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Exploring the impacts of COVID-19 on travel behavior and mode preferences

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ABSTRACT

Various measures were recommended or imposed by the governments to control the spread of COVID-19. Travel behaviors are significantly influenced due to such measures. However, people have various travel needs ranging from grocery shopping to work. This study examines the changes that occurred in travel behavior due to the COVID-19 pandemic. Data were collected through an online questionnaire survey that included questions on trip purpose, mode choice, distance traveled, and frequency of trips before and during COVID-19. 1203 responses were collected from various countries around the world.

Results explained that trip purpose, mode choice, distance traveled, and frequency of trips for the primary travel were significantly different before and during the pandemic. Further, the majority of trips were made for shopping during the pandemic. There was a significant shift from public transport to private transport and non-motorized modes. People placed a higher priority on the pandemic related concerns while choosing a mode during the pandemic as compared to the general concerns. Gender, car ownership, employment status, travel distance, the primary purpose of traveling, and pandemic-related underlying factors during COVID-19 were found to be significant predictors of mode choice during the pandemic.

Outcomes of this study could be useful in transport planning and policymaking during pandemics based on the travel needs of people. In particular, government authorities could utilize such knowledge for planning smart and partial lockdowns. Service providers, e.g., taxi companies and retailers, could use such information to better plan their services and operations.

1. Introduction

Past studies have highlighted that human mobility and interaction patterns directly contribute to the spread of infectious diseases, particularly during pandemics (Funk et al., 2010; Belik et al., 2011; Rizzo et al., 2014; Yan et al., 2018; Peixoto et al., 2020). Thus, in general, travel is restricted during pandemics (Zhang et al., 2011; Cooley et al., 2011; Peak et al., 2018; Muley et al., 2020). Further, to control the spread of the virus and to 'flatten the curve', various control and preventive measures have been recommended or imposed by the governments of different countries depending upon the local governance, socio-economic conditions, and cultural context. Such strategies include school closures, remote or online teaching, working from home, closure of shops and restaurants, restrictions on public gatherings, social events and meeting, locking down countries or cities, imposing curfews, suspending public transport and taxi operations to limit travels, imposing norms for social distancing, closing international borders and airports, etc. Recent studies have explained that working from home (i.e., limiting home-based work trips) and reducing consumption (i.e., limiting home-based shopping trips), limiting community contacts, and restricting international travel are effective mitigation policies (Jones et al., 2020; Yilmazkuday, 2020). However, these policies might not only affect people's travel behavior but also their health and well-being (De Vos, 2020).

Fear of infection and perceived risk also significantly influence travel behaviors, particularly for transit use, and the influence varied based on the infected area and demographic characteristics of the people (Kim et al., 2017; Cahyanto et al., 2016). During pandemics, people perceive a higher risk for all types of trip types and avoid traveling to places where they perceive medium to high risk (Hotle et al., 2020). Nevertheless, people have various travel needs during pandemics and such trips range from daily grocery shopping trips to work trips. Characteristics of such trips can be remarkably different for different employment categories, for example, trip patterns and characteristics of essential service personnel, such as healthcare (hospitals and pharmacies) and military personnel, could be different from a general

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office worker. It should be noted that different countries impose different levels of travel restrictions and such policies could also affect the travel behaviors of the general public. In addition, peoples' understanding, perceptions, and attitudes could also affect the travel decisions and mode choice during pandemics.

Understanding and predicting travel behaviors is vital for transport planning, decision making, and policymaking during pandemic situations based on the travel needs of people. For example, government authorities could utilize such knowledge for rescheduling public transport operations and taxi operators and ride-sharing firms could better plan their services using such information.

Since the COVID-19 pandemic is a global health crisis compared to the previous pandemics, the findings from the previous research studies may not be directly applicable. Hence, the present study is aimed at exploring the effects of the COVID-19 pandemic on human travel behavior. The characteristics of changes in travel behavior before and during COVID-19 and factors influencing such changes are examined. This study specifically focuses on the trips that are made due to necessity and people feel compelled to make those trips due to various reasons hereafter referred to as primary trips. Data were collected through a questionnaire survey that was distributed globally through social media platforms and emails. Further, the trip characteristics of different employment categories, e.g., essential service staff, and other regular employees are also examined.

The remainder of this paper is organized as follows: previous studies on the influence of pandemics on travel behaviors, patterns, and mode choices are discussed in the next section. Then the methods, which include details of the questionnaire survey that was conducted to collect required data and the analysis techniques, are presented. Then the results obtained through statistical analyses are presented along with the discussion. Finally, conclusions are presented along with policy implications and limitations.

2. Related works

During pandemics, different countries have adopted different degrees of restrictions to prevent and control the spread of the virus. Such restrictions could largely affect peoples' lifestyles, social interactions, and economic conditions. In particular, the travel and outdoor activities of humans could be significantly affected (de Haas et al., 2020; Mogaji, 2020). On the other hand, fear of infection and perceived risk could also affect travel behaviors and mode choices.

A review of previous studies suggested that air transport could accelerate and amplify the propagation of respiratory viruses, e.g., influenza, MERS, SARS, coronavirus, (Browne et al., 2016). Sirkeci and Yucesahin (2020) indicated that the total numbers of the migrant and immigrant populations of Chinese origin are important indices for predicting the spread of the COVID-19 worldwide. However, as explained by Epstein et al. (2007), only international travel restrictions would not control a disease outbreak, but this could delay the spread or flatten the curve. Kraemer et al. (2020) also stated that when the outbreak is spread widely, travel restrictions are less effective. In addition, mobility restrictions might not be effective when the overall epidemic size is considered, and therefore, high- and low-risk communities should be identified (Espinoza et al., 2020). Several previous studies have highlighted that individuals tend to cancel or delay international trips or flights to avoid infection during pandemics. Such self-protective behaviors depend mainly on demographic characteristics (mainly, age and race) and perceived risk of infection (Fenichel et al., 2013; Sharangpani et al., 2011). In particular, several studies explained that older travelers were willing to delay their travels compared to young travelers (18–35 years old) during the outbreak of H1N1 (Leggat et al., 2010; Sharangpani et al., 2011).

Not only air travel, but people also tend to avoid domestic land travels due to the perceived risk of contracting the viruses. A cross-sectional web-based questionnaire survey was conducted by Goodwin et al. (2011) to explore behavioral responses to influenza A or H1N1 pandemic. The outcomes of their survey explained that 20% of the respondents (English or Portuguese nationals) planned to delay or cancel flights and 22% intended to use public transport less frequently. Results of an online survey carried out by Jones and Salathe (2009) during the beginning of the swine flu outbreak explained that older age was linked with more avoidance behaviors including the avoidance of large gatherings, and public transport. Cahyanto et al. (2016) conducted an online survey to study the factors influencing the avoidance of domestic travels by Americans due to the confirmed Ebola virus cases. They concluded that perceived vulnerability, perceived risk, subjective knowledge, and self-efficacy affect the avoidance of domestic travel significantly. Demographic characteristics, such as age and gender, were also found to have a significant relationship with travel avoidance. Kim et al. (2017) examined the differences in travel behavior in Seoul, South Korea before and after the MERS outbreak using smart card data associated with transit use. The findings of this study indicated that travel behavior was significantly influenced by fear. That is, travel frequency was significantly reduced in Seoul following the MERS outbreak in 2015. Statistical analyses further revealed that land prices, availability of potential MERS hotspots in the analysis zone, the number of businesses and restaurants, and the number of individuals over 65 are the variables, which are significantly affecting the reduction in trip frequency during MERS. Sadique et al. (2007) conducted a questionnaire survey on SARS and influenza risk perception in European and Asian countries. They reported that approximately 75% of the survey participants responded that they would avoid public transportation. A recent study conducted in Hong Kong during the early phase of COVID-19 reported that 40% of the online survey respondents answered that they would avoid public transportation (Kwok et al., 2020). Another recent study conducted in Budapest, Hungary reported that the demand for public transport decreased by approximately 80% while the car usage increased from 43% to 65% (Bucsky, 2020). A study conducted in Turkey concluded that one of the most adopted preventive behaviors during COVID-19 was the avoidance of public transportation (Yıldırım et al., 2020).

