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# Exploring the travel behavior changes caused by the COVID-19 crisis: A case study for a developing country

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ABSTRACT

This study aims to examine the extent to which SARS-Cov-2 and associated governmental interventions to mitigate virus transmission has affected daily travel decisions in Bangladesh. A questionnaire survey was used to record opinions of respondents hailing from diverse socio-economic backgrounds on trip number and mode preferences for a variety of trip purposes for "before" and "during" COVID-19 situation. This was used to assess changes in (i) trip frequencies, and (ii) travel mode preferences using contingency tables, ordinal logistic regression and Sankey diagrams. Analyses revealed that COVID-19 caused large variation in mode preferences but small variation in trip frequencies. Males still go outside for work and shopping, putting them at greater risk than females. COVID-19 has drastically cut recreational trips, but not so many work trips. Although online work or education (950%) and shopping (170%) has risen, this seems to be limited to urban areas. Besides, buses continue to be preferred the most during pandemic for trips involving short distance recreation (26.75%), markets (43.18%), and long distance recreation (35.66%). Results suggest the lack of online penetration in rural and suburban areas have prevented worktrip reductions in those places, putting the inhabitants at heightened risk from virus. Moreover, majority of the people continue to use buses at the expense of their health for lack of cheaper alternatives. Results imply that the government needs to ensure proper hygiene practices in public transit and non-motorised paratransit vehicles. Moreover, Information and Communication Technology (ICT), pedestrian and bicycle facilities need to be improved.

## 1. Introduction

Countries are trying to determine the optimal time to re-open their economies and strike a balance between health and economy after lockdowns and travel bans were induced by COVID-19 pandemic (Bhuiyan et al., 2020; Shammi et al., 2020). However, countries have experienced mixed results, with developing countries faring worse than developed ones, due to their inability to reduce virus contagion (Bhuiyan et al., 2020; Mamun and Griffiths, 2020). Because travel is one of the main factors spreading infectious diseases worldwide (Gezairy, 2003), inability to change travel patterns poses a hurdle to adapt to pandemic situation, and can damage a country's economy and health standards.

Although Bangladesh, a developing country, took travel restriction measures from the beginning of March 2020, countrywide lockdown was not imposed until March 26, 2020 (Anwar et al., 2020), placing doubt on such measure's effectiveness (Monjur and Hassan, 2020). In developing countries including Bangladesh, prevalence of informal sector and low-skill jobs with little scope to work from home or while maintaining physical distancing mean that people cannot afford to stay inside homes even if they want to. Many families live on a hand-to-mouth basis with insufficient savings, and need to leave their homes daily to access basic necessities. High-density urban neighbourhoods make it difficult to maintain spatial distancing (Salman, 2009; Hasnat et al., 2018a, 2018b; Ray et al., 2020). As a result, lockdown and physical distancing strategies failed to produce intended consequences in Bangladesh (Shammi et al., 2020). Now, Bangladesh wants to recover economically while minimizing COVID-19 transmission, and hence has replaced indiscriminate lockdown with partial lockdown on places on case-by-case basis after 30 May 2020 (Ministry of

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Public Administration, 2020). However, such intervention may not have the intended effect for the aforementioned reasons. Consequently, Bangladesh has comparatively high COVID-19 mortality rate (6.2%) (Sakib et al., 2020) and infection number (World Health Organization, 2020). It is thus important to identify the exact reasons for which Bangladeshis could not adapt properly to pandemic situation and failed to change their travel patterns. This study aims to do this specifically by assessing travel pattern change in "before" and "during" COVID-19 situations for various trip purposes through trip numbers and mode used with respect to a range of socio-economic factors.

This brief introduction is followed by a literature review concerning previous work done on COVID-19, as well as a general overview of work done on travel pattern change, focusing eventually on COVID-19 induced travel modifications. This is directed to address the research gap that no significant study has been previously done to access the effect of COVID-19 prompted travel pattern changes in developing countries. The experimental context is next described in detail, focusing on questionnaire survey used to assess travel tendency amendments. The fifth section explains the analysis results of the survey. Finally a brief general discussion of the work and overall research findings are provided.

## 2. Literature review

### *2.1. Background on COVID-19*

Although coronaviruses were first discovered in the world in the 1930s and in humans in 1960s (Ye et al., 2020), researchers have shown extreme interest in the latest strain of the virus, Severe Acute Respiratory Syndrome Coronavirus 2 SARS-CoV-2. The virus can cause Coronavirus Disease 2019 (COVID-19), which was first identified in December 2019 in Wuhan, Hubei, China. Since then the virus spread rapidly worldwide. The first international case of COVID-19 was reported in Thailand on 13 January 2020 (Andersen et al., 2021).

