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Exploring the changes in travel behavior between the first and second waves of the COVID-19 pandemic in Dhaka

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ABSTRACT

The COVID-19 outbreak created immense disruptions in our daily lives. Travel is one of the major areas severely impacted by the pandemic. Bangladesh experienced two waves of COVID-19 between March 2020 and July 2021. Although several studies focused on significant changes in the travel behavior of urban road users before and during the pandemic, hardly any research examined the differences between the two waves. Hence, it was important to study the differences in travel behavior between the two waves of the COVID-19 pandemic to understand how the effects of travel restrictions, health concerns, and the severity of the pandemic on people's travel decisions change over time. This study intends to investigate the changes in travel behavior between the first and second waves of the COVID-19 pandemic in Dhaka and the factors that influence these changes. Data were collected through online questionnaire surveys using the Google form. Voluntary response and convenience sampling techniques were used to collect responses from 447 people in Dhaka. Descriptive statistics and non-parametric tests were conducted to analyze the data. In addition, two multinomial logistic models were developed to identify the factors behind the changes in travel behavior. This study reveals that work and shopping trips increased, whereas work-from-home and online shopping somewhat decreased during the second pandemic wave compared to the first pandemic wave. Most non-car owners who reduced their use of public transportation during the first pandemic increased their use during the second wave. There was no significant increase in the use of active transport modes for work and shopping trips in Dhaka. The perceived risk of COVID-19 infection was relatively lower during the second wave, influencing the respondents to travel more frequently for work and shopping purposes. Ensuring more adaptive public transportation, flexibility to work from home, and creating supportive infrastructures for active transport modes might help to provide a safe, affordable, and efficient transportation system for all during the future waves of the pandemic and other unprecedented events.

1. Introduction

The unprecedented COVID-19 pandemic drastically altered people's lifestyles and travel behavior all over the world (Awad-Núñez et al., 2021; Beck and Hensher, 2020; de Haas et al., 2020; De Vos, 2020). Coronavirus disease (COVID-19) is a respiratory illness caused by SARS-CoV-2, first reported in Wuhan City, China, in December 2019 (WHO, 2020). Globally, around 516,922,683 confirmed cases of COVID-19, including 6,259,945 deaths, had been reported to WHO (as of May 12, 2022) (WHO, 2022). The first case in Bangladesh was reported on March 8, 2020, and the country experienced the first and second waves of the COVID-19 pandemic in 2020 and 2021, respectively (Mamun, 2021; Paul, 2020). In January 2022, Bangladesh faced the third peak of COVID-19 because of both Delta and Omicron variants (Mahmud, 2022).

To reduce the spread of the Coronavirus, many countries took various measures such as countrywide lockdowns, social distancing, a ban on travel, work-from-home policies, and shutdown of educational institutes, offices, and restaurants (Abdullah et al., 2020; de Haas et al., 2020; De Vos, 2020; Hadjidemetriou et al., 2020; Klein et al., 2020; Muley et al., 2020; Warren and Skillman, 2020). Like other countries, during the first pandemic wave, a countrywide lockdown was imposed

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in Bangladesh from 26 March to 30 May 2020 (Shammi et al., 2021). The enforcement of this lockdown banned travel throughout the country by road, rail, water, and air routes (Anwar et al., 2020; Kamruzzaman and Sakib, 2020). During the second wave of the pandemic in 2021, the government of Bangladesh again imposed a second countrywide lockdown from 5 April to 16 May 2021, suspending all domestic flights, river, and railway transport (Hasan, 2021; Khatun, 2021). However, this lockdown was more relaxed and less effective over time than the first lockdown (Tayeb, 2021). Though this wave was more severe both in the number of COVID-19 cases and deaths than the first wave, the streets of Dhaka were more crowded, and around 10 million people left Dhaka on the occasion of Eid-al-Fitr (2021) during the second lockdown (Adhikary, 2021; Amin, 2021; Kamruzzaman, 2021; Lasker, 2021; WHO, 2021).

Travel behavior is one of the most important yet complex aspects of transportation studies, which refers to individuals' decision-making process regarding aspects such as travel frequency, mode use, time of travel, and trip destination (Barnes and Davis, 1999; Kadiyali, 2013; Li et al., 2019; Rahman et al., 2015; Vuuren and Slabbert, 2012). It is influenced by various factors, such as age, gender, household size, household composition, income, employment status, vehicle ownership, residential and workplace locations, lifestyle, and perception (Abdullah et al., 2020; Bhattacharya et al., 2014; Christiansen et al., 2017; Gärling and Fujii, 2009; Ma and Cao, 2017; Pawar et al., 2021; Rahaman and Ahmad, 2010; Rahman et al., 2015). It can also be affected by any natural or manmade catastrophic situation and changes in response to its surrounding circumstances (Goulias et al., 2020). For example, people's travel behavior significantly changed during the COVID-19 pandemic (Anwari et al., 2021; Jamal and Paez, 2020). Some of these behavioral changes were in response to the lockdown, while others were impelled by their safety perceptions and limited access to choices (Bhaduri et al., 2020).

Numerous studies have already addressed the changes in travel behavior during the first wave all over the world (Abdullah et al., 2020; Deyshappriya, 2020; Hotle et al., 2020; Neuburger and Egger, 2020; Parady et al., 2020; Rana et al., 2021; Warren and Skillman, 2020). In Bangladesh, some studies have focused on changes in trip frequency (Jamal and Paez, 2020), impacts of COVID-19 on travel behavior and mode choice (Anwari et al., 2021; Paul et al., 2022), changes in travel patterns (Paul et al., 2021), impact on active travel mode choice (Zafri et al., 2021), impacts of COVID-19 on public transportation and road safety (Shaik et al., 2021), and effects of COVID-19 on shopping behavior (Zannat et al., 2021). Most of these studies represented the scenario of the first wave of the pandemic and explored the changes in travel behavior between before and the first pandemic wave. To the best of the authors' knowledge, no study was conducted on changes in people's travel behavior in Dhaka between the two waves of the COVID-19 pandemic. Therefore, this study compares the two waves of the COVID-19 pandemic to explore the changes in travel behavior for work and shopping trips in Dhaka. Specifically, this study investigates the changes in travel behavior aspects, such as trip frequency and mode choice, between the first and second waves of the COVID-19 pandemic in Dhaka, and it identifies the factors that influence these changes. During the peak of these two waves, distance learning was the primary option for education in Bangladesh, and thus, only work and shopping trips were the main reasons for making trips. It is expected that the study's findings will help policymakers and planners plan more proactively during unprecedented events like COVID-19.

