcome is ordinal in nature, the ordered logit framework was used to model this outcome. The ordered logit model that is utilized in the 2SOL models is based on a specific case of the generalized ordered logit model, in which separate parameters are not estimated for each outcome. In the ordered logit model, the probability of individual i providing response j , given that they are willing to consider using ride-sourcing during the COVID recovery period, is given by (Williams, 2006):

$$P(y_i = j | j \neq 0) = F(\alpha_{j-1} + \beta' x_i) - F(\alpha_j + \beta' x_i), j = 1, \dots, 6 \tag{5}$$

$$F(\alpha_j + \beta' x_i) = P(y_i > j) = \frac{\exp(\alpha_j + \beta' x_i)}{1 + \exp(\alpha_j + \beta' x_i)} \tag{6}$$

where α_j represents the value of the constant corresponding to outcome j , β is a vector of parameters, and x_i is a vector of explanatory variables for individual i . In this version of the ordered logit model, the constants play a role similar to that of the threshold parameters in the calculation of $P(y_i = j)$. The unconditional probability of individual i providing response j is then given by:

$$P(y_i = j) = \begin{cases} P(y_i = 0) & = \frac{\exp(\Gamma' z_i)}{1 + \exp(\Gamma' z_i)} & j = 0 \\ P(y_i \neq 0) * P(y_i = j | j \neq 0) & = \frac{1}{1 + \exp(\Gamma' z_i)} * [F(\mu_j - \beta' x_i) - F(\mu_{j-1} - \beta' x_i)] & j \neq 0 \end{cases} \tag{7}$$

The 2SOL models were estimated using a program written in GAUSS, using its maximum likelihood estimation application, *MaxLik 5.0* (Aptech Systems Inc., 2012).

5.2. Results

The development of the two models was informed by the findings of previous studies on the adoption and utilization of ride-sourcing services. A variety of variables pertaining to socio-economic attributes, household characteristics, and latent attitudinal factors were tested, as were several pandemic-related variables. The decision to include variables in the final model specification was made based on the sign and the t-statistic of the corresponding parameter. Overall, a large portion of the parameters in the two models were significant at the 95% confidence level; however, a few insignificant parameters were retained in the model due to the insights that they provided. The adjusted rho-squared values of the models pertaining to the consideration of using exclusive and shared ride-

Table 3
Final specification of the 2SOL model pertaining to exclusive ride-sourcing.

	Binary logit model (Stage 1)		Ordered logit model (Stage 2)	
	Estimate	t-stat	Estimate	t-stat
Latent Attitudinal Factors				
Belief that the pandemic has increased the risk associated with using shared modes	-	-	0.215	2.336
Comfort with resuming pre-pandemic travel during the pandemic	-0.208	-1.677	-0.813	-10.530
Aversion towards travel due to the pandemic	-	-	0.086	0.939
Personal and Household Characteristics				
Age	0.023	3.248	-	-
Person is 30 or younger (1 if yes, 0 otherwise)	-	-	-0.109	-0.633
Person is 60 or older (1 if yes, 0 otherwise)	-	-	0.439	1.808
Person is currently a student (1 if yes, 0 otherwise)	-	-	-0.288	-1.490
Highest level of education: Bachelor's degree or higher (1 if yes, 0 otherwise)	-0.469	-2.211	-	-
Number of household vehicles	-	-	0.146	1.914
Household owns more than one vehicle (1 if yes, 0 otherwise)	0.306	1.408	-	-
Living status: Non-family adults living together (1 if yes, 0 otherwise)	-	-	-0.508	-2.052
Ride-sourcing-related Variables				
Experience using exclusive ride-sourcing prior to pandemic (1 if yes, 0 otherwise)	-2.417	-7.078	-0.469	-3.135
Pandemic-related Variables				
Person indicated that health and safety measures would make them more willing to use ride-sourcing during the COVID recovery period (1 if yes, 0 otherwise)	-1.474	-4.001	-0.804	-5.278
Person always wears a mask or face covering when going out (1 if yes, 0 otherwise)	-	-	0.641	3.951
Person believes that social distancing is essential to control the spread of COVID-19 (1 if yes, 0 otherwise)	-	-	0.597	1.967
Person is going about their normal routine without social distancing (1 if yes, 0 otherwise)	-	-	-0.545	-1.560
Constants and Threshold Parameters				
Constant	-1.708	-4.074	-	-
$\alpha(1)$	-	-	2.440	6.915
$\alpha(2)$	-	-	1.149	3.247
$\alpha(3)$	-	-	0.035	0.100
$\alpha(4)$	-	-	-0.632	-1.781
$\alpha(5)$	-	-	-1.325	-3.713
Model Fit Statistics				
Number of observations	920			
Loglikelihood of constants-only model	-1705.16			
Loglikelihood of final model	-1389.63			
ρ^2 (Adjusted ρ^2)	0.224 (0.210)			
BIC	2949.87			