A qualitative study was conducted by Ives et al. (2009) using focus groups and interviews targeting healthcare staff. Several survey participants mentioned that, due to the fear of infection, they were reluctant to use public transport and as a result, more people would be willing to travel to work using private cars. They further mentioned that they are willing or able to work if adequate parking spaces are available to accommodate additional demand for private cars. Blendon et al. (2008) reported the results of a national survey that was conducted in the US to explore public opinion on community mitigation measures for pandemic influenza. 89% of the survey participants responded that they would limit the use of public transportation (buses and trains). Further, 85% of them mentioned that they would not allow their children to use public transport and undertaking out of home activities (public events and gatherings) while schools are closed.

De Vos (2020) explained that due to COVID-19, people will reduce their travel, and will prefer to use active modes or cars over public transport. This will reduce the traffic volumes and affect people's well-being. Globally, a large decline was observed in mobility due to fear from COVID-19 and the government's orders to mitigate the spread (Warren and Skillman, 2020). In the severely affected cities, mobility was reduced by up to 90% (Muhammad et al., 2020). In the USA, population mobility was reduced by 7.87% due to official stay-home orders. Further, a rise of the local infection rate from 0% to 0.0003% lowered the mobility by 2.31% (Engle et al., 2020). A study conducted in Switzerland revealed that the number of trips per weekday and average kilometers traveled reduced up to around 60% during the second week of March in 2020. This study further mentioned that males continued to travel more compared to females (Molloy et al., 2020).

All these previous studies highlight that travel behaviors during pandemic situations could be remarkably different compared to the normal daily life. Many factors (demographic as well as attitudes) affect such changes in travel behaviors and patterns. Gleaning insights from these studies, a questionnaire was designed and disseminated online to collect data to explore key changes in travel behaviors before and during COVID-19. Details of the questionnaire survey and obtained data are described in the next section.

3. Methods

3.1. Survey design and sample

The questionnaire was designed using Google forms. It was prepared in the English language and distributed through emails and social media channels such as Facebook, LinkedIn, Reddit, and ResearchGate during May 09, 2020 and May 31, 2020. Snowball sampling technique was used to collect responses. One thousand two hundred and three (1203) responses were achieved from various countries around the world. Questions were designed as per the guidelines of the University of Management and Technology, Pakistan. The questionnaire consisted of three sections: (1) socio-demographic characteristics, (2) characteristics of primary travel before and during the COVID-19 pandemic, and (3) factors affecting mode choice for primary travel before and during the COVID-19 pandemic.

Socio-demographic characteristics consisted of gender, age, country of residence, marital status, monthly household income (in USD), car ownership, motorbike ownership, number of members in the household, education level, employment status, and whether or not the respondent is an essential service worker.

The primary purpose of travel was defined as the purpose for which people mainly undertake their trips. People may be able to reduce other less important trips during a pandemic, however, they may be compelled to travel for a certain primary trip purpose. Hence, it is vital to focus specifically on the primary purpose of travel as it determines the regular or main trips performed, distance traveled, and mode chosen. A section of the questionnaire contained questions on the primary purpose of traveling before and during the COVID-19 pandemic. The information on distance covered, the number of trips made, and mode choice for the primary trip purpose were also inquired.

In addition to these questions, the level of priority respondents placed on the factors, such as safety and security, comfort, cleanliness, cost, travel time saving, personal and social status, infection concern, passengers wearing face masks, social distance, pre-paid fare system, door-to-door service, while choosing a transport mode was also queried using a 5-point Likert scale.

The virus had considerably spread around the world when this survey was conducted i.e., during May 2020. The respondents, in general, have already had the experience of living through the COVID-19 pandemic. In addition, evidence suggests that voluntary social distancing played a significant role during COVID-19 besides mandatory lockdowns (Goolsbee and Syverson, 2020). Hence, the collected data can be analyzed as a whole regardless of the lockdown timelines in various countries.

3.2. Analysis methods

Descriptive analysis as well as quantitative comparative analyses were conducted on the collected data. For inferential statistical analyses, nonparametric tests were mainly used in this study unless specified otherwise. Non-parametrical tests can be used for ordinal and ranked data, require fewer assumptions, and are easier to understand and use (Colquhoun, 1971). There is some power loss when using non-parametrical tests; however, when the data is normally distributed and all other assumptions are met, the loss in power will be relatively small (Kitchen, 2009). Colquhoun (1971) suggested utilizing a non-parametric test as an alternative to a parametric test whenever available unless there is experimental evidence about how the errors are distributed. This study deals with both independent and paired observations about travel behavior before and during COVID-19. Therefore, proper attention was paid while carrying out statistical analyses on the data as described below.

3.2.1. Statistical analyses for paired observations

McNemar-Bowker test was conducted on paired nominal data such as the primary purpose of traveling and mode choice for the primary purpose of traveling before and during COVID-19. McNemar-Bowker is a nonparametric test for paired nominal data with more than 2 categories for each nominal variable summarized in a $k \times k$ contingency table where k is the number of categories. Further, post-hoc tests were required to investigate which categories of nominal variables differed significantly. McNemar's nonparametric test was used as a post-hoc test for paired nominal data with 2 categories summarized in 2×2 contingency tables. Since the test statistic follows a chi-square distribution, McNemar's test is sometimes referred to as McNemar's Chi-Square test. As multiple hypothesis testing was carried out, a correction was needed to avoid false positives, i.e., to reduce type I errors. Bonferroni correction was applied in such cases which can be calculated as alpha/n, where alpha is the significance level and n is the number of tests to be performed. To compare the ordinal paired observations between groups, such as distance traveled and the number of trips performed for the primary purpose of traveling before and during COVID-19, Wilcoxon signed-rank test, which is the non-parametric equivalent of the paired *t*-test, was used.

3.2.2. Statistical analyses for independent observations

For independent observations, such as the effect of car ownership on distance traveled for the primary purpose, Mann Whitney *U* test was used. Mann Whitney *U* test is robust to violations of the assumption of homogeneity of variance. In addition, Spearman Correlation was used to study the correlation between ordinal/continuous variables such as monthly income and distance traveled for primary trip purpose. Spearman correlation was used to find the association between two ordinal variables such as age and the number of outdoor trips.

3.2.3. Exploratory factor analysis on factors affecting mode choice

Exploratory factor analysis (EFA) was applied to uncover the underlying factors affecting the mode preferences. After conducting EFA, the relative standing of each respondent on the extracted factors can be computed in the form of factor scores. In this study, factor scores were computed using a refined approach known as the Bartlett method because the refined methods are more exact (DiStefano et al., 2009).

3.2.4. Multinomial logistic regression

Mode choices for the primary trip purpose before and during COVID-19 were modeled using multinomial logistic regression. In these models, the mode was set as the outcome variable and four demographic and 2 factors obtained from EFA were entered as predictors.

4. Results

4.1. Demographics

The demographic characteristics of the respondents of the questionnaire survey are summarized in Table 1. Countries, from where the majority of the responses were received, are shown in Fig. 1 along with the percentages of responses. Out of the 1203 responses received, the majority (approximately 70%) of the respondents were from South

Table 1
Demographic Information of the Sample.