2. Literature review

2.1. COVID-19 scenario in Bangladesh during the first and second waves of the pandemic

In Bangladesh, the first wave of the COVID-19 pandemic (March 2020–August 2020) was less severe than the second wave of the pandemic (March 2021–July 2021), both in respect of COVID-19 cases and deaths (Fig. 1). Being a densely populated country, it is difficult to strictly maintain social distancing in Bangladesh (Anwar et al., 2020). However, people maintained these measures comparatively more seriously during the first wave than in the second wave (Khan, 2020; Tayeb, 2021; WHO, 2021). Some probable reasons could be the more relaxed lockdown during the second wave, perceiving the pandemic as a normal situation, initiation of the vaccine program, losing patience to stay at home, or being compelled to violate social distancing measures for the sake of livelihood (Akanda and Ahmed, 2020; Anwar et al., 2020; Khan, 2020; Siam et al., 2020; Tayeb, 2021).

Dhaka, the capital and main economic center, was the epicenter of the COVID-19 outbreak in Bangladesh (Siam et al., 2021). As per DGHS (2022) information, the first COVID peak in Dhaka was observed on 22 June 2020, with 1105 confirmed cases. However, from July 2020 to November 2020, the number of daily confirmed cases ranged from 550 to 1200 in Dhaka, which dropped in December and suddenly increased in March 2021. The second peak was observed on 1 April, with 4509 confirmed cases, three times greater than the cases of the first wave (DGHS, 2022). A few days before the stricter lockdown was enforced during this wave, a large number of people left Dhaka for their hometowns despite restrictions on long-distance transportation modes (Bari and Sultana, 2021). These scenarios indicate that people perceived the second wave as relatively more normal than the first wave, and therefore, they were less likely to follow COVID-19 preventive measures in this wave.

2.2. Factors influencing travel behavior during the pandemic

In general, travel behaviors are influenced by various factors during normal times. These are presented in Table 1 below.

However, during the pandemic, people's travel behavior is not only influenced by traditional factors but also affected by some other additional factors such as personal safety, perception of risk, fear of COVID-19, social distance, cleanliness, infection concern, and fewer working days (Abdullah et al., 2020; Cori et al., 2020; Madubuike, 2020; Pawar et al., 2021). Some effects of these factors on travel behavior during the pandemic are presented in Table 2.

2.3. Changes in travel behavior around the world during the pandemic

In recent times, the COVID-19 pandemic caused massive disruption to society and had both direct and indirect effects on the travel behavior of people all over the world (Abdullah et al., 2020; Bhaduri et al., 2020; de Haas et al., 2020; Deyshappriya, 2020; Katrakazas et al., 2020; Parady et al., 2020; Pawar et al., 2021; Shamshiripour et al., 2020). For example, mobility reduced significantly, such as 76% mobility reduction in Spain, 60% in the U.S.A., and 50% in Hungary (Abdullah et al., 2020; Aloi et al., 2020; Bucsky, 2020). Many developed and developing countries witnessed a notable reduction in trip frequency (Bhaduri et al., 2020; de Haas et al., 2020; Deyshappriya, 2020; Katrakazas et al., 2020; Parady et al., 2020; Pawar et al., 2021; Politis et al., 2021; Shamshiripour et al., 2020; Wang et al., 2024). Teleworking, e-shopping, and telehealth increased substantially in 20 European cities during the pandemic (Christidis et al., 2022). Mandatory trips were the main purpose for traveling during the pandemic in the Netherlands (Chao et al., 2022). In Hong Kong, local shopping trips decreased by 42% (Zhang et al., 2021b). Other discretionary trips, such as commuting, eating outside, sightseeing, and social trips, were reduced almost by half in Indonesia (Irawan et al., 2021).

In terms of modal share, people tried to shift to private modes from shared modes during the pandemic (Aloi et al., 2020; Beck and Hensher, 2020; Bhaduri et al., 2020; Bucsky, 2020; Deyshappriya, 2020; Jenelius and Cebecauer, 2020; Loa et al., 2021; Marra et al., 2022; Pawar et al., 2021; Wang et al., 2021, 2024). However, the shift from public to private mode was not that high in developing countries like India due to

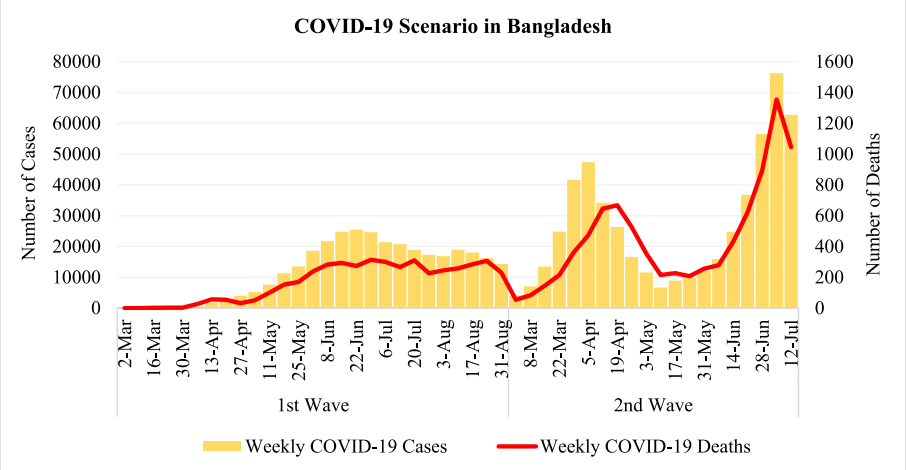


Fig. 1. COVID-19 situation in Bangladesh (Source: Authors' construction from WHO, 2021).