sourcing were 0.210 and 0.223, respectively; both values are indicative of relatively good model fit. A key assumption when utilizing an ordered logit model is that the parallel regression assumption holds. This assumption, which gives rise to the proportional odds restriction, allows the probability of observing a given ordinal outcome to be modelled using a single regression equation (Greene & Hensher, 2010). If this assumption is violated, the implication is that a generalized ordered logit model (which allows separate regression equations to be estimated for each ordinal outcome) would be a more appropriate modelling framework. To ensure that the parallel regression assumption was not violated, the Brant test was applied to the two ordered logit models (Brant, 1990). The final specifications of the 2SOL models pertaining to the consideration of using exclusive and shared ride-sourcing are summarized in Table 3 and Table 4, respectively.

5.2.1. Binary logit model

The binary logit component of the 2SOL model suggests that the decision to consider using exclusive and shared ride-sourcing services during the COVID recovery period is affected by several factors. In particular, older individuals and individuals from households that own more than one vehicle are more likely to indicate that they would never use exclusive or shared ride-sourcing again. The former can be attributed to the tendency for ride-sourcing use to be less prevalent among older individuals, while the latter is likely due to the ability of individuals from households with multiple vehicles to either drive themselves or be driven by another member of their household (Grahm et al., 2020; Zhang & Zhang, 2018). In both cases, these individuals may be more willing to abstain from using ride-sourcing because they do not rely on these services to satisfy their mobility needs. Additionally, individuals who did not use exclusive or shared ride-sourcing services during the pre-COVID period were more likely to indicate that they will never use these services, all else being equal. This could suggest that the growth in the number of customers served by TNCs in the post-COVID period will be less than that of the pre-COVID period. Given that the availability of ride-sourcing services has been found to affect activity-travel behaviour, congestion, and emissions (Erhardt et al., 2019; Schaller, 2021), changes in the utilization of ride-sourcing has the potential to have system-level impacts on the transportation network. Additionally, the potential adverse impacts of the pandemic on the adoption of shared ride-sourcing services could limit the benefits of these services, which include increased vehicle occupancy rates, reductions in the number of vehicle-kilometers travelled by ride-sourcing vehicles, and reduced emissions (Brown, 2020; Santos, 2018; Tirachini, 2019).

Conversely, individuals with greater levels of comfort with resuming pre-pandemic travel during the pandemic are less likely to indicate that they would never use exclusive ride-sourcing again. This is reasonable, as the preferences and behaviours of these individuals may be less impacted by the pandemic. Additionally, individuals who have earned at least a bachelor's degree are less likely to indicate that they would never use exclusive or shared ride-sourcing again. This is consistent with previous ride-sourcing studies, which have found that higher levels of educational attainment were associated with an increased likelihood that an individual has adopted ride-sourcing services and uses them on a frequent basis (Circella et al., 2018; Deka & Fei, 2019; Dias et al., 2017). Besides, individuals who owned transit passes and those who are currently students are less likely to indicate that they would never use shared ride-sourcing services again. This could be due to the relatively lower per-distance costs of shared services (compared to exclusive ride-sourcing), the similarities between shared ride-sourcing and public transit services, and the potential for ride-sourcing to serve as an access and egress mode for public transit (Dean & Kockelman, 2021; Diao et al., 2021; Shaheen, 2018; Young et al., 2020). Overall, the results suggest that certain individuals could abstain from using ride-sourcing services even after COVID-19 is no longer a public health threat, particularly those who did not use ride-sourcing prior to the pandemic. However, there are many individuals who appear to be willing to using ride-sourcing services, even during the COVID recovery period.