### *2.2. Scenario in Bangladesh and her response to the pandemic*

Bangladesh confirmed its first coronavirus case on 08 March 2020, Dhaka, the capital and the most populous city of Bangladesh (Islam, 2018; Shammi et al., 2020). In response to virus advent, Bangladesh delayed mass congregations from the first week of March, restricted international flights, enforced thermal scanner checking, and closed down educational institutions. Unfortunately, offices continued with regular schedules until 26 March 2020 when the government enforced a countrywide lockdown (Anwar, Nasrullah and Hosen, 2020). Thus, researchers are sceptical about the efficacy of measures taken in Bangladesh because of uncoordinated and reactionary policies and enforcements (Monjur and Hassan, 2020). From 31 May 2020 the government gradually lifted closures and movement restrictions. The government ordered partial lockdown on places on case-by-case basis (Ministry of Public Administration, 2020). During the study period in this paper (01 May to 30 June 2020), partial lockdowns were in effect around the country (Shammi et al., 2020). Because Bangladesh has already suffered economically (Bhuiyan et al., 2020), the country wants to recover while minimizing COVID-19 transmission. Consequently, Bangladesh prepared a COVID-19 response plan following International Health Regulations (2005) (Ministry of Health and Family Welfare, 2020). The main guidelines set forth in the plan that were followed during the study period, and the subsequent measures taken by the government to ensure compliance with the guidelines, are presented below:

1. **Enforcement of compulsory mask-wearing and safe hygiene practices outside the home, including within the workplace, school and public transport:** The law enforcement institutions of the government have coordinated among themselves to enforce compulsory mask wearing. Enforcement of mask-wearing and access to water and soap/sanitizers to ensure safe hand washing/sanitizing has been accompanied by a communications campaign on mask wearing, social distancing and safe hygiene practices to raise awareness and sustain behavior change. Local industry has been allowed to manufacture reusable masks to prevent dependence on more expensive imports and disposable masks.
2. **Zoning approach to containment:** Technology-enabled epidemiological health surveillance was used to identify COVID-19 hotspots. Such hotspots were coded as red, yellow or green to indicate the severity of cluster infections. Various restrictive measures were taken on each zone to mitigate virus transmission. Thus protectionist measures were taken in geographically-focused areas (zones) without the need for full national lockdown. For example, red zones, yellow zones and green zones were under full lockdown, partial lockdown, and no lockdown respectively. Such zones were evaluated by infection rate on a monthly basis to assess the necessity for a change in restrictive practices in a given area.
3. **Community-based prevention practices, case identification, and quarantining by utilizing local community health capacity and digital platform to reduce virus transmissions and sustain behavior change after lockdown:**
   a. Full family quarantine for individuals with symptoms of COVID-19 for 14 days;
   b. Targeted food distribution for 14 days to vulnerable households under isolation. Zoned containment and quarantine is important for supporting those families most in need and ensuring quarantine compliance;
   c. Supportive monitoring of home quarantine via telemedicine and by local community health service providers;
   d. Strong nationwide communications to empower symptomatic individuals and their families to report symptoms. The government felt that destigmatizing the disease was essential for people to feel safe in divulging symptoms and seeking necessary assistance;
   e. Effective community engagement strategies to empower communities to support and enforce safe behaviours of mask wearing, social distancing and safe hygiene practices are essential for ensuring and sustaining safe behaviours and practices;
   f. Locally managed isolation centres for dwellers of slums and other congested areas where home quarantine or isolation are not possible because of shared facilities.
4. **Maintenance of social distancing regulations based on latest expert and industry guidance as developed and enforced by the government:** Social distancing measures were applied based on epidemiological evidence with the primary objective of ensuring that virus transmission does not cause hospital beds to be exceeded. Regulations for public transportation, factories, offices, markets, shops, including in the informal sector, were developed and reviewed regularly based on epidemiological assessments. Measures were introduced at local and national levels to decelerate virus reproduction rate while minimizing the broader negative impacts to the economy.
5. **Empowerment of frontline health workers and other essential workers through communications and behavioral change:** The government realized that ensuring safety of essential frontline workers is vital to maintaining morale and preventing disease transmission by the workers themselves. The healthcare workers were equipped with necessary information and guidelines. Moreover, periodic reporting of symptoms and tracking of worker statuses helped health supervisors make timely management decisions like withdrawing workers from field duty.