Table 1
Factors and sub-factors influencing travel behavior during normal times.

Factors	Sub-factors	Source
Structural Factors	Transport operations, transport infrastructure	(Pawar et al., 2021)
Demographic Factors	Age, gender, household size, household composition, country of residence, marital status	(Christiansen et al., 2017; Nasrin et al., 2012)
Socio-Economic Factors	Income, education, employment status, occupation, vehicle ownership	(Abdullah et al., 2020; Haque et al., 2013; Kamruzzaman et al., 2020; Rahman, 2008)
Travel-Related Factors	Travel purpose, travel cost, travel distance, comfort level of the mode, parking availability	(Christiansen et al., 2017; Islam, 2019; Pawar et al., 2021)
Behavioral & Psychosocial Factors	Individual attitudes, perceptions, lifestyle, norms, beliefs, and acquaintance	(Elias and Shiftan, 2012; Gärling and Fujii, 2009; Pawar et al., 2021)
Spatial Factors	Residential and workplace locations, the places of origin-destination	(Rahman et al., 2015; Rahman, 2008)
Other Broader Factors	Built environment, pattern of land uses, economic growth, and technological changes	(Rahaman and Ahmad, 2010; Rahman and Ashik, 2020)

Table 2
Other factors influencing travel behavior during COVID-19.

Factors	Effects on Travel Behavior	Source
Personal Safety	Unprecedented growth in car usage, decline in the share of public transport, increase in cycling and walking, avoidance in using crowded shared means of transportation	(Abdullah et al., 2020; De Vos, 2020; Marra et al., 2022; Molloy et al., 2021; Wang et al., 2024)
Perception of Risk	Modal shift from the subway to the bike-sharing system, avoid public spaces, decrease in the frequency of non-work activity trips, and increase in preference for online shopping	(Bhaduri et al., 2020; Parady et al., 2020; Pawar et al., 2021; Teixeira and Lopes, 2020)
Infection Concern	Teleworking, social distance maintaining, increase in travel distance per trip; using sanitizer, wearing masks, disinfecting of vehicle handlebar practices seen while traveling	(Awad-Núñez et al., 2021; Nguyen, 2021; Truong and Truong, 2021)

people's inaccessibility to private vehicles (Pawar et al., 2021). Therefore, a significant portion of the population used their previous modes (Bhaduri et al., 2020). Several studies found that the use of public transport had decreased significantly for fear of getting infected by the virus (Advani et al., 2021; Awad-Núñez et al., 2021; Ding and Zhang, 2021; Eisenmann et al., 2021; Jamal and Paez, 2020; Zhang et al., 2021a). Usage of active transport, such as bicycle use, had increased significantly in many countries, such as the U.S.A., U.K., Japan, Canada, Hong Kong, Spain, Chile, Switzerland, Melbourne, and Netherlands (Beck and Hensher, 2020; Brooks et al., 2021; Büchel et al., 2022; Bucsky, 2020; De-Toledo et al., 2024; Iglesias and Raveau, 2024; Marra et al., 2022; Molloy et al., 2021).

2.4. Travel behavior in Dhaka during the first & second waves of the pandemic

During the first pandemic wave, many people tried to avoid public transport. However, they were compelled to use overcrowded tempos or buses, risking their health due to the lack of affordable options (Anwari et al., 2021; Jamal et al., 2022; Jamal and Paez, 2020; Mahmud, 2020). Travel by ride-hailing, bus, and C.N.G. auto-rickshaw reduced significantly, whereas the use of non-motorized vehicles increased during the pandemic (Anwari et al., 2021; Fardin and Islam, 2022; Hossain et al., 2023; Jamal and Paez, 2020; Paul et al., 2021, 2022). Most people in Bangladesh do not have the flexibility to work from home (Mahmud, 2020). Therefore, work trips did not drop significantly during the pandemic.

During the second pandemic wave, the streets of Dhaka were found to be more crowded than during general holiday periods (Amin, 2021; Lasker, 2021). As private and public offices were open, people were seen commuting by C.N.G. auto-rickshaws, ride-hailing services like Uber, and cars without maintaining social distancing (Amin, 2021; Lasker, 2021). From the above discussion, it is evident that prior studies in Bangladesh mostly focused on the changes in travel behavior before and during the first pandemic wave. Therefore, this study will contribute to the existing literature by exploring the changes in travel behavior between the first and second waves of the pandemic and the underlying reasons behind those changes.

3. Methods

3.1. Data collection

Considering the ongoing COVID-19 situation, online questionnaire surveys were conducted in July 2021 to collect data for this study. A

single dataset was used to gather information for two periods. Several social distancing measures and safety regulations had to be maintained during the pandemic. These measures would have been breached if face-to-face surveys had been conducted. For the safety of the surveyors and respondents, online surveys were the only feasible data collection method. During the COVID period, online surveys were conducted in similar studies all over the world (Abdullah et al., 2020; Bhaduri et al., 2020; Mayo et al., 2021; Pawar et al., 2021; Zafri et al., 2021, 2023).