5.2.2. Ordered logit model

The ordered logit component of the 2SOL model highlights the influence of latent attitudinal factors, socio-economic characteristics, and pandemic-related variables on the earliest stage of the COVID recovery period where an individual would consider using exclusive and shared ride-sourcing. As expected, the belief that the pandemic has increased the risk associated with using shared modes and an aversion towards travel due to the pandemic are both associated with a greater likelihood of waiting until a later stage of the COVID recovery period to consider using exclusive and shared ride-sourcing. Conversely, comfort with resuming pre-pandemic travel during the pandemic is associated with a higher likelihood that a person will consider using ride-sourcing earlier in the COVID recovery period. The results also indicate that people who are taking precautions when leaving their homes, such as wearing a face covering and practicing social distancing, appear to be more likely to wait until a later stage in the COVID recovery period to consider using exclusive and shared ride-sourcing services. Similarly, individuals who indicated that they practice social distancing when they leave their homes are more likely to wait until a later stage of the COVID recovery period to consider using shared ride-sourcing. Conversely, respondents who indicated that they were maintaining their regular routine without practicing social distancing are more likely to consider using exclusive ride-sourcing at an earlier stage. Overall, these results underscore the different ways in which the pandemic has affected the decision to use ride-sourcing services.

Similar to the results obtained through the binary logit component of the 2SOL model, age and household vehicle ownership were found to influence the stage at which an individual would consider using exclusive and shared ride-sourcing services. In particular, older individuals and those from households that own more vehicles are more likely to wait until a later stage of the COVID recovery period to consider using ride-sourcing. This is likely due to the tendency for ride-sourcing use to be more prevalent among younger individuals and individuals from households with lower rates of household vehicle ownership (Alemi, Circella, & Sperling, 2018; Deka & Fei, 2019). This also suggests that individuals who have access to a private vehicle may prefer to avoid using ride-sourcing until a later stage of COVID recovery period. Interestingly, age and household vehicle ownership appear to have a greater impact on the consideration of using exclusive ride-sourcing services. This could be due to the tendency for the decision to use shared ride-sourcing to

Table 4
Final specification of the 2SOL model pertaining to shared ride-sourcing.

	Binary logit model (Stage 1)		Ordered logit model (Stage 2)	
	Estimate	t-stat	Estimate	t-stat
Latent Attitudinal Factors				
Belief that the pandemic has increased the risk associated with using shared modes	–	–	0.461	4.676
Comfort with resuming pre-pandemic travel during the pandemic	–0.496	–4.687	–0.731	–9.175
Aversion towards travel due to the pandemic	–	–	0.091	0.938
Personal and Household Characteristics				
Age	0.023	3.497	0.012	2.015
Person owns a transit pass (1 if yes, 0 otherwise)	–0.428	–2.092		
Person is currently a student (1 if yes, 0 otherwise)	–0.628	–1.628		
Highest level of education: Bachelor's degree or higher (1 if yes, 0 otherwise)	–0.515	–2.855	0.420	2.826
Employment status during pandemic: Full-time at workplace (1 if yes, 0 otherwise)	–	–	–0.489	–2.876
Number of household vehicles	–	–	0.082	1.007
Household owns more than one vehicle (1 if yes, 0 otherwise)	0.271	1.477	–	–
Ride-sourcing-related Variables				
Experience using exclusive ride-sourcing prior to pandemic (1 if yes, 0 otherwise)	–1.250	–5.003	–0.222	–1.331
Pandemic-related Variables				
Person indicated that health and safety measures would make them more willing to use ride-sourcing during the COVID recovery period (1 if yes, 0 otherwise)	–	–	–0.708	–4.382
Person always wears a mask or face covering when going out (1 if yes, 0 otherwise)	–	–	0.510	3.005
Person believes that social distancing is essential to control the spread of COVID-19 (1 if yes, 0 otherwise)	–	–	0.959	3.233
Person is required to visit their workplace, but is practicing social distancing when going out (1 if yes, 0 otherwise)	–	–	0.247	1.460
Constants and Threshold Parameters				
Constant	–1.726	–4.455	–	–
$\alpha(1)$	–	–	1.941	4.393
$\alpha(2)$	–	–	0.390	0.889
$\alpha(3)$	–	–	–0.769	–1.737
$\alpha(4)$	–	–	–1.391	–3.131
$\alpha(5)$	–	–	–2.077	–4.644
Model Fit Statistics				
Number of observations	920			
Loglikelihood of constants-only model	–1648.07			
Loglikelihood of final model	–1365.18			
ρ^2 (Adjusted ρ^2)	0.237 (0.223)			
BIC	2900.97			