Items	Category	Frequency	Percent
Gender	Male	809	67
	Female	387	32
	Prefer not to say	7	1
Age	18–30	662	55
	31–50	508	42
	>50	33	3
Education level	Bachelors and below	593	49
	Masters	391	33
	PhD	219	18
Employment	Student	425	35
	Employed/Business	706	59
	Other	72	6
Monthly household income (USD)	Below 500	305	25
	500–2000	370	31
	Above 2000	528	44
Essential worker	Yes	302	25
	No	901	75
Number of people in the household	1–2	322	27
	3–4	488	41
	5 and more	393	33
Car ownership	Yes	671	56
	No	532	44
Motorbike ownership	Yes	354	29
	No	849	71
Marital status	Single	540	45
	Married	650	54
	Prefer not to say	13	1

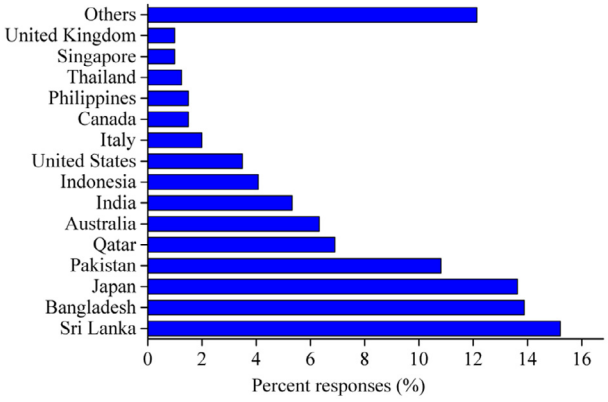

Fig. 1. Resident countries of the respondents.

and South-East Asian countries. Approximately 15% of the responses were from Oceania and Middle-Eastern countries. Further, around 12% of the responses were received from European and North American regions.

4.2. Impact of COVID-19 pandemic on overall commuting behavior

The overall impact of the pandemic on respondents' commuting behavior is shown in Fig. 2. Most of the respondents (56.6%) declared that they do not go to the office or school and work from or study at home. About 11.4% mentioned that nothing changed due to the COVID-19 pandemic.

4.3. Impact of COVID-19 pandemic on primary outdoor trips

The primary purpose of traveling/outdoor trips is the main reason for which people travel during their daily life. For some people, it might be their work, for some, it might be studying and for others, it might be an entirely different purpose. This study specifically focuses on the primary outdoor trips because they are made out of necessity and an individual may not have full control over them. It is likely that people may avoid making trips for other reasons during a pandemic but they may not be able to avoid making trips for the reasons they consider to be primary, of utmost importance and are not under their control. The primary purpose of traveling, distance traveled, and mode choice may change under certain circumstances such as during a pandemic.

The primary purpose of traveling for most of the respondents (58%) before COVID-19 was work. However, it reduced to only 30% during COVID-19 (see Fig. 3). On the other hand, shopping became the primary purpose of traveling for about 44% of the respondents during COVID-19, which was a primary purpose for only 4% of the respondents before COVID-19.

As social, recreational/sports, and other activities were a primary purpose for a small percentage of the respondents, they were combined into a single category titled “others” for the analysis purposes. The McNemar-Bowker test showed that there were significant differences between the primary purpose of traveling before and during the COVID-19 pandemic (χ^2 (6) = 526.342, $p < 0.001$). Further, post-hoc tests were performed to confirm which of the primary purposes changed significantly before and during COVID-19. The Bonferroni correction was applied to reduce type I errors. In this particular case, alpha and n were set as 0.05 and 6, respectively. The cross-tabulation table and results of the McNemar tests are shown in Fig. 4. Post-hoc McNemar tests showed that, the primary purpose of traveling significantly changed from work, study, and others to shopping during COVID-19. The Primary purpose also changed significantly from work and study to others during COVID-19.

4.3.1. Distance traveled for primary outdoor trips

As Fig. 5 describes, about 71% of the respondents traveled a distance between 0 and 10 km during COVID-19, whereas only 45% traveled this distance before COVID-19. A study conducted in Switzerland also stated that the median daily travel distance varied between 0 km and 10 km while travel restrictions were in place, i.e., during 15th March and 30th April 2020 (Molloy et al., 2020). Wilcoxon signed-ranks test showed that there was a statistically significant difference in the distance traveled for the primary trip purpose before and during the COVID-19 pandemic, (Z = −17.034, $p < 0.001$).

The average distances traveled by the respondents, who traveled mainly for work before and during COVID-19, were 3.6 km and 2.6 km, respectively. The average distances traveled by the respondents, who traveled mainly for studying before and during COVID-19, were 15.5 km and 12.9 km, respectively. The average distances traveled by those who traveled mainly for shopping before and during COVID-19 were 4.4 km and 1.5 km, respectively. These statistics indicate that the respondents considerably reduced their distances traveled during COVID-19.

The Mann Whitney *U* test was conducted to evaluate the effect of socio-demographic factors on distance traveled for primary trip purpose. The results are summarized in Table 2. No significant difference was found between the distance covered by males and females before COVID-19. However, males traveled significantly longer distances for primary trip purposes during COVID-19. This observation is consistent with the finding from Molloy et al. (2020) who stated that males traveled more during COVID-19 compared to females. People who owned a car traveled significantly longer distances for the primary trip purpose before COVID-19 as compared to those who did not own a car. However, car ownership did not have a significant impact on the distance traveled for the primary trip purpose during COVID-19. Those who owned a motorbike covered significantly more distances for primary trip purpose before and during COVID-19. Essential workers traveled significantly more distances for primary trip purpose before

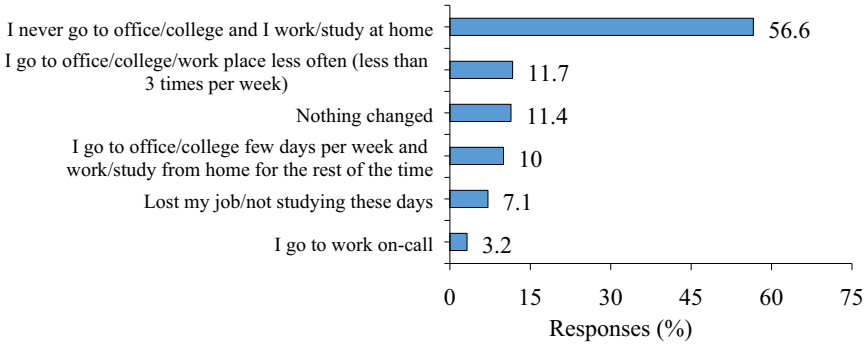

Fig. 2. Change in commuting behaviors due to COVID-19.

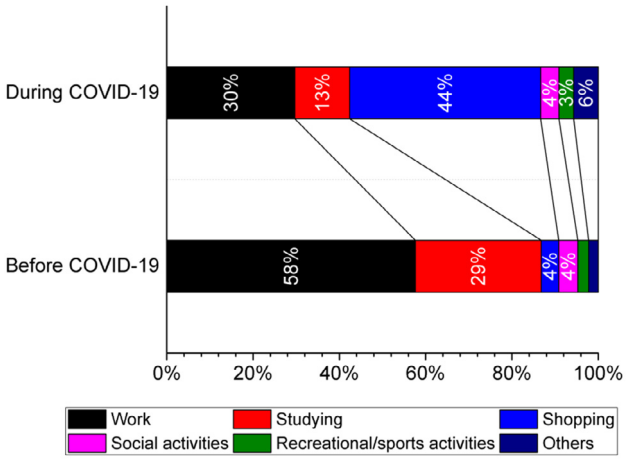

Fig. 3. Primary purpose of traveling before and during COVID-19 pandemic.

and during COVID-19. It is because the essential service workers have to perform their duties and sometimes additional duties during a pandemic. The primary purpose of traveling for other people might change to shopping and their travel distance may reduce, but the primary purpose remains the same for essential workers even during a pandemic.

Correlation between socio-demographic factors and distance traveled for primary purpose are summarized in Table 3. No significant correlation was found between age and distance traveled before COVID-19. However, there was a weak negative correlation between age and distance traveled during COVID-19. This finding is consistent with the findings of several previous studies which mentioned that older travelers tend to travel less compared to young people (Leggat et al., 2010; Sharangpani et al., 2011) and avoid public transport (Jones and Salathe, 2009). COVID-19 has been found to be particularly dangerous for older people. A negative correlation between distance traveled and age demonstrates a safer behavior. Nonetheless, this correlation was found to be weak in this study. In addition, no correlation was found between monthly household income and distance covered for the primary purpose of traveling before and during COVID-19. It should be noted that all these correlations were either weak or very weak and have little practical importance. However, the trends provide some important indications on the relationship between travel behaviors and socio-demographic variables.