Specific actions regarding COVID-19 taken in the transportation sector and for travel in Bangladesh during the study period of 01 May to 30 June 2020 are presented as follows:

1. All passenger flights coming into and going out of Bangladesh were cancelled until 16 May 2020. Cargo, special flights, air ambulances, relief carrying flights and emergency landing aircrafts were outside the purview of the ban.
2. All travellers arriving in Bangladesh were required to undergo mandatory 14-day quarantine, regardless of nationality and traveller type.
3. While most forms of transportation such as intercity and commuter busses and trains and ferries were shut down, public transport operations resumed gradually from 31 May 2020, depending on the situation of that place. Buses were limited to only 50% of capacity to ensure passengers could travel while maintaining physical distancing.
4. The country was in full lockdown until 30 May 2020. During that time, only essential services such as shops and banks were open at fixed times during the week. Besides, emergency services including hospitals were exempt from lockdowns. From 31 May until 15 June 2020, movement was not allowed outside from 8 pm until 8 am. Outside these hours the people were allowed to leave their homes only in case of an urgency. Non-compliance risked legal actions. From 16 June 2020, the curfew hours were restricted to the period of 8 pm to 6 am.
5. Starting from 15 June 2020, the government designated COVID-19 affected spots as red, yellow or green. The government declared a 21-day general holiday for the people living or working in red zones. People were asked to work from home. All forms of transport were barred from operating in such places. However, emergency services were exempted. People living in yellow zones have slightly relaxed restrictions, with offices and factories allowed to run physically with a limited number of workers. People were allowed to visit places of worship while maintaining social distance inside those places. Most shops except pharmacies and departmental stores would remain closed. Restaurants could only operate by providing parcel deliveries. Only public transport was barred in yellow zones. Green zones faced the least restrictions, as they were the least infected. All forms of activities except recreation were allowed. However, people had to wear masks and maintain physical distancing while outside (Ministry of Health and Family Welfare, 2020).

### 2.3. Why physical restriction policies fail in developing countries

Shammi et al. emphasized that robust policies need to be followed to reduce virus transmission and mitigate detrimental effects of COVID-19 (Shammi et al., 2020). However, following proper guidelines is easier said than done because of various socio-economic aspects, prevalent especially in developing countries (Salman, 2009; Ray et al., 2020), frustrating lockdown efforts to mitigate disease transmission (Loayza, 2020). In such cases, people are forced into crowded residences, leading to social compression instead of social distancing. Loayza warned that large displacement of people resulting from lockdown orders, particularly from urban to rural areas, can increase spatial coverage of virus. Lockdowns are fruitless when compliance is low, leading to fleeting inhibition gains and heightened risk of disease reemergence. Low compliance results not only from weak enforcement capability but also from the dire need that poor people have to work and make an income. Thus blanket lockdowns are more ineffective and dearer in developing countries than in developed ones (Loayza, 2020). Such aspects have encouraged the authors to assess whether and how travel patterns have changed resulting from lockdowns and social distancing in Bangladesh.

### 2.4. Travel pattern

"Travel pattern changes" has been defined as "abrupt, substantial, and persistent changes in the underlying pattern of travel behavior" (Zhao et al., 2018). This topic has received extensive coverage in the literature focusing on relation of travel incidence variation with climate change (Urry, 2008), lifestyle change (Zhao et al., 2018), public transit induced change (Combs, 2017), residential location (Buchanan and Barnett, 2006), telecommunication (Salomon, 1998), and transport policy changes (Keuleers et al., 2006).

Travel is one of the main factors spreading infectious diseases worldwide, which has been exacerbated in recent times (Gezairy, 2003). Hence, several researchers have paid attention to travel pattern changes caused by COVID-19 and other outbreaks. Studies on previous outbreaks reveal that travel had been reduced considerably during Ebola (Peak et al., 2018), SARS, MERS (Joo et al., 2019) and Zika Virus (Widmar et al., 2017) outbreaks. However, the impacts of previous outbreaks were limited to specific geographic areas, while current COVID-19 pandemic eclipses all previous outbreaks.

### 2.5. COVID-19 travel pattern change studies

The immediate response from researchers worldwide to assess the travel pattern change due to COVID-19 has contributed significantly to the state of art of transportation engineering to apprehend the nature and probable implications of this new normal world. Social distancing is expected to be the new norm (De Vos, 2020). Many researchers predicted that the number and types of out-of-home activities will change significantly (De Vos, 2020). It has been expected that travel demand will be reduced and people will travel less by public transport (Brough et al., 2020; De Vos, 2020). A study in Switzerland reported that the use of public transport has dropped to 90% (Molloy et al., 2021). People will shift to a large extent from shared mobility to private mobility (Shamshiripour et al., 2020). Some researchers have seen high potential in "Work from home" for moving towards a more sustainable future (Shamshiripour et al., 2020). A study showed that in the Netherlands 80% people reduced their outdoor activities, 44% of workers started working from home, and 30% have conducted/ attended more remote meetings. Such people wish to continue working from home even in the future. Moreover, the amount of trips and distance travelled dropped by 55% and 68% respectively compared to the previous year (de Haas et al., 2020). Many studies marked airway as the most sufferer among all the modes due to COVID-19 (Gössling et al., 2020; Shamshiripour et al., 2020). On the other hand, online shopping, entertainment media, social and internet based communication sectors have seen their apogee during COVID-19 (Shamshiripour et al., 2020). In Hong Kong, local trips to shopping areas, amusement areas and borders decreased by 42%, 81% and 99% respectively (Zhang et al., 2021). Some researchers expressed deep concerns on such changes since reduction of such trips can have negative consequences on mental and physical health (De Vos, 2020). Even these behavioural changes due to COVID-19 differ among various age groups (Zhang et al., 2021). Many researchers suggest to emphasize on walking, cycling as well as on equitable, sustainable and resilient transportation infrastructure (De Vos, 2020; Shamshiripour et al., 2020; Molloy et al., 2021), rather than enforcing hard restrictive policies to fight against COVID-19 (Parady et al., 2020).