be driven by travel time and cost considerations (Amirkiaee & Evangelopoulos, 2018; Hou et al., 2020) or the aversion towards sharing a vehicle with a stranger among some private vehicle users (Schaller, 2021).

Additionally, students are more likely to consider using exclusive ride-sourcing earlier in the COVID recovery period, while individuals who are employed full-time and must work at their usual place of work are more likely to consider using shared ride-sourcing at an earlier stage of the COVID recovery period. Both results are likely indicative of the mobility tools and resources that these two groups have at their disposal. In particular, the members of these groups may be trying to minimize their use of public transit, given the potential to share space with strangers and to come into contact with shared surfaces over the course of a trip. In the case of students, who tend to use public transit and active modes more frequently than the population as a whole (Whalen et al., 2013), the willingness to consider using exclusive ride-sourcing earlier in the COVID recovery period may stem from relatively lower levels of vehicle ownership. On the other hand, individuals who are still working at their place of work are more likely to be employed in essential industries (such as retail and healthcare) and belong to lower-income households or households with relatively lower levels of household vehicle ownership. Because these individuals have had to return to work at an earlier stage of the pandemic (or in some cases, were never able to work from home), this finding could be indicative of a desire to have an alternative to public transit that is still offers relatively lower fares. This is consistent with previous studies on the topic, which have found that lower-income individuals (as well as the elderly and those with mobility impairments) tend to rely on public transit to satisfy their mobility needs (Brown & Taylor, 2018; Krizek & El-Geneidy, 2007). This is also supported by the work of Loa, Hossain, Mashrur, et al. (2021) who, using the same dataset, found that individuals who utilized transit for non-mandatory trips during the pandemic were more likely to be students, belong to a household that earns less than \$50,000 annually, and belong to households with relatively low levels of vehicle ownership.

In addition, experience using ride-sourcing prior to the pandemic is associated with an increased likelihood that a person will consider using exclusive and shared ride-sourcing at an earlier stage of the COVID recovery period. This may be the result of the level of familiarity that ride-sourcing users have with this service, a reliance on these services due to a lack of other options, or a reluctance to use other modes. As outlined in Section 4.2, a reluctance to use public transit was one of the more common reasons why a small percentage of respondents are using exclusive ride-sourcing more frequently during the COVID recovery period than they were during

the pre-COVID period. Interestingly, experience using exclusive ride-sourcing was found to be statistically significant at the 95% confidence level, while experience using shared ride-sourcing was not. This may be indicative of an aversion towards sharing space with strangers during the COVID recovery period, coupled with the continued availability of exclusive ride-sourcing services.

6. Discussion on policy implications

As the results presented in this paper have shown, the COVID-19 pandemic has affected the utilization of ride-sourcing, including how often these services are used and the willingness to use these services. Although ride-sourcing usage is down as a whole, the results of the survey suggest that there are also people who have increased their use of ride-sourcing since the start of the pandemic. These respondents indicated that their increased ride-sourcing use could be attributed to reliability issues with public transit, the desire to avoid crowding (both in public spaces and in vehicles), and their reluctance to use transit. This highlights the need for transit agencies to monitor both the frequency and reliability of the service that they provide, especially as they attempt to regain ridership that was lost at the beginning of the pandemic. This also has implications for the transportation network as a whole, as the reluctance to use both transit and ride-sourcing has the potential to increase the number of vehicles on the road. On the other hand, health concerns, the desire to avoid shared surfaces, and concerns about the cleanliness of the vehicles have led some respondents to reduce their usage of ride-sourcing. Although these findings pertain to the use of ride-sourcing services, they may also provide insights into the reasons why some individuals may have reduced their use of public transit and taxis during the pandemic. There are, however, a subset of respondents who would be more willing to use ride-sourcing during the COVID recovery period if additional health and safety measures were implemented. There also appears to be a subset of respondents that will not continue their use of ride-sourcing, even after the pandemic has ended.