4.3.2. Number of primary outdoor trips

In this study, a trip was defined as a one-way journey from an origin to a destination. For example, a one-way journey from home to the office was counted as one trip and the one-way journey from office to home was counted as another trip. Fig. 6 compares the number of primary trips (weekly trips) before and during COVID-19. It can be understood that the number of trips remarkably reduced during the pandemic as expected. Fig. 6 explains that most of the respondents (65%) undertook 0–2 trips per week for the primary purpose of traveling during COVID-19. Wilcoxon signed-ranks test explained that there was a statistically significant reduction in the number of trips undertaken for the primary trip purpose before and during COVID-19 ($Z = -21.073$, $p < 0.001$).

Socio-demographic factors that could affect the number of trips before and during pandemics were examined and results are summarized in Table 2. No significant difference was found between trips performed by males and females for the primary trip purpose before COVID-19. However, males undertook significantly more trips for the primary trip purpose during COVID-19. This finding indicates that females might be more concerned about the infections during pandemics as explained in several previous studies (Bukhari et al., 2016; Collignon, 2020). Other than that, most of the time, males are financially responsible for their houses and choose to travel out to cater for family needs, e.g., for shopping purposes, during pandemics.

Those who owned a car undertook significantly more trips for the primary trip purpose before COVID-19 as compared to those who did not own a car. However, car ownership did not have a significant impact on the number of trips for the primary trip purpose during COVID-19. Those who owned a motorbike performed significantly more trips for the primary trip purpose before the pandemic. However, there was no significant difference during COVID-19. No significant difference was found between the number of trips performed for the primary trip purpose by essential service workers and other people before COVID-19. However, essential workers undertook significantly more trips for primary trip purpose during COVID-19.

The correlation between ordinal demographic variables and the number of trips performed for the primary trip purpose was calculated using Spearman correlation and the results are shown in Table 3. The correlation between the number of people in the household and the trips performed for primary purpose during COVID-19 was not significant. Further, weak correlations were observed between age, education, and the number of trips for primary trip purpose before COVID-19. However, these were non-significant during COVID-19. All other correlations were very weak and have little practical importance.

4.3.3. Mode for primary outdoor trips

Fig. 7 compares the travel mode shares for primary outdoor trips before and during COVID-19. The majority of respondents (36%) declared that they were using public transport for their primary travel purposes before COVID-19. A sharp decline in public transport use was observed during COVID-19, i.e., only 13% of respondents used public transport. In contrast, the use of private cars increased from 32% before COVID-19 to 39% during COVID-19. In general, people tend to avoid public transport during pandemics (Goodwin et al., 2011;

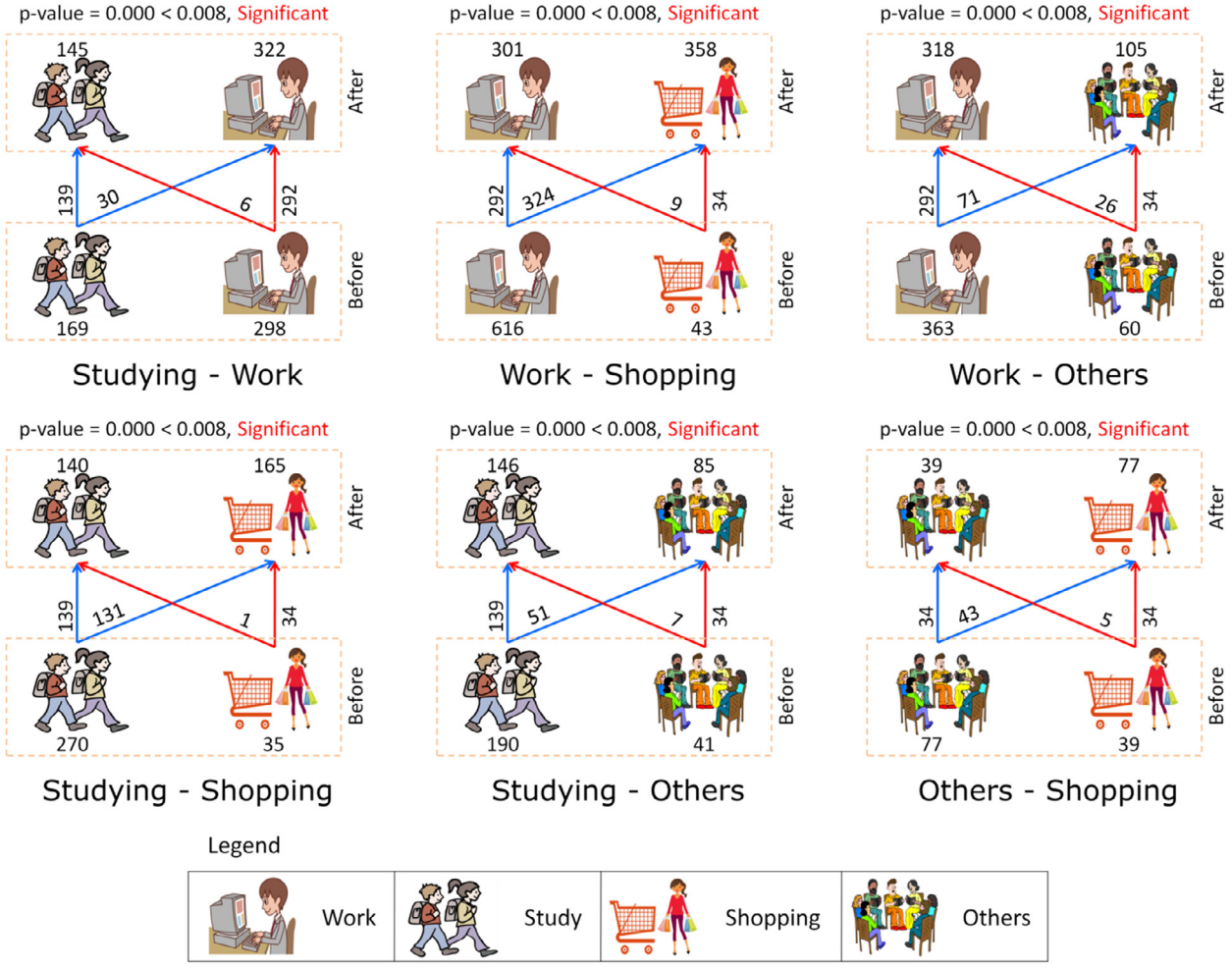

Fig. 4. Change in primary trip purpose and McNemar Test results.

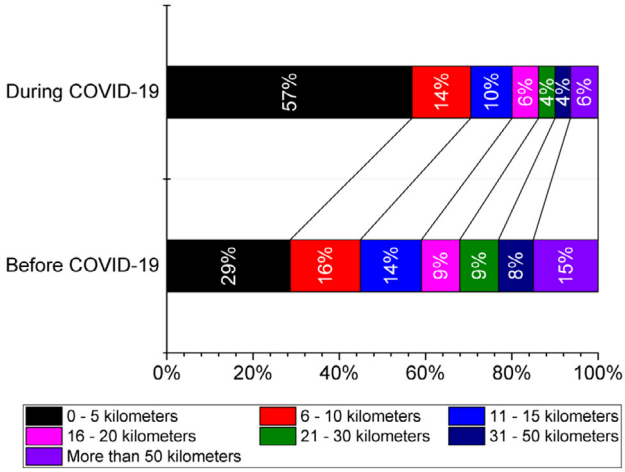

Fig. 5. Distance traveled for primary outdoor trips before and during COVID-19 pandemic.