Unfortunately, the majority of the studies related to travel pattern change caused by COVID-19 has been conducted in advanced countries. Few studies in advanced nations tried to focus on the effects of socioeconomic disparities in travel behaviour during COVID-19 (Brough et al., 2020; Shamshiripour et al., 2020). However, they have rarely been successful in representing the true scenario of developing countries, where socioeconomic, demographic and trip characteristics vary significantly from the developed countries (Hasnat et al., 2018a, 2018b; Islam et al., 2019, 2020; Ahmed et al., 2021). This research gap has motivated the authors most to investigate the trend of travel behaviour change in developing countries. Being one of the top 20 highest COVID-19 case holder (World Health Organization, 2020) and a devel-

oping country, Bangladesh is a suitable candidate to study effect of lockdown on travel pattern changes.

## 3. Methodology and study area

A web-based survey was used to record opinions and travel decisions of respondents hailing from diverse socio-economic backgrounds on trip number and mode preferences for a variety of trip purposes for "before" and "during" COVID-19 situation. In-person/ face-to-face interviews were not possible because of pandemic related physical distancing restrictions. The questionnaire survey was circulated through various electronic means such as social media sites, phones, electronic mails, etc. Moreover, a widespread social media campaign (such as, Facebook advertisement) was conducted to reach a broader audience in Bangladesh. The survey was promoted in various social media sites and groups and using the personal and professional networks of the authors. The survey contained both English and Bangla (native language) versions.

After data screening, the survey conducted from 1 May 2020 to 30 June 2020 produced 572 response sets. For various trip purposes, the study used R software to assess (i) trip numbers (ii) travel modes used, and (iii) effect of various socio-economic and demographic characteristics on trip numbers and modes. Data were collected regarding six types of demographic and socio-economic characteristics, namely, Gender, Age, Division, Region, Occupation and Monthly Income. Social mobility characteristics assessed change in trip numbers for three trip purposes, namely, Work, Shopping, and Recreational Travel. Travel mode choice assessed change in respondent's preferred mode for variety of trip purposes, namely, Work, Green-grocery, Short Distance Recreational Trip, Medical service, Market, Long Distance Recreational Trip, and Most used mode. The specific modes were presented as options specified by the authors in the questionnaire survey, after consultation with transportation experts. Since information regarding effect of COVID-19 on society is critically needed, the current research will present data in a mostly descriptive way. Moreover, logistic regression is used to assess the change caused by the pandemic in terms of relative importance of various trip purposes. In addition, Sankey diagrams have been used to ascertain the tendencies of respondents to continue with pre-pandemic trip frequencies and mode preferences. The main methods of analysis are briefly discussed below.

### 3.1. Contingency table

Contingency table is a two-way frequency table to show categorical data. Generally, a contingency table has at least two rows and two columns to show frequency counts. The intersection of row and column is called a cell. Specifically, a contingency table is a $r * c$ matrix (r = row, c = column) to show different categorical variable contents in the form of percentage, mean, standard deviation etc (Kateri, 2014).

### 3.2. Sankey diagrams

Sankey diagram can visualize the quantitative information of flows between multiple entities or processes. When analyzing event sequence data, the diagrams focus on presenting the subjects' quantitative change/flow between event types while highlighting their temporal convergence and divergence patterns. In Sankey diagrams, several nodes are represented using rectangles or text. Links among the rectangles are represented with arrow or arcs, whose widths indicate the importance of the flow (Chou et al., 2016). In this study the Sankey diagrams are used to assess the changes in travel behaviour between two events: Before COVID-19 and During COVID-19.

### 3.3. Logistic regression

The General logistic regression model estimates the odds of success or expressing as an event for the dichotomous response variable given a set of predictors (Bender and Grouven, 1998; Liu and Koirala, 2012). The model can be defined as:

$$log\left(\frac{p(Y)}{1-p(Y)}\right) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n \quad (1)$$

where, P is the probability of dependent variable Y.