Initially, 29 pilot surveys were conducted using the draft questionnaire in June 2021. Based on the feedback from the pilot survey, the questionnaire was modified so that it became more explicit to the respondents. Then the final questionnaire was disseminated through various online platforms, such as Facebook, Messenger, WhatsApp, and E-mail. The questionnaire sought respondents' socio-demographic characteristics, travel-related information, and perceptions regarding COVID-19. The travel-related information regarding trip frequency and mode choice was collected for two time periods – during the first and second waves of the pandemic. Participation in this online survey was completely voluntary. The purpose of the survey and confidentiality information were included in the questionnaire. The surveys were administered in English and Bengali (the native language of Bangladesh) so that people could respond in their preferred language. A total of 447 people from the entire Dhaka district participated in the survey. The spatial distribution of the sample is presented in Fig. 2.

This study is both longitudinal and retrospective. Similar to this study, retrospective measures were used in relevant research to collect information based on respondents' recall during the pandemic and other outbreaks (Barbieri et al., 2021; Joo et al., 2019; Shamshiripour et al., 2020). This data collection method is commonly used in travel behavior research to identify changes over time (Behrens and Mistro, 2010; Cao and Ermagun, 2017; Schoenduwe et al., 2015). According to the study by Thigpen (2019), prospective and recalled responses are highly correlated, indicating that the passage of time has little effect on the collected response. Moreover, to reduce the probability of recall bias, changes in trip frequency were measured in ordinal scale in this study so that respondents could easily recall the accurate answer from the scale regarding the changes in their travel behavior between the two waves of the pandemic (Cao and Ermagun, 2017).

In this study, non-probabilistic sampling methods were used, and hence the collected data were not free from selection bias. The questionnaire was only available to individuals with internet access, and most respondents were young and students. The descriptive statistics of

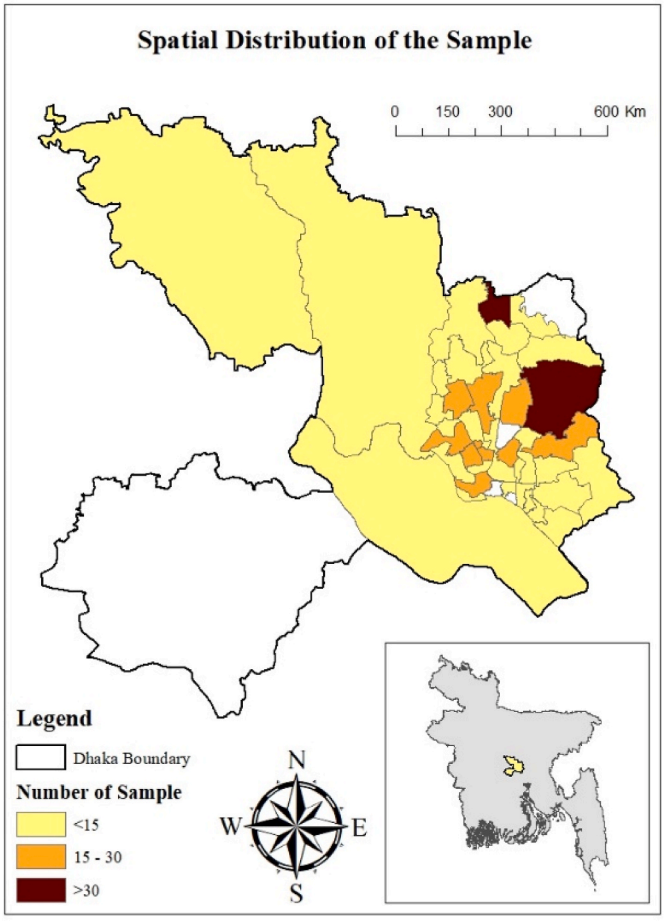


Fig. 2. Spatial distribution of the sample over Dhaka.

Table 3
Descriptive statistics of the independent variables.

Variables	Description/ Levels	Sample		Census Distribution*
		Frequency	Percentage	
Gender	Male	247	53.7%	54%
	Female	200	44.7%	46%
Age	Young (<30 years)	337	75.4%	63%
	Middle aged (30–60 years)	100	22.4%	32%
	Old (>60 years)	10	2.2%	5%
Education Level	Illiterate	1	0.2%	19%
	Primary	1	0.2%	28%
	SSC or equivalent	9	2%	34%
	HSC or equivalent	130	29.1%	9%
	Graduate or equivalent	251	56.2%	6%
	Postgraduate or equivalent	55	12.3%	4%
Monthly Household Income**	Low Income (<20,000 BDT)	136	30.4%	NA
	Middle Income (20,000–60000 BDT)	160	35.8%	NA
	High Income (>60,000 BDT)	151	33.8%	NA
Household Size	<5	263	58.8%	4.21
	5	112	25.1%	(Average)
	>5	72	16.1%	
Respondent's Household Bicycle Ownership	Yes	91	20.4%	NA
	No	356	79.6%	NA
Respondent's Household Motorcycle Ownership	Yes	76	17.0%	NA
	No	371	83.0%	NA
Respondent's Household Private Car Ownership	Yes	145	32.4%	NA
	No	302	67.6%	NA
Household members got infected with COVID-19	Yes	199	44.5%	NA
	No	248	55.5%	NA
Number of COVID-19 vaccine doses received by the respondent	None	311	69.6%	NA
	One	56	12.5%	NA
	Two	80	17.9%	NA

*Census Report 2011(BBS, 2015).
*Income Classification Source (Billah, 2020; JICA, 2016; Zafri et al., 2021)

the independent variables of the sample are presented in Table 3. Census data for some variables are also included in Table 3. Sample distribution by gender, age, and household size is representative compared to the population statistics (Table 3). Biases exist in sample distributions in the case of education level. Nevertheless, it is expected that slight biases in the sample would not significantly impede generalizability.