Kim et al., 2017, Sadique et al., 2007; Kwok et al., 2020). On the other hand, public transport operations are suspended by authorities as a measure to control the spread of the viruses. Therefore, people tend to rely on private vehicles more as it is safer compared to private transport or other alternatives, such as taxis (Ives et al., 2009). It is interesting to note that walking (as a primary transport mode) was also increased by 7% during COVID-19 compared to pre-COVID times.

To explore the modal shifts, office/campus transport, taxi (Private, UBER), and Rickshaw/Tuk-tuk were combined into a single category called “paratransit”. Private car and motorbike were combined into a single category called “private transport”. Similarly, bicycle and walking were combined into a single category called “non-motorized”. Responses with “Nothing/No” were removed from the analysis for the sake of brevity. The McNemar-Bowker test showed that there were significant differences between mode choice for the primary trip purpose before and during COVID-19 (χ^2 (6) = 169.268, $p < 0.001$). Additional post-hoc tests are necessary to understand and compare the modal shifts between different modes. The results of these tests are graphically presented in Fig. 8. As can be understood from Fig. 8, there was a significant shift from public transport to private transport and non-motorized modes. However, the modal shift from private transport to non-motorized modes and from public transport to paratransit was not significant. There was a significant mode shift from paratransit to private transport and non-motorized modes as well.

4.4. Factors affecting mode choice before and during COVID-19

In general, many factors affect the mode choice by people. Out of those, several key factors, which are likely to affect the mode choices, particularly during a pandemic, were identified. The distributions of

Table 2
Effect of socio-demographic factors on distance traveled, and number of trips for the primary purpose.

Item	Group	Before COVID-19			During COVID-19		
		Mean Ranks	U	P	Mean Ranks	U	P
Effect on distance traveled for the primary trip purpose							
Gender	Male	607.25	149,463	0.197	613.19	144,655	0.018*
	Female	580.21			567.79		
Essential Worker	Yes	674.08	114,283	0.000*	717.16	101,273	0.000**
	No	577.84			563.40		
Car ownership	Yes	619.80	166,541	0.042*	616.65	168,655	0.068
	No	579.55			583.52		
Motorbike ownership	Yes	648.65	133,757	0.002*	656.31	131,048	0.000**
	No	582.55			579.36		
Effect on number of trips for the primary trip purpose							
Gender	Yes	599.98	155,348	0.828	623.47	136,342	0.000**
	No	595.42			546.31		
Essential Worker	Yes	571.36	126,797	0.072	662.20	117,871	0.000**
	No	612.27			581.82		
Car ownership	Yes	628.59	160,646	0.002*	615.97	169,111	0.093
	No	568.47			584.38		
Motorbike ownership	Yes	567.28	137,983	0.023*	588.36	145,443	0.346
	No	616.48			607.69		

* Significant at the 0.05 level
** Significant at the 0.001 level.

Table 3
Correlation between socio-demographic factors and number of trips for the primary purpose.

Item	Before		During	
	r_s	p	r_s	P
Correlation with distance traveled for the primary trip purpose				
Age	−0.041	0.154	−0.057	0.048*
Education	−0.140	0.000*	−0.190	0.000**
Household members	0.187	0.000*	0.192	0.000**
Monthly household income	−0.004	0.891	−0.018	0.528
Correlation with the number of trips for the primary trip purpose				
Age	0.061	0.035*	0.051	0.079
Education	0.138	0.000*	0.056	0.05
Household members	−0.114	0.000*	−0.045	0.117
Monthly household income	0.099	0.001*	0.095	0.001*

* Significant at the 0.05 level
** Significant at the 0.001 level.

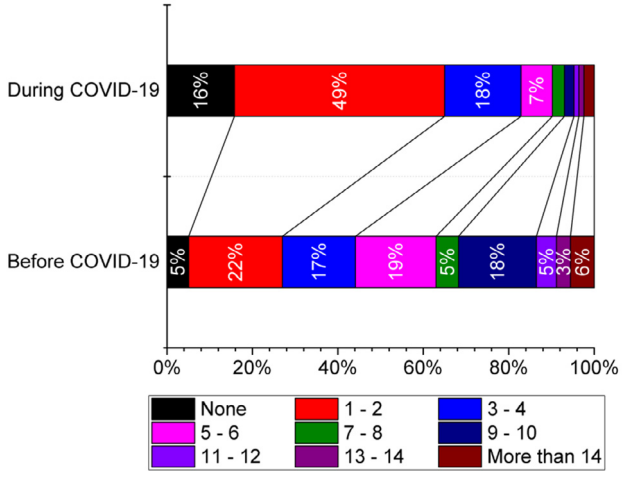

Fig. 6. Number of primary outdoor trips per week before and during COVID-19 pandemic.

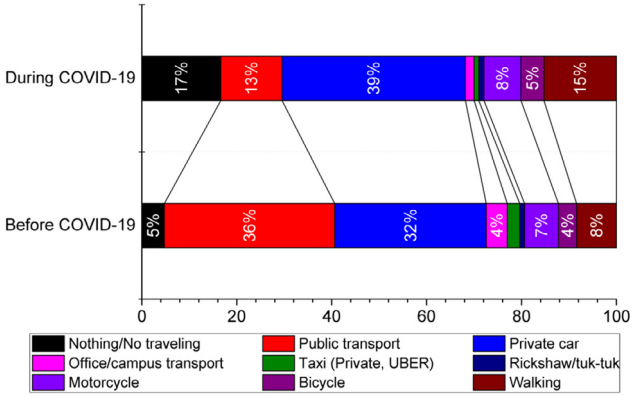

Fig. 7. Mode for primary outdoor trips before and during COVID-19 pandemic.

responses for various factors before and during the COVID-19 pandemic are shown in Fig. 9 and Fig. 10, respectively.

It can be noted that respondents placed a high priority on infection-related factors, e.g., passengers with face masks, social distance, cleanliness, and infection concern, during COVID-19. On the other hand, factors that generally affect mode choice, e.g., travel time saving, comfort, and cost, become less priority during pandemic. Previous studies

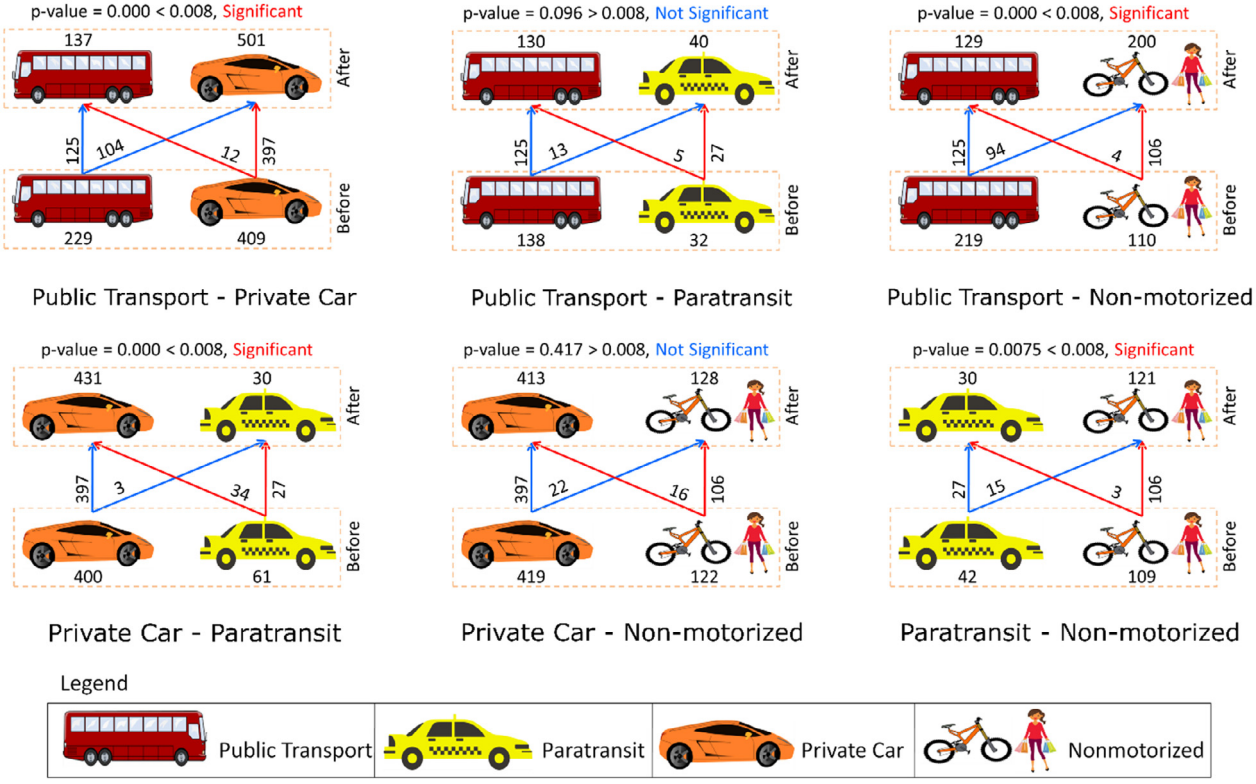

Fig. 8. Mode shift for the primary purpose and McNemar Test results.