$\alpha$ = Regression Intercept
$\beta$ = Co-efficient of Independent Variable
X = Independent Variable
n = 1,2,3…

## 4. Data collection and analyses

Table 1 summarises demographic characteristics of respondents of the questionnaire survey, which was designed to obtain opinions on 3 major attribute classes, namely: (i) social mobility characteristics, (ii) travel mode choice before COVID-19, and (iii) travel mode choice during COVID-19. Each of the major classes contain studied attributes as portrayed in Table 1. Data reliability of 572 respondents has been confirmed by Cronbach's alpha value of 0.8266 (Cheng et al., 2018). In this paper, the presented results have been divided into three categories, namely, (i) Analyses of demographic characteristics of respondents, (ii) Analyses of trip purposes, and (iii) Analyses of mode preferences. These have been discussed in the following sections.

### 4.1. Analyses of demographic characteristics of respondents

Demographic and socio-economic attributes show that most respondents are male (62.41%) with a dominant age group at 21–30 years (49.83%). The study area – Bangladesh – was administratively divided into eight divisions at the time of the study, which is protrayed in Table 1. Dhaka (31.29%), Khulna (18.53%), and Chittagong (14.51%) are the most responsive groups among the divisions. Most respondents are from modern cities (46.85%). This may be due to the digital nature of the survey, where information and technology facilities are limited in rural areas. In terms of occupation, service holders (36.71%), businessman (16.43%), and students

**Table 1**
Demographic characteristics of respondents.

| Variable | Count (%) | Variable | Count (%) |
|---|---|---|---|
| Gender | | Region | |
| Female | 215(37.59) | Modern-city | 268(46.85) |
| Male | 357(62.41) | Suburban | 162(28.3), |
| | | Rural | 142(24.83) |
| Age (years) | | Occupation | |
| 0–20 | 94(16.43) | Student | 177(30.94) |
| 21–30 | 285(49.83) | Service-holder | 210(36.71) |
| 31–40 | 106(18.53) | Businessman | 94(16.43) |
| 41–50 | 21(3.67) | Day laborer | 30(5.24) |
| 51–60 | 29 (5.07) | Housewife | 18(3.15) |
| 60 + | 37(6.47) | Unemployed | 37(6.47) |
| | | Other | 6(1.05) |
| Division | | Monthly Income (BDT) | |
| Dhaka | 179(31.29) | 0–8000 | 303(52.97) |
| Khulna | 106(18.53) | 8001–15000 | 73(12.76) |
| Chittagong | 83(14.51) | 15001–25000 | 30(5.24) |
| Barisal | 44(7.69) | 25001–40000 | 43(7.52) |
| Rajshahi | 42(7.34) | 40000 + | 123(21.50) |
| Mymensingh | 32(5.59) | | |
| Rangpur | 49(8.57) | | |
| Sylhet | 37(6.47) | | |

(30.94%) are the most active participants. Majority of the respondents were low income people (0–8000 BDT).

### 4.2. Travel pattern change reflected by trip purposes

Travel pattern change has been demonstrated using exploratory analysis showing percentage change in travel trip frequencies for various trip purposes. In addition, contigency tables have been used to identify differences in travel behaviour among various demgraphic groups. Moreover, Sankey diagrams are used to reflect the tendency of respondents to continue with their pre-COVID travel frequencies. The results are presented below.

#### 4.2.1. Analyses of trip purposes

Table 2 presents the count and percentage of respondents making trips of various frequencies for three purposes, namely, work, shopping and recreation. The trip counts have been compared between "before COVID-19 pandemic" and "during COVID-19 pandemic" situations. Most people would go to work physically 1–2 times before COVID-19 outbreak, which remains largely unchanged during the outbreak. It indicates that people have to work at least once physically per week from office to ensure smooth operation. On the other hand, more frequent outings have been replaced by a tenfold increase in online activities, indicating people's interest in emerging online office technology. Before pandemic, monthly visits to shops would mostly be in the double digits (5–12 times and 13–24 times), which has been brought to single digits (< 5 times) during the pandemic. Moreover, a growing interest has developed for online shopping (one and a half fold increase). People need to go physically to shops for possibly buying fresh green grocery. On the other hand, other items can be acquired online. It is interesting to note that online work tendencies have seen a sharper rise than online shopping tendencies have, indicating that people were already more accustomed to online shopping than they did to online work before the pandemic.

Recreational travel has been reduced significantly, which mostly makes up non-essential travel. The number of people with no interest in such travel has doubled during the pandemic, indicating their desire to protect themselves from virus contagion. Such findings may indicate an overall decrease in work and shopping related physical trips, with many previous activities being done online. On the other hand, non-essential travel has experienced the steepest decline.