In addition, the results of the two empirical models highlight the role that perceptual and socio-economic factors play in the decision to consider using ride-sourcing during the COVID recovery period and in determining the earliest stage of the COVID recovery period at which a person would consider using ride-sourcing. In particular, older individuals and those from households with relatively high levels of vehicle ownership are more likely to indicate that they would never use ride-sourcing again. Conversely, experience using ride-sourcing prior to the pandemic and greater levels of comfort with resuming pre-pandemic travel reduce the likelihood that an individual will never use ride-sourcing again. Additionally, perceptions of risk and the tendency to take precautions when leaving home are associated with waiting until a later stage of the COVID recovery period to consider using ride-sourcing. Given that concerns about contracting the virus appear to be deterring people from using ride-sourcing, assuaging concerns about the cleanliness of the vehicles could help increase the utilization of ride-sourcing services. The tendency for students and individuals who are working full-time at their usual place of work to consider using ride-sourcing at earlier stages of the COVID recovery period could imply that the mobility options that a person has available may affect their willingness to consider using ride-sourcing. In particular, these individuals may regard ride-sourcing as a means of satisfying their mobility needs and reducing their use of public transit, particularly for longer trips. This underscores the need for transit agencies to ensure that they provide sufficient levels of service throughout their jurisdictions. Besides, providing service at a level that allows passengers to practice physical distancing can also help build public confidence, which is an important factor in rebuilding transit ridership both during and after the pandemic (Wang and Thiel, 2014).

The results presented in this paper underscore the impacts that perceptual and attitudinal factors have had on the willingness to use ride-sourcing during the COVID recovery period. As the pandemic situation continues to change, the utilization of ride-sourcing services will likely vary based on the perceptions of risk and aversion towards travel. As previous studies have shown, these factors typically lead individuals to favour modes where the perceived risk of infection is lower, such as private vehicles, walking, and bicycling (Bucksky, 2020; Molloy, 2020b; Shamshiripour et al., 2020; Teixeira & Lopes, 2020). As a result, ride-sourcing utilization may fluctuate based on factors such as the number of new COVID-19 cases being reported, vaccination status, the emergence of new variants of the SARS-CoV-2 virus, and the prevailing pandemic-related public health restrictions. Besides, while COVID-19 is still considered a public health threat, certain individuals (particularly those without access to a private vehicle) may turn to ride-sourcing as a means of reducing their risk of infection while travelling.

The influence of perceptions of risk and the aversion towards travel on ride-sourcing use during the pandemic also have the potential to affect post-pandemic travel behaviour. Given the impacts of TNCs prior to the pandemic, changes in ride-sourcing use have the potential to affect post-pandemic modal preferences, activity patterns, and travel demand (which can in affect emissions and congestion) (Alemi, Circella, Mokhtarian, et al., 2018; Clewlow & Mishra, 2017). A continued aversion towards shared spaces and shared surfaces post-pandemic could also limit the utilization of shared ride-sourcing services, which have the potential to mitigate the negative externalities associated with ride-sourcing. More broadly, the persistence of travel habits and modal preferences developed during the pandemic could lead to increased auto dependence post-pandemic, which could have negative implications for congestion and emissions. Additionally, a continued aversion towards using public transit during the post-COVID period has the potential to initiate a cycle of service cuts and reduced ridership, given the role that fares play in funding operational costs (Vuchic, 2005).