showed that factors, such as travel time, fare (Horowitz, 1993), comfort, and convenience (Morikawa et al., 2002), play a role in mode choice behaviors in normal conditions (i.e., no pandemic).

Table 4 summarizes the results of the Wilcoxon signed-rank test was conducted to compare the factors affecting mode choice before and during COVID-19. The statistical tests confirmed that the respondents placed more priority on factors, such as safety and security, cleanliness, infection concern, social distance, passengers with face masks, online pre-paid fare system, door-to-door service, during the pandemic. On the contrary, they put significantly less priority on comfort, cost, and travel time saving during a pandemic. This indicates that the factors associated with infection risk (as perceived by people) become prominent when choosing a travel mode during a pandemic.

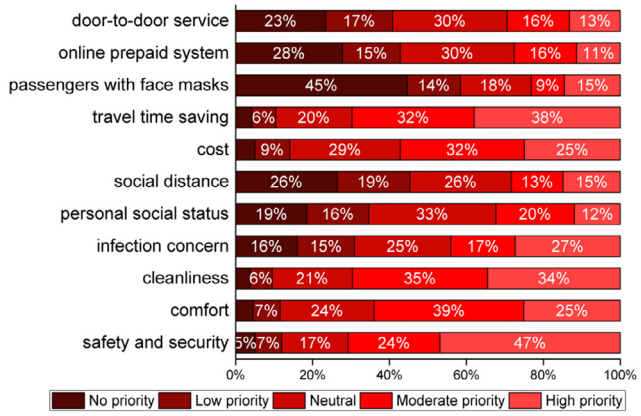

Fig. 9. Distribution of responses for factors affecting mode choice before COVID-19.

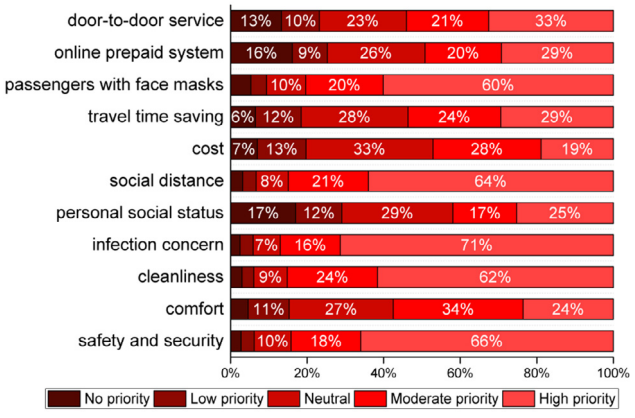

Fig. 10. Distribution of responses for factors affecting mode choice during COVID-19.

As mentioned earlier, the primary purpose of traveling determines the main travel mode. The primary travel purpose could be substantially different during a pandemic compared to normal situations. Further, people, regardless of their traveling purpose, place similar importance on various modes mainly because of the infection concerns during a pandemic. Mode choice behavior during the COVID-19 pandemic was explored using exploratory factor analysis and multinomial logistic regression. The details of such analyses are explained in the next section.

4.5. Factors affecting mode choice before and during COVID-19

Exploratory factor analysis, principal axis factoring with Varimax rotation, was carried out on the items related to mode choice before

Table 4
Comparison of factors affecting mode choice before and during COVID-19.

Item	Mean Ranks		Z	Asymp. Sig. (2-tailed)
	Negative	Positive		
Safety & security	192.24	234.91	−13.044	< 0.001*
Comfort	251.26	245.65	−4.148	< 0.001*
Cleanliness	263.66	294.85	−15.695	< 0.001*
Infection concern	220.04	407.57	−22.023	< 0.001*
Personal social status	219.87	279.20	−8.881	< 0.001*
Social distance	187.26	478.19	−24.760	< 0.001*
Cost	293.71	281.49	−7.111	< 0.001*
Travel time saving	316.83	280.67	−9.939	< 0.001*
Passengers with face masks	167.30	474.23	−24.913	< 0.001*
Online pre-paid fare system	250.16	334.79	−15.244	< 0.001*
Door-to-door service	227.78	351.12	−15.912	< 0.001*

* Significant at the 0.001 level.

and during COVID-19. The solutions produced two factors based on the Eigen values criteria (i.e., eigenvalues >1) which accounted for about 63.941% and 61.432% of the total variance for before and during COVID-19 scenarios, respectively.

The factor loadings for before and during COVID-19 scenarios are presented in Table 5. A cut-off value of 0.40 was used for item loadings. The sampling adequacy was satisfactory (Kaiser-Meyer-Olkin measure >0.750) and Bartlett's test of sphericity was significant (0.000). The determinants of the matrices were 0.066 and 0.012 for before and during COVID-19 scenarios, respectively. Cronbach's alpha was adequate for factor 1 and factor 2 for both scenarios. A refined approach, known as Bartlett method, was used to compute the factor scores

4.5.1. Effect of socio-demographic variables on factors affecting mode choice during COVID-19

Mann Whitney *U* test was used to compare the effects of socio-demographic variables on the pandemic-related factor, i.e., Factor 1 presented in the Table 5, during COVID-19. Outcomes of the statistical test are presented in Table 6. It should be noted that the respondents put a lower priority on the other factor, i.e., Factor 2 that represents general items. Therefore, Factor 2 was omitted in this analysis.

As can be explained from Table 6, it was identified that respondents, who owned a car, put a higher priority on pandemic related items, whereas respondents, who owned a motorbike, placed less priority on pandemic related items. However, those effects were not statistically significant. It was interesting to note that the essential workers placed significantly less priority on pandemic related items as compared to other people (U = 123639, p = 0.018). In general, essential workers are required to report to work even during pandemics, and transport is arranged by the workplaces. Thus, it is logical for them to place less priority on pandemic related items compared to the general public.

It was also established that males perceived significantly less priority on pandemic related items as compared to females (U = 137025, $p < 0.001$). This means that the females are more concerned and worried about the spread of the virus and this finding is consistent with the findings from previous studies (Al Shehri et al., 2006; Bukhari et al., 2016; Collignon, 2020).

In addition, as statistical tests explained, students put a significantly less priority on pandemic related items as compared to employed respondents (U = 135084, $p = 0.005$). Employed respondents are likely to be older and therefore more concerned about the infection compared to the students. Previous studies have also explained that older age was linked with more avoidance behaviors, e.g., avoidance of large gatherings and public transport, particularly during pandemics (Jones and Salathe, 2009).

Table 5
Principal axis factor analysis of the factors affecting mode choice.