The right-most column in Table 2 represents percentage change in trip frequency between "before" and "during" pandemic situation. Online work has increased the most (953%) indicating that more people are working from home during COVID-19 situation. People try to go the minimum possible number of times (< 5 times) physically to shops, usually to buy bare necessities. Remaining items are probably bought online, which has increased by 164%. It implies that people are trying to reduce physical contact during pandemic. A 138% increase in people wishing to travel annually less than 6 times, and a 78% rise in the "no interest in travel" category of recreational travel indicate that people are discouraged to travel unnecessarily during COVID-19 situation.

#### 4.2.2. Association between different group responses

Contigency tables have been developed to show the change in trip frequencies of various demographic characteristics for three trip purposes, namely work trips (Table 3), shopping trips (Table 4) and recreational trips (Table 5). The results have been presented below.

Table 3 shows association of work trips with demographic factors. There has been a general increase in preference for online work activities among most groups. Male percentage wishing to travel 3–4 times per week physically has fallen significantly. However, female percentages in the higher frequencies (5–6 times and 6+ times) are lower than those of males during pandemic, indicating that males are at higher risk of virus contraction. In this study, people having high work trip travel frequency are those who travelled at least 5 times per week (5–6 and 6+ groups). Although people aged 21–30 have the highest online activity during pandemic, many of them have high travel frequencies. 51–60 age group has the greatest share of people in high travel frequencies.

Dhaka has the highest online activity among divisions and one of the lowest share in high travel frequencies. The situation is reversed in Khulna. This may be because of presence of greater infrastructure and more sophisticated jobs in Dhaka than in Khulna. Among regions, modern cities have seen the greatest increase in online activity (16 percentage points). On the other hand, sub-urban areas have the largest share of respondents making 6+ trips per week during pandemic. So, people in sub-urban areas are at greatest risk.

Table 4 shows association of shopping trips with demographic factors. The table shows a decrease in preference for 30+ trips during pandemic, and an increase in online shopping. However, other subcategories have not experienced much change. Since the data contains trips for both green-grocery and markets, it can be assumed that the online shopping increased only for markets.

Table 5 shows association of recreational trips with demographic factors. There has been a general shift in modal trip class from 6 to 12 times before pandemic to 1–5 times, while percentage of people disinterested in trips has increased across most classes during pandemic. This may indicate a reduction in physical trips. On the contrary, the percentage of people at 15+ trips has changed insignificantly during pandemic. This group probably travels frequently between their city and village homes to settle various affairs. Considering age groups, people aged 51–60 have the highest percentage of trips for atleast 12 trips during pandemic. This situation was applicable to 41–50 age group before the pandemic. These people are at high risk of contracting COVID-19. Modern cities have experienced lower trip numbers during pandemic compared to other regions. Similar situation has been reported for work and shopping trips.

#### 4.2.3. Inertia analysis for trip frequencies

Inertia analysis of trip frequencies using Sankey diagrams assess the tendency of individual respondents to continue travelling at pre-COVID-19 frequencies. This is outlined in Fig. 1. In Fig. 1, travel tendencies of respondents before pandemic are shown on the left-hand side of each figure (bc), while travel tendencies during pandemic are shown on the right-hand side of figure (dc). In the figure, bc stands for "Before COVID-19" while dc stands for "During COVID-19". Fig. 1 shows full inertia for people working online or travelling to work 6 times a week. High inertia is also seen for other work trip frequencies. A noticeable number of respondents have switched from other travel frequencies to working online. Inertia has been observed to be lower in other trip purposes. For shopping and recreational trips, there is a general tendency for lower frequencies to have higher stickiness during COVID-19. These may indicate that work trips are necessary while others more discretionary in nature.

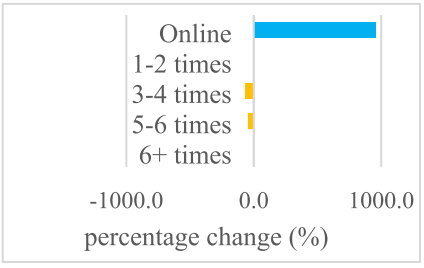
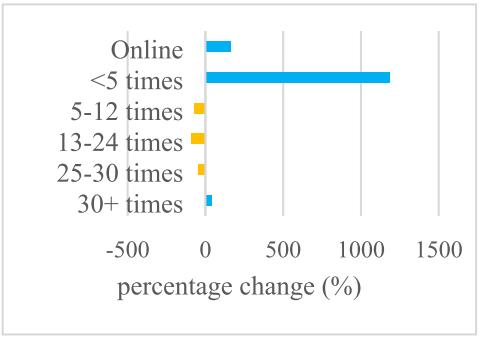
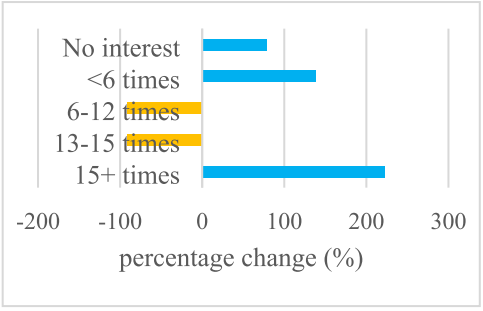
### 4.3. Travel pattern change reflected by mode preferences