7. Conclusion and recommendations for further research

This paper presents the results of an investigation into the impacts of COVID-19 on the use of ride-sourcing services. This study uses data obtained through a web-based survey of GTA residents to examine the impacts that the pandemic has had on different aspects of their use of ride-sourcing. In addition, this data is also used to estimate two-stage ordered logit (2SOL) models of the earliest stage of the COVID recovery period at which a person would consider using exclusive and shared ride-sourcing. As expected, the pandemic resulted in ride-sourcing being used less frequently, although a small percentage of respondents reported that their use of ride-sourcing

had increased since the start of the pandemic. These increases were most often attributed to the desire to avoid public transit and to avoid crowded spaces. Conversely, those who reduced their use of ride-sourcing reported doing so because of health concerns and the desire to avoid shared surfaces. Based on the results of the 2SOL models, it appears that perceptual and socio-economic factors affect the earliest stage at which a person would consider using ride-sourcing during the COVID recovery period. In particular, the belief that the pandemic has increased the risk associated with using shared modes increases the likelihood that a person will wait until a later stage of the COVID recovery period to consider using ride-sourcing. On the other hand, comfort with resuming pre-pandemic travel during the pandemic increases the likelihood that a person would consider using ride-sourcing at an earlier stage of the COVID recovery period.

These results highlight the importance of accounting for attitudes and perceptions when studying the impacts of COVID-19 on travel behaviour. Given the novelty of the COVID-19 situation, understanding how people perceive the risks associated with the pandemic and their willingness to engage in out-of-home activities can provide valuable insights into the decision-making process during the COVID recovery period. With regards to ride-sourcing, it appears that usage is likely to gradually increase as restrictions are lifted, however, demand is unlikely to reach pre-pandemic levels while COVID-19 is still considered a public health threat. This can primarily be attributed to concerns about the risk of contracting the virus and apprehension towards being in a vehicle that contains multiple shared surfaces. The decision to consider using ride-sourcing services, however, varies based on perceptions of risk, socio-economic factors, and the tendency to take precautions when spending time outside the home.

Although the results outlined in this paper shed light on the impacts of the COVID-19 pandemic on the use of ride-sourcing, two key limitations should be noted. First, the novelty of the pandemic means that the situation is constantly evolving, which means that the perception of risk and the willingness to engage in certain behaviours can also change as the pandemic situation continues to evolve. This means that the influence of these factors may fluctuate over the course of the COVID recovery period. Second, the data for this study was obtained from members of a consumer panel, who may be more technologically savvy on average than the average member of the target population. Additionally, the under-representation of persons over the age of 65 and individuals from lower-income households in the sample has the potential to affect the results presented in this study. In particular, the under-representation of lower-income households may have contributed to the omission of income variables in the final specifications of the 2SOL models. Improving the representation of individuals from lower-income households in the sample may have helped the 2SOL models better capture the impacts of household income on the decision to use ride-sourcing during the COVID recovery period. Similarly, improving the representation of persons over the age of 65 in the sample may have allowed the 2SOL models to provide deeper insights into the role that age plays in the decision to use ride-sourcing during the COVID recovery period, given that age and education have been found to influence the use of ride-sourcing among seniors (Mitra et al., 2019).

There are two approaches that future studies could be taken to expand on the work presented in this paper. The first approach is to apply a hybrid modelling framework that includes the estimation of latent attitudinal factors, such as the integrated choice and latent variable model. While the use of factor scores is a practical means of incorporating attitudes into the empirical model, it also has the potential to introduce measurement bias into the results, as the responses to the attitudinal questions are not direct measures of attitudes (Alemi, Circella, Handy, et al., 2018). Besides, hybrid modelling frameworks are able to jointly utilize all available information, which ensure that the variances of the parameters corresponding to the latent variables are not underestimated (Raveau et al., 2010). The second approach is to capture heterogeneity in the influence of the explanatory variables on the decision to use ride-sourcing during the COVID recovery period. As part of this approach, random parameters could be included in the 2SOL model, which would allow for preference heterogeneity to be captured. Additionally, the ordered logit component of the 2SOL framework could be modified to facilitate the estimation of parameter values specific to each outcome. This shift from an ordered logit to a generalized ordered logit model would allow the model to capture systematic heterogeneity. Future work could also involve conducting a similar survey at a later stage of the COVID recovery period, which could provide insights into how the perceptions of risk, and the decision to use ride-sourcing, have evolved.

CRedit authorship contribution statement

Patrick Loa: Methodology, Formal analysis, Writing – original draft, Writing – review & editing. **Sanjana Hossain:** Formal analysis, Visualization, Writing – original draft, Writing – review & editing. **Yicong Liu:** Formal analysis, Visualization, Writing – original draft, Writing – review & editing. **Khandker Nurul Habib:** Conceptualization, Investigation, Writing – review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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