Items	**Factor 1**	**Factor 2**
Factors affecting mode choice before COVID-19		
Social distance before COVID19	0.847	
Passengers wearing face masks before COVID19	0.835	
Infection concern before COVID19	0.672	
Cleanliness before COVID19		0.784
Comfort before COVID19		0.701
Safety & security before COVID19		0.690
% of variance explained	**34.264**	**29.677**
Cronbach's alpha	**0.846**	**0.786**
Factors affecting mode choice during COVID-19		
Items	**Factor 1**	**Factor 2**
Infection concern during COVID19	0.890	
Social distance during COVID19	0.826	
Cleanliness during COVID19	0.789	
Passengers wearing face masks during COVID19	0.788	
Safety & security during COVID19	0.760	
Travel time saving during COVID19		0.730
Cost during COVID19		0.646
Comfort during COVID19		0.557
% of variance explained	**42.941**	**18.491**
Cronbach's alpha	**0.919**	**0.706**

4.6. Modeling the mode choice before and during COVID-19 pandemic

Multinomial logistic regression was applied to model the mode choice for primary trip purpose before and during COVID-19. The nominal outcome variable was the mode chosen for the primary trip purpose. Certain categories of modes were combined, i.e., public and paratransit transport services were combined into a single category called "Public/paratransit"; private car and motorbike were combined into a single category called "Private transport"; and walking and bicycling were combined into a single category called "Non-motorized". Hence, the multinomial response variable for mode choice consisted of three categories namely, public/paratransit, private transport, and non-motorized. Public/paratransit was set as the reference category. People, who responded that they did not travel at all during the pandemic, who did not disclose their gender, and who did not mention their employment status, were removed. Consequently. 1071 and 932 responses were used in the mode choice models development for before and during COVID-19 scenarios, respectively. Three demographic variables, the primary trip purpose, travel distance, and two underlying factors affecting mode choice before and during COVID-19 were entered as predictors. The other variables were either found to be non-significant or had very small number of responses in each category and were, therefore, excluded from the regression models. The regression analysis was performed using a variable selection technique known as the forward stepwise method.

Table 6
Effect of socio-demographic variables on factors affecting mode choice during COVID-19.

Item	Group	Factor 1		
		Mean Ranks	U	P
Car ownership	Yes	612.46	171,464	0.241
	No	588.80		
Essential Worker	Yes	560.90	123,639	0.018*
	No	615.78		
Gender	Yes	574.38	137,025	0.000**
	No	648.93		
Motorbike ownership	Yes	585.81	144,543	0.297
	No	608.75		
Employment	Student	530.85	135,084	0.005*
	Employed	587.16		

* Significant at the 0.05 level

Likelihood ratio tests were significant for the models developed for mode choice before and during COVID-19, which indicates that the developed models are a significant improvement over the intercept-only models (Table 7 and Table 8). The goodness of fit test, the chi-square test based on deviance was non-significant for both before ($\chi 2 = 1566.650$, $df = 1994$, $p = 1.000$) and during ($\chi 2 = 1220.256$, $df = 1666$, $p = 1.000$) the pandemic indicating that the data and the model predictions were similar. However, the Pearson's chi-square test was significant for both before ($\chi 2 = 5300.750$, $df = 1994$, $p = 0.000$) and during ($\chi 2 = 7105.737.750$, $df = 1666$, $p = 0.000$) COVID-19. The McFadden R-square values of 0.248 and 0.317 indicated an excellent fit for before and during the pandemic scenarios, respectively (McFadden, 1977). The multinomial logistic regression model classified 67% and 73% of the cases correctly for before and during COVID-19 scenario, respectively. Gender, car ownership, employment status, travel distance, primary purpose of traveling, Factor 1, and Factor 2 were significant predictors of mode choice for the primary purpose of traveling before the COVID-19 pandemic (Table 7). Gender, car ownership, employment status, travel distance, primary purpose of traveling, and Factor 1 were found to be significant

Table 7
Parameter estimates and model fitting information for mode choice before COVID-19.

Parameter Estimates								
Mode for primary purpose			Regression Coefficient	Std. Error	Sig.	Odds Ratio	95% Confidence Interval for Odds Ratio	
							Lower Bound	Upper Bound
Private Transport	Intercept		−0.956	0.303	0.002			
	Travel distance		−0.023	0.005	0.000	0.978	0.968	0.987
	Factor 1		0.134	0.073	0.066	1.143	0.991	1.318
	Employment status	Student	0.257	0.175	0.142	1.293	0.917	1.823
		Employed	0[b]					
	Car ownership	Yes	2.096	0.172	0.000	8.132	5.800	11.403
		No	0[b]					
	Gender	Male	0.955	0.172	0.000	2.599	1.854	3.642
		Female	0[b]					
	Primary purpose	Work	−0.722	0.258	0.005	0.486	0.293	0.805
		Study	−1.502	0.287	0.000	0.223	0.127	0.391
		Shopping & Others	0[b]					
	Factor 2		0.23	0.071	0.001	1.259	1.095	1.447
Nonmotorized	Intercept		0.798	0.414	0.054			
	Travel distance		−0.138	0.018	0.000	0.871	0.841	0.903
	Factor 1		−0.144	0.106	0.176	0.866	0.703	1.067
	Employment status	Student	−0.655	0.306	0.032	0.520	0.285	0.947
		Employed	0[b]					
	Car ownership	Yes	−0.374	0.238	0.116	0.688	0.432	1.096
		No	0[b]					
	Gender	Male	−0.106	0.228	0.641	0.899	0.575	1.406
		Female	0[b]					
	Primary purpose	Work	−0.649	0.400	0.105	0.523	0.239	1.146
		Study	0.024	0.402	0.953	1.024	0.466	2.252
		Shopping & Others	0[b]					
	Factor 2		0.045	0.099	0.647	1.046	0.862	1.270

a. The reference category is: Public/Paratransit.
b. This parameter is set to zero because it is redundant.

Model Fitting Information

Model	**Model Fitting Criteria**	**Likelihood Ratio Tests**		
	−2 Log Likelihood	**Chi-Square**	**df**	**Sig.**
Intercept Only	2097.808			
Final	1575.203	522.605	16	0.000

Table 8
Parameter estimates and model fitting information for mode choice during COVID-19.

Parameter Estimates								
Mode for primary purpose			Regression Coefficient	Std. Error	Sig.	Odds Ratio	95% Confidence Interval for Odds Ratio	
							Lower Bound	Upper Bound
Private Transport	Intercept		−0.967	0.419	0.021			
	Travel distance		−0.023	0.008	0.006	0.977	0.962	0.994
	Factor 1		0.217	0.107	0.043	1.242	1.007	1.532
	Employment status	Student	−0.569	0.269	0.034	0.566	0.334	0.959
		Employed	0[b]					
	Car ownership	Yes	2.654	0.224	0.000	14.205	9.152	22.047
		No	0[b]					
	Gender	Male	0.748	0.237	0.002	2.113	1.327	3.365
		Female	0[b]					
	Primary purpose	Work	0.154	0.369	0.676	1.166	0.566	2.402
		Study	−0.383	0.460	0.404	0.682	0.277	1.678
		Shopping	1.160	0.380	0.002	3.189	1.514	6.715
		Others	0[b]					
Nonmotorized	Intercept		1.543	0.425	0.000			
	Travel distance		−0.185	0.028	0.000	0.831	0.787	0.878
	Factor 1		−0.004	0.115	0.969	0.996	0.795	1.247
	Employment status	Student	−0.068	0.275	0.804	0.934	0.545	1.602
		Employed	0[b]					
	Car ownership	Yes	0.189	0.258	0.464	1.208	0.728	2.003
		No	0[b]					
	Gender	Male	0.236	0.255	0.355	1.267	0.768	2.090
		Female	0[b]					
	Primary purpose	Work	−1.214	0.412	0.003	0.297	0.132	0.666
		Study	−0.543	0.467	0.245	0.581	0.232	1.452
		Shopping	0.261	0.379	0.491	1.298	0.618	2.730
		Others	0[b]					

a. The reference category is: Public/Paratransit.
b. This parameter is set to zero because it is redundant.