3.2. Data analysis

Descriptive analysis was used to explore the changes in respondents' trip frequency and mode preferences for shopping and work trips during the first and second waves of the pandemic. Non-parametric tests such as the McNemar-Bowker test and Wilcoxon signed-rank test were mostly used in this study for inferential statistical analyses, as these tests can be applied with ordinal and ranked data and require fewer assumptions (Abdullah et al., 2020). Two multinomial logistic regression models were developed for work and shopping trips in this study to identify the factors influencing the changes in travel behavior between the first and second pandemic waves. Since work and shopping trips differ substantially in nature, motivation, flexibility, and constraints, separate models were developed for each type of trip (Joewono et al., 2017; Macioszek et al., 2022; Shah et al., 2022).

The multinomial logistic regression model is an extension of the binomial logistic regression model. This logistic regression model can be useful for modeling when the dependent variable has more than two nominal categories (Bayaga, 2010). A generalized equation of multinomial logistic regression is shown below:

$$ln\frac{\pi_i}{\pi_I}=\ln\left[\frac{P\ (y=i)}{P\ (y=I)}\right]=\alpha_i+\sum_{j-1}^{j}\beta_{ij}x_j, i=1,2,3,\ldots\ldots,I-1$$

where α_i is the constant and b_{ij} is the coefficient of the x_j independent variable for the i th outcome of the dependent variable and the outcome I of the dependent variable is selected as the reference outcome.

If a categorical dependent variable has a Q number of outcomes, this method will develop (Q-1) logistic regression models where a dependent variable outcome must be designated as a reference outcome (Zafri et al., 2021). The dependent variable is dummy coded, meaning there is a variable for all but one category, so there will be P-1 dummy variables if there are P categories. The dummy variable for each category has a value of 1 for its category and a value of 0 for all others. The reference category does not require its own dummy variable as it is uniquely identified because all other variables are 0 (Bayaga, 2010).

In this study, two multinomial logistic models were developed where dependent variables were "Change in work trip frequency from the first wave to second wave" and "Change in shopping trip frequency from the first wave to second wave." There were three outcomes for both the dependent variables: "more than the first wave," "same as the first wave," and "less than the first wave." In both cases, "less than the first wave" was designated as the reference outcome. The other outcomes of these tests are discussed in the results and discussion section.

4. Results and discussion

4.1. Changes in trip frequency

This study defined a trip as a one-way journey from an origin to a destination. Wilcoxon signed ranked test indicates statistically significant differences at a 99% confidence level (p = 0.000) in the number of work and shopping trips during the first and second waves of COVID-19. Fig. 3 depicts that nearly 50% of respondents' work and shopping trips increased during the second pandemic wave compared to the first wave. Work-from-home and online shopping also decreased somewhat during the second wave (Fig. 3).

Fig. 4 somewhat explains the changes in trip frequency for work and shopping trips. Almost 71% of the people prefer e-activities during the pandemic in Dhaka (Fig. 4). However, Fig. 3 shows that only 5% of people shifted online during the second wave. Work from home had increased in many countries during the COVID-19 pandemic. However, it did not increase considerably in Dhaka because 52% of the people responded that they do not have the flexibility to work from home (Fig. 4).

4.2. Change in modal share

The McNemar-Bowker test showed that the respondents' mode choice significantly differs at a 99% confidence level (p = 0.000) from the first wave to the second wave. For work trips, the most used mode was the private car (34%), followed by a bus (16%), C.N.G. auto-rickshaw (14%), and rickshaw (13%) during the first wave of the pandemic (Fig. 5). However, during the second pandemic wave, except for private cars, the modal share of almost all modes increased somewhat for work purposes (Fig. 5). As private car users did not shift their mode, the modal share of private cars for work trips remained almost the same (Fig. 5).

For shopping trips, most of the people used rickshaws (34%) and private cars (23%) during the first wave (Fig. 5). Around 17% of people preferred walking during this period. However, during the second wave, except for walking, the use of all modes increased (Fig. 5).

Though the respondents perceived the public bus as the riskiest

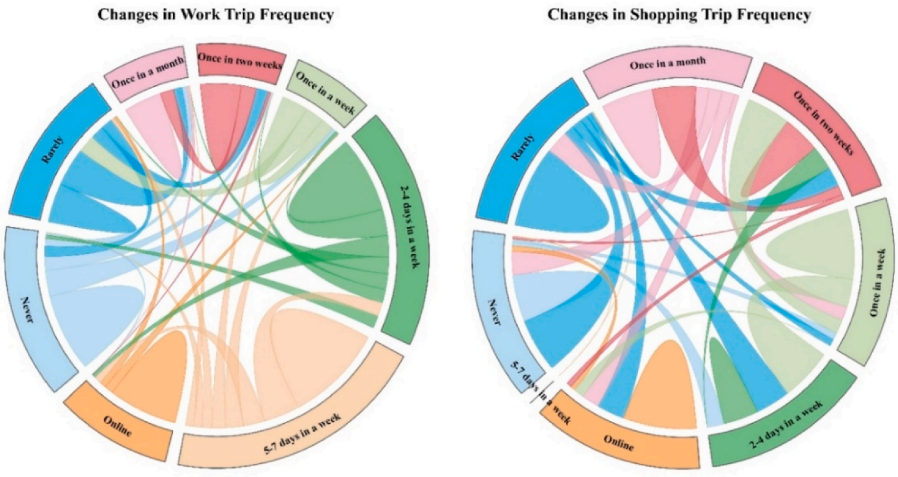


Fig. 3. Change in trip frequency for work and shopping trips from the first wave to the second wave.