Travel pattern change has been demonstrated using exploratory analysis showing percentage change in mode preferences for various trip purposes. In addition, OLR has been used to model the effect of modes chosen for various trip purposes on the overall mode chosen. Moreover, Sankey diagrams are used to reflect the tendency of respondents to continue with their pre-COVID-19 travel modes. The results are presented below.

#### 4.3.1. Analyses of mode choices

Table 6 presents the count and percentage of respondents making trips using various modes for six purposes, namely, work, green-grocery shopping, short distance recreation, medical service, market shopping and long distance recreation. The trip counts for each mode

**Table 2**
Temporal comparison of trip frequency for various trip purposes.

| Trip Frequency | Count (%) of Respondents Making a Particular Trip Frequency | | Percentage Change in Trip Frequency During Pandemic with respect to Before Pandemic |
|---|---|---|---|
| Work Trips (Weekly) | | | |
| | Before Pandemic (A1) | During Pandemic (B1) | |
| Online | 13 (2.27), | 137 (23.95) |  |
| 1–2 times | 320 (55.94) | 319 (55.77) | |
| 3–4 times | 141 (24.65) | 45 (7.87) | |
| 5–6 times | 62 (10.84) | 35 (6.12) | |
| 6 + times | 36 (6.29) | 36 (6.29) | |
| Shopping Trips (monthly) | | | |
| | Before Pandemic (A2) | During Pandemic (B2) | |
| Online | 48 (8.39) | 127 (22.20) |  |
| <5 times | 24 (4.20) | 309 (54.02) | |
| 5–12 times | 209 (36.54) | 52 (9.09) | |
| 13-24times | 175 (30.59) | 9 (1.57) | |
| 25–30 times | 98 (17.13) | 49 (8.57) | |
| 30 + times | 18 (3.15) | 26 (4.55) | |
| Recreational Trips (annual) | | | |
| | Before Pandemic (A3) | During Pandemic (B3) | |
| No travel interest | 100 (17.48) | 178 (31.12) |  |
| <6 times | 129 (22.55) | 308 (53.85) | |
| 6–12 times | 179 (31.29) | 16 (2.80) | |
| 13–15 times | 146 (25.52) | 12 (2.10) | |
| 15 + times | 18 (3.15) | 58 (10.14) | |







of each purpose have been compared between "before COVID-19 pandemic" and "during COVID-19 pandemic" situations. In Table 3, NMVs means non-motorized vehicles. Moreover, launch refers to a type of small ship used for navigating inland waterways of Bangladesh.

Analyses of travel mode choice show that the majority used public transport for work before outbreak, whose preference has shifted to private vehicle (25%), and Non-Motorised Vehicles (NMVs) (21.33%) during pandemic. This indicates that people try to avoid public transport during the pandemic.

In this study, shopping is considered as two activities in mode choice, namely Green-grocery and Markets. Markets represent shops selling non green-grocery products. Green-grocer shops are usually located closer to home than offices are, hence a large percentage of respondents (25%) already used NMVs when going to green-grocers before outbreak. NMV usage has overtaken public transport usage for green-grocer trips during the pandemic. On the other hand, public transport has remained the most popular transport for market during pandemic (43.18%).

In terms of workplace mode choice online activity (28%), private vehicle (120%), NMVs (22%), and pedestrian activity (62%) have increased during COVID-19 situation, indicating that people try to avoid public mode. When choosing mode for green-grocery shopping, Online (69%), private vehicle (52%) and NMVs (52%) have increased during COVID-19. While going to the non green-grocer market during COVID-19, online shopping (139%), pedestrian activity (200%), and other modes (425%) have increased the most. The need for social distancing has popularised online shopping and walking to the market. Thus, people have an increasing tendency to both work and shop online during the pandemic.

In this study, short distance recreation involves visits to restaurants, movie theatres, friends and relatives, which are close to the person's house. Long distance recreation includes visits to faraway places (often crossing country borders) on vacation, or to ancestral homes, which are comparatively further away. Although public transport has remained the most popular transport for short distance recreational trips during pandemic (26.75%), its usage has decreased by more than half, with a similar portion of respondents preferring private vehicles (23.25%) during pandemic. The segment of people shunning travel has also doubled. Table 3 shows that the preferences for paratransit mode (146%) and private vehicle (104%) have increased in short distance recreational travel. Similarly, in long distance recreational travel, bus has remained the cheapest and most popular option.