Model Fitting Information

Model	Model Fitting Criteria	Likelihood Ratio Tests		
	−2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	1823.236			
Final	1238.264	584.972	16	0.000

predictors of mode choice for primary purpose during the COVID-19 pandemic (Table 8).

4.6.1. Mode choice before COVID-19

Private transport relative to public/paratransit: People who were traveling for longer distances are less likely to choose private transport relative to public/paratransit when compared to those traveling for shorter distances. The chance of choosing private transport relative to public/paratransit increased with the increase in Factor 1 and Factor 2 scores. Males showed a higher likelihood of choosing private transport relative to public/paratransit when compared to females. Moreover, car owners displayed a higher probability of choosing private transport relative to public/paratransit when compared to non-car owners. It is also observed that the respondents, who were traveling primarily for work and study, have lower probabilities of choosing private transport relative to public transport and paratransit when compared to those traveling for shopping and other purposes, respectively.

Non-motorized modes relative to public/paratransit: People traveling for longer distances are less likely to choose non-motorized modes relative to public/paratransit when compared to those traveling for shorter distances. Students displayed lesser chances of choosing non-motorized modes relative to public/paratransit when compared to employees.

4.6.2. Mode choice during COVID-19

Private transport relative to public/paratransit: Respondents, who were traveling for longer distances, were less likely to choose private transport relative to public/paratransit when compared to those traveling for shorter distances. The chances of choosing private transport relative to public/paratransit increase with the increase in Factor 1 scores. Males have a higher likelihood of choosing private transport relative to public/paratransit when compared to females. Moreover, car owners have a higher chance of choosing private transport relative to public/paratransit when compared to non-car owners. It is also observed that the people who are traveling primarily for shopping have higher chances of choosing a private transport mode relative to public transport or paratransit when compared to those traveling for social, recreational, and other purposes.

Non-motorized modes relative to public/paratransit: Respondents who were traveling for longer distances were less likely to choose non-motorized modes relative to public/paratransit when compared to those traveling for shorter distances. People who were traveling primarily for work are less likely to choose non-motorized modes relative to public transport or paratransit when compared to those traveling for social, recreational, and other purposes. Respondents were more likely to use NMT for shopping trips compared to other trip purposes during COVID-19.

5. Discussion and conclusions

It is speculated that travel behaviors and mode preferences are substantially different during pandemic situations compared to normal (pre-pandemic) situations mainly due to the restrictions imposed by authorities and fear of infection by individuals. This study presented the outcomes of an online questionnaire survey that was conducted

to explore the changes in travel behaviors due to the ongoing COVID-19 pandemic. It focused specifically on primary travel during the pandemic because trips for primary purposes are made out of necessity. Some key findings of this study are summarized below.

It was observed that shopping became the primary purpose of traveling during COVID-19. The significant shift from work, study, and other trips to shopping trips indicate that shopping trips need additional attention during a pandemic. Self-isolation or lockdowns imposed by the authorities could reduce trips for work or education. However, shopping could be the primary reason why people need to make trips during a pandemic regardless of the level of restriction, i.e., complete, partial, or smart lockdown. Further, shopping trips during a pandemic would generally be made for buying grocery and other household items, and are likely to be shorter in distance and time as compared to those for work, study, and other purposes.

The findings of this study further explained that travel distances tend to become shorter and trips tend to become less frequent during pandemics. Since most of the respondents were traveling primarily for shopping during the pandemic and the social distancing requirements will be required for a considerable amount of time. The policymakers and the private sector operators can focus on further reducing the outdoor trips undertaken for shopping purposes. Online activities including online shopping could be a viable alternative to further reduce the outdoor trips. Although a surge in online activities has been observed around the world during the pandemic, there are still several barriers to online activities, particularly to online shopping. Reducing these barriers to internet-based activities can help in reducing outdoor trips for shopping as well as for certain other purposes. In addition, secure online banking and electronic payment systems have the potential to further enhance the use of online shopping.

Increased use of private cars and active transport modes (e.g., walking and bicycles) and decreased use of public transport and paratransit (e.g., taxi) for primary trip purposes were observed during COVID-19. Such observations indicate that people tend to use safer (in terms of infection) transport modes during pandemics. Further, this finding has some implications for future transport trends in the post-COVID-19 and new-normal era. A recent report by Lime Micro-mobility also explained that people might shift to more flexible, short-distance, greener, and community-focused modes, such as bicycles, e-scooters, and e-bikes (Thigpen, 2020). However, the current study revealed that the shift from private cars to non-motorized modes (i.e., walking and bicycles) was not significant even though distance traveled was significantly reduced during the pandemic. It could be attributed to the fact that many cities around the world lack proper pedestrian and bicycle infrastructure. Since motorized traffic has reduced during the pandemic, urban and transport planners should utilize this opportunity to focus on promoting active modes of travel. Further, as explained in De Vos (2020), active modes, i.e., walking and cycling, would aid in enhancing the physical activities and maintaining the health and wellbeing of people during pandemics.

Respondents placed a high emphasis on infection-related factors, e.g., passengers with face masks, social distance, cleanliness, and infection concern, when choosing a travel mode during COVID-19. On the other hand, factors that generally affect mode choice, e.g., travel time saving, comfort, and cost under normal circumstances, become less important during pandemics. Public transport ridership decline during pandemics mainly due to government restrictions, i.e., suspended services, and infection concerns by people. However, public transport will remain to be a need of the society although it is not safe from the pandemic viewpoint. It is further supported by the outcome of this study that respondents were highly concerned about pandemic related risks associated with public transport. Hence, strategies should be adopted to make public transport safer during the pandemic. The maximum number of passengers in a bus or a train can be reduced to follow the social distancing protocols even though it might cause additional delays to certain passengers. Nonetheless, the results of this study indicated that the respondents were less concerned about travel time saving and comfort during the pandemic. In addition, making face masks mandatory inside public transport may also help resolving the concerns of the public transport users. Additionally, facilities for sanitization can be made available on public transport and stations to provide a sense of safety to passengers. Although there are low chances of transfer of viruses through banknotes, paying fare inside a bus/train may increase the contact between passengers and drivers. Hence, transport operators can explore other alternatives, such as contactless or prepaid online ticketing systems, to reduce person-to-person contacts.

Gender, car ownership, employment status, travel distance, primary purpose of traveling pandemic-related factor (Factor 1), and general factor (Factor 2) were found to be significant predictors of mode choice before the COVID-19 pandemic. Whereas, gender, car ownership, employment status, travel distance, primary purpose of traveling, and Factor 1 were found to be significant predictors of mode choice during COVID-19.

It should be noted that there are some limitations associated with this study. Firstly, this study is based on the data collected through a global survey. The scatter and the variation due to the geographical location is high, i.e., different countries had different levels of restrictions and different percentages of the infected population. Secondly, the people, who had access to the internet and who could understand and communicate in English, responded to this questionnaire. Thus, generalizing outcomes for an average population in a given society might not be practical. Further, social, economic, and health inequalities also play a vital role and the behaviors and responses depend on such factors as well (van Dorn et al., 2020). In addition, it is likely that the reported behavior might not be a true representative of their actual travel behavior, particularly before the pandemic. Certain demographic variables such as monthly household income and marital status could not be included in the multinomial logistic regression model as some cells (mode choice levels by subpopulations) had zero frequencies. An increase in the sample size and diversity of the sample is recommended for future studies to tackle this issue. Nevertheless, the findings of this study could have implications for transport planning during the post-COVID or new-normal era. Further, identification of user needs, requirements, and concerns are also possible and such aspects are important in satisfying the transport needs of the general public particularly during possible future pandemic situations.

CRediT authorship contribution statement

Muhammad Abdullah: Conceptualization, Methodology, Data curation, Formal analysis, Writing - original draft, Visualization, Software. **Charitha Dias:** Conceptualization, Methodology, Data curation, Formal analysis, Writing - original draft. **Deepti Muley:** Conceptualization, Methodology, Data curation. **Muhammad Shahin:** Conceptualization, Methodology, Data curation.

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