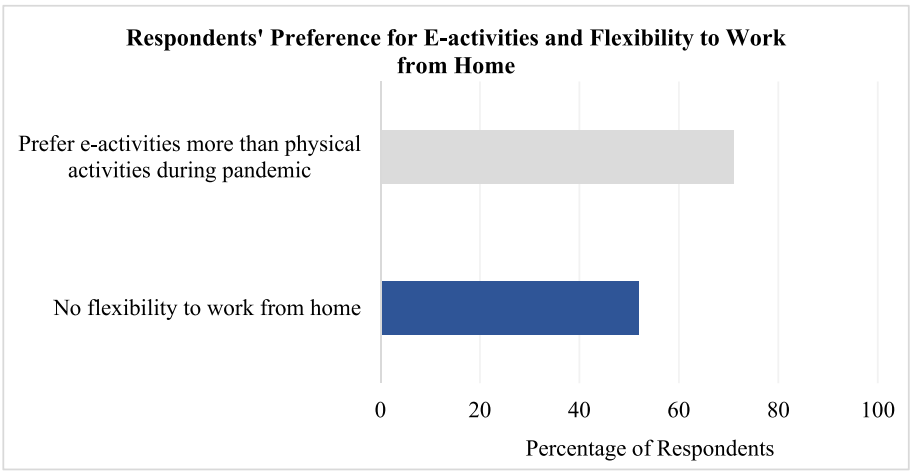
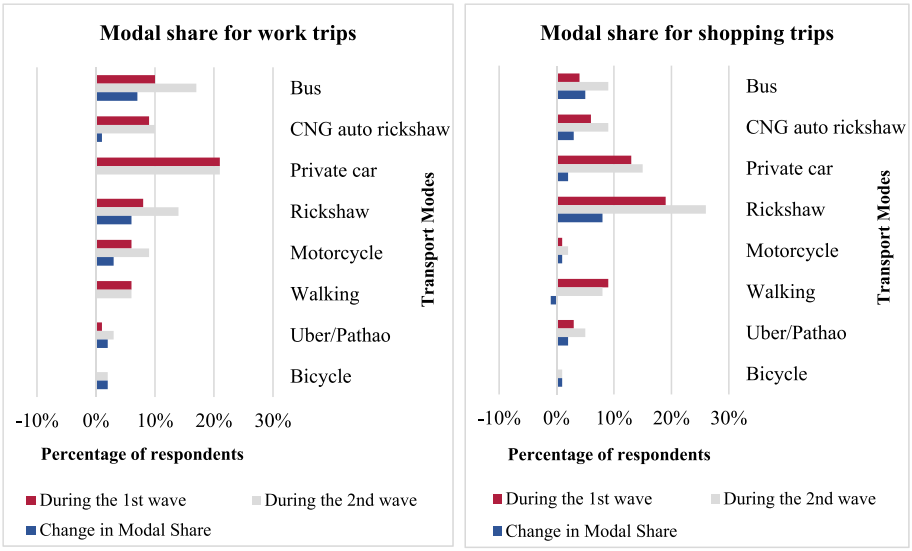


Fig. 4. Preference for e-activities and flexibility to work from home.



(a) (b)

Fig. 5. Changes in modal share from the first wave to the second wave of the pandemic for (a) work trips and (b) shopping trips.

travel mode, bus use increased more during the second wave than during the first wave of the pandemic (Fig. 5). Around 66% of these bus users' family members got infected with COVID-19, and only 14% of them own a private car. This means that most bus users had no other option, so they were compelled to use the bus.

The use of C.N.G. auto-rickshaws also slightly increased for middle and high-income people. This finding is consistent with the previous study by Rahman (2008), who revealed that C.N.G. auto-rickshaws are a convenient alternative mode for people who can not afford a private car. Though several studies conducted in other countries revealed an increase in the use of active transport modes during the pandemic (Brooks et al., 2021; Bucsky, 2020; Irawan et al., 2021), there was no significant increase in the use of active transport modes for work and shopping trips in Dhaka.

4.3. Modal shift of car owners and non-car owners

For car owners, the majority used to make their work trips by private car, which did not change that much during the second wave of the pandemic (Fig. 6). A significant modal shift was observed among non-car owners compared to car owners. The majority of non-car owners who decreased their usage of public transport during the first wave of the pandemic later increased their travel in public transport during the second wave of the pandemic (Fig. 6).

Like work trip mode use, car owners' trip-making using car did not change much during the second wave of the pandemic for shopping trips. Private cars were the major mode of shopping trips for most car owners (Fig. 6). But, for non-car owners, rickshaws were seen as their major mode of transport for shopping trips. A notable percentage of non-car owners shifted from other modes to public transport during the second wave of the pandemic (Fig. 6).

4.4. Factors influencing changes in travel behavior

Two multinomial models were developed to identify the factors that might influence the change in work and shopping trip frequency between the first and second waves of the COVID-19 pandemic. Model statistics for work and shopping trips were statistically significant at 99% confidence levels. Correlations between the predictor variables were also analyzed. There exists no multicollinearity among the independent variables, as the highest V.I.F. value for both work and shopping trip models is 1.01. The coefficient (β), odds ratio (OR), and p-value