**Table 3**
Characteristics related to work trip purposes using the contingency test.

| Characteristic | Before COVID-19 (%) | | | | | During COVID-19 (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Work (A1) | | | | | Work (B1) | | | | |
| | Weekly trip Percentage | | | | | Weekly trip Percentage | | | | |
| | Online | 1–2 tines | 3–4 times | 5–6 times | 6 + times | Online | 1–2 tines | 3–4 times | 5–6 times | 6 + times |
| Gender | | | | | | | | | | |
| Male | 5 | 37 | 45 | 10 | 3 | 15 | 54 | 17 | 9 | 5 |
| Female | 10 | 43 | 40 | 5 | 2 | 45 | 20 | 30 | 4 | 1 |
| Age | | | | | | | | | | |
| 0–20 | 3 | 45 | 30 | 15 | 7 | 10 | 44 | 27 | 13 | 6 |
| 21–30 | 27 | 15 | 32 | 21 | 5 | 25 | 25 | 28 | 18 | 4 |
| 31–40 | 12 | 30 | 42 | 14 | 2 | 20 | 39 | 27 | 12 | 2 |
| 41–50 | 15 | 23 | 35 | 14 | 13 | 17 | 37 | 25 | 12 | 9 |
| 51–60 | 13 | 35 | 25 | 15 | 12 | 15 | 40 | 22 | 13 | 10 |
| 60 + | 25 | 42 | 12 | 11 | 10 | 23 | 47 | 11 | 10 | 9 |
| Division | | | | | | | | | | |
| Dhaka | 20 | 32 | 35 | 11 | 2 | 45 | 28 | 12 | 11 | 4 |
| Khulna | 12 | 32 | 34 | 12 | 10 | 23 | 28 | 30 | 10 | 9 |
| Chittagong | 15 | 34 | 31 | 15 | 5 | 35 | 30 | 21 | 12 | 2 |
| Barisal | 16 | 31 | 35 | 17 | 1 | 25 | 28 | 31 | 15 | 1 |
| Rajshahi | 12 | 34 | 31 | 15 | 8 | 32 | 30 | 18 | 13 | 7 |
| Sylhet | 13 | 37 | 26 | 15 | 9 | 33 | 33 | 23 | 13 | 8 |
| Region | | | | | | | | | | |
| Modern-city | 11 | 17 | 28 | 42 | 2 | 27 | 16 | 25 | 30 | 2 |
| Suburban | 12 | 25 | 37 | 15 | 11 | 15 | 29 | 33 | 13 | 10 |
| Rural | 15 | 24 | 25 | 27 | 9 | 11 | 25 | 32 | 24 | 8 |
| Occupation | | | | | | | | | | |
| Student | 5 | 21 | 32 | 32 | 10 | 25 | 18 | 28 | 20 | 9 |
| Service-holder | 8 | 20 | 33 | 35 | 4 | 15 | 18 | 29 | 31 | 7 |
| Businessman | 7 | 22 | 34 | 34 | 3 | 17 | 19 | 30 | 31 | 3 |
| Day laborer | 9 | 24 | 25 | 37 | 9 | 8 | 29 | 22 | 33 | 8 |
| Housewife | 10 | 15 | 20 | 30 | 25 | 27 | 13 | 18 | 27 | 15 |
| Unemployed | 12 | 35 | 29 | 15 | 9 | 14 | 31 | 26 | 13 | 16 |
| Other | 11 | 25 | 30 | 28 | 6 | 13 | 30 | 27 | 25 | 5 |
| Monthly Income (BDT) | | | | | | | | | | |
| 0–8000 | 14 | 32 | 38 | 11 | 5 | 25 | 27 | 34 | 10 | 4 |
| 8001–15000 | 15 | 36 | 32 | 15 | 2 | 27 | 32 | 25 | 14 | 2 |
| 15001–25000 | 22 | 24 | 28 | 22 | 4 | 25 | 26 | 25 | 19 | 5 |
| 25001–40000 | 25 | 35 | 12 | 24 | 4 | 26 | 31 | 16 | 21 | 6 |
| 40000 + | 32 | 27 | 12 | 18 | 11 | 35 | 27 | 12 | 16 | 10 |

However, shares of public transit have decreased while those of private modes have increased. In fact, private mode has experienced the largest growth (630%) for long distance recreational trips. People mostly rely on bus and paratransit for such type of travel during the outbreak.

People mostly relied on public transport to visit doctors or go to the hospital or clinic before pandemic. The choices have become more evenly distributed now, with private vehicles being the most popular. Telemedicine has only experienced a modest increase in preference, accounting for just over a tenth of all travels during the outbreak. Telemedicine remains the second least popular travel mode during outbreak, suggesting