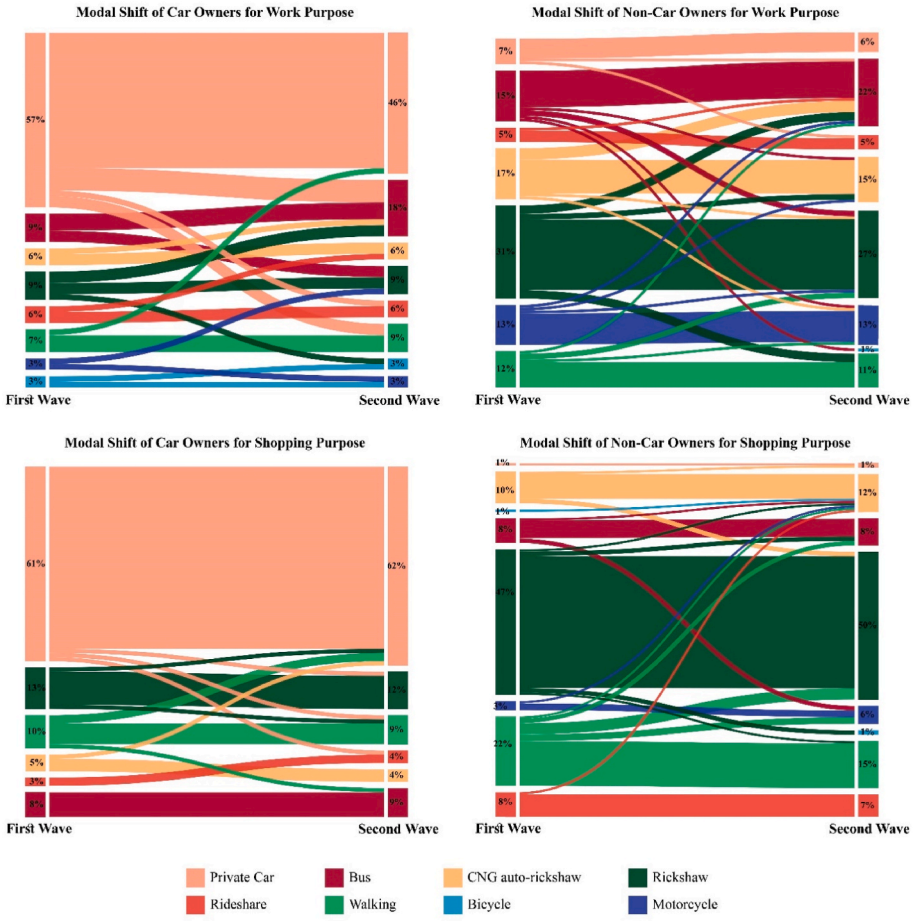


Fig. 6. Modal shift of car and non-car owners for work and shopping purposes.

of these models are presented in Table 4. Model results are interpreted in the following section.

4.4.1. Socio-economic factors

Income group-wise significant differences were found only for shopping trips. Both low- and middle-income respondents were less likely to depend on online shopping than high-income groups to buy necessary daily products. This might be why they made more shopping trips than high-income groups during the second wave.

The 'Increase in household income during the pandemic' was statistically significant for work trips during the second wave (Table 4). This could be because lockdown restrictions were weakly enforced during the second wave, workplaces reopened, and people started earning more.

4.4.2. COVID-19 risk perception related factors

Among the COVID-19 risk perception-related factors, "Less worried about COVID-19 infection during the second wave" was the only factor found to be statistically significant for both work and shopping trips. Respondents who worried less about COVID-19 infection were more likely to increase their trip frequency during the second pandemic wave than the first wave (Table 4). Moreover, respondents who were more aware of COVID-19 and always took precautionary measures before going out were less likely to increase their shopping trips.

4.4.3. Travel behavior-related factors

In the case of work trips, respondents who switched to public transport during the second wave were more likely to increase their trip frequency. People had become accustomed to the pandemic during the second wave and were less worried about COVID-19 infection, which might be one reason behind this. During the first pandemic wave, people somewhat tried to avoid public transportation and shared modes, but during the second wave, they returned to their pre-COVID mode for regular work trips. However, people who shifted to relatively expensive modes, such as CNG auto-rickshaws and ridesharing services, were less likely to increase their trip frequency.

In the case of shopping trips, respondents who could afford to use more costly and convenient modes, like private transport and CNG auto-rickshaw, were more likely to increase their shopping trip frequency during the second wave.

4.4.4. Work-specific factor

"No flexibility to work from home" was found to be statistically significant, which indicates that the number of work trips remained unchanged for some respondents during the second wave compared to the first wave because teleworking is not a common practice in Bangladesh (Table 4). Though employees were asked to work from home to keep the operations running during the lockdown period of the first wave (Antara and Bari, 2020), the workplaces started to operate physically in full swing after the ease of the lockdown on May 31, 2020 and continued onwards (Siam et al., 2020).

5. Policy recommendations

Based on the findings of the study, the following policy measures are recommended.

Table 4
Results of multinomial logistic regression models.

Factors	Change in work trip frequency during the second wave[a]				Change in shopping trip frequency during the second wave[a]			
	More than First Wave		Same as First Wave		More than First Wave		Same as First Wave	
	β	OR	β	OR	β	OR	β	OR
Socio-economic Factors								
Income Group (Ref: High Income Group)								
Low income group					1.491***	4.443	1.242***	3.461
Middle income group					0.934***	2.545	0.780**	2.182
Household income increased during the pandemic (Ref: No)								
Yes	1.094**	2.985	1.571***	4.812				
COVID Risk Perception-related Factor								
Less worried about COVID-19 infection during the second wave (Ref: Disagree)								
Agree	1.390***	4.014	1.116***	3.051	0.716*	2.046	0.223	1.250
Neutral	1.255*	3.509	1.099*	3.001	−0.086	0.918	0.036	1.037
Took precautions before going out (Ref: No)								
Yes					−0.711*	0.491	−0.524	0.592
Travel Behavior-related Factors								
Shifted to Public Transport (Ref: No)								
Yes	0.944*	2.569	−0.907	0.404				
Shifted to Private Transport (Ref: No)								
Yes					1.850*	6.361	0.492	1.635
Shifted to C.N.G Auto-rickshaw (Ref: No)								
Yes	0.415	1.514	−1.506*	0.222	1.789*	5.982	−0.389	0.678
Shifted to Rideshare (Ref: No)								
Yes	−0.931	0.394	−2.996**	0.050				
Work-specific Factor								
No flexibility to work from home (Ref: No)								
Yes	0.487	1.628	0.944***	2.571				
Constant	−0.994*		−0.838		0.123		0.833*	
Model Statistics	Chi-Square = 67.095, df = 14, p-value = 0.000***				Chi-Square = 51.222, df = 14, p-value = 0.000***			

*** **99%** significance level, ** **95%** significance level, * **90%** significance level.
[a] Less than first wave = Reference Category.

- **Safer Public Transportation:** This study shows that respondents perceived a higher risk of infection while traveling by public transport like Bus, Leguna/Tempo. However, low and middle-income individuals had no option but to use these modes during the pandemic. Non-car owners who avoided public transport during the first wave later shifted to it during the second wave. During the second wave, people became accustomed to the new normal, although death and infection rates were higher in this wave. Movement restrictions were more relaxed, and people were not following the rules and restrictions like before. People had to move for their livelihoods and sustain the country's economic activities during peak pandemic periods. Therefore, it is the responsibility of policymakers to ensure that public transport is made safer for all people during peak pandemic periods.
- **Regulating the Fare of C.N.G. Auto-Rickshaw:** This study reveals that a small percentage of respondents started using C.N.G. auto-rickshaws during the pandemic. Therefore, the fare of C.N.G auto-rickshaws must be regulated to keep them affordable, especially for middle-class individuals. Moreover, it would increase mobility options for people and reduce the pressure on public transport.
- **Supportive Infrastructures for Active Transport Modes:** A wide range of literature found that the use of active transport modes increased significantly during the pandemic (Abdullah et al., 2020; Beck and Hensher, 2020; Vallejo-Borda et al., 2022). However, this study shows that the people in Dhaka did not resort to more active modes during peak pandemic periods. Active transport is not only conducive to maintaining a safe social distance, but it is also helpful for boosting the immune system against the Coronavirus through physical exercise (Amatriain-Fernandez et al., 2020; da Silveira et al., 2021; Islam et al., 2021; Tjandrawati et al., 2021). Dhaka is not renowned for being a cycling and walking-friendly city. Active transport is much more important than at any other time in the past. However, most of the streets of Dhaka do not have wide and safe footpaths, continuous pedestrian ways, pedestrian-friendly intersections, separate cycle lanes, wheelchair ramps for disabled persons, and enough shading and sitting facilities on the footpath. Therefore, pedestrian and active transport-friendly designs need to be incorporated into the policy. Lessons should be taken from the measures applied in many cities to promote cycling and walking during COVID-19, for example, reallocating public spaces, widening sidewalks, creating pop-up cycle lanes, and providing e-bike subsidies (Cummins, 2020; Lock, 2020; Nikitas et al., 2021).
- **Acknowledge the Role of Non-Motorized Transport:** As per the results of this study, the rickshaw was a popular choice among the respondents during the pandemic. It is a convenient mode for trip lengths exceeding the usual walking limit and could also act as a feeder service for public transport. However, the role of the rickshaw is not acknowledged that much in Bangladesh. Rather than trying to ban rickshaws to solve traffic problems, planned rickshaw routes can be established to integrate non-motorized transport with public transportation services.
- **Flexibility to Work from Home:** Unlike other cities worldwide, work from home did not increase considerably in Dhaka during the pandemic. Most of the respondents in this study (52%) do not have the flexibility to work from home. Developing countries like Bangladesh can not afford long-time work from home. However, during peak pandemic periods, all government and private organizations can be more flexible in allowing people to work from home so that they do not have to travel as much in these situations. It would help reduce the demand for public transport and keep vehicles less crowded through passenger-number capping.

6. Conclusion

The unprecedented COVID-19 created an immense disruption in people's travel behavior all over the world. In Bangladesh, the second wave of the pandemic was more severe than the first wave in respect of both COVID-19 cases and deaths. The study reveals that both work and shopping trip frequency increased during the second wave compared to the first wave of the pandemic. Work-from-home and online shopping

also decreased somewhat during the second pandemic wave. Non-car owners who decreased their public transport use during the first wave later increased their public transport travel during the second wave of the pandemic. Car owners mostly used their private car for both work and shopping trips during these two pandemic waves. No significant increase was found in the use of active transport modes in Dhaka between these two waves. People were less worried about COVID-19 infection during the second wave, influencing them to travel more frequently. Gender-wise no significant differences were found regarding the changes in travel behavior from the first wave to the second wave of the pandemic. People who could afford convenient modes (e.g., private cars, CNG auto-rickshaws) tended to increase their shopping trips.

The findings of this study indicate that over time, pandemic fear reduced, for which physical trip frequency and use of public transport increased, and technology-based alternatives of commuting and shopping decreased in Dhaka. Similar to Dhaka, some studies showed that people started traveling more frequently and shifted back to public transit options with the decrease in COVID-19 in India, Sri Lanka, Bangkok, the United Arab Emirates, Malaysia, and low and medium socio-economic status areas of the United States (Airak et al., 2023; Hamad et al., 2024; Ranaweera and Jayasinghe, 2022; Thaithatkul et al., 2023; Velmurugan et al., 2023; Wang et al., 2022; Xi et al., 2023). This study also found that people perceive cycle rickshaws and C.N.G. auto-rickshaws as safer during the pandemic. Similar findings are found in Lagos, Nigeria, where demand and cost of local minibus services named Danfo increased during the pandemic (Mogaji et al., 2022). Moreover, like Dhaka, telecommuting options are also limited in other developing countries, such as India (Nayak and Pandit, 2021). Therefore, it is expected that the policy measures recommended in this study might be helpful to ensure a safe, affordable, and efficient transportation system for all during the future pandemic waves in Dhaka and cities with similar contexts.

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CRediT authorship contribution statement

Farzana Faiza Farha: Methodology, Visualization, Writing – original draft, Writing – review & editing, Conceptualization, Data curation, Formal analysis, Investigation. **Farabi Sarker Shanto:** Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Fyrooz Anika Khan:** Formal analysis, Investigation, Writing – original draft, Writing – review & editing. **Maria Mehrin:** Formal analysis, Investigation, Writing – original draft, Writing – review & editing. **Asif Khan:** Conceptualization, Supervision, Writing – review & editing. **Nawshin Tabassum:** Supervision, Writing – review & editing. **Paromita Nakshi:** Supervision, Writing – review & editing.

Declaration of competing interest

None.

Data availability

The data that has been used is confidential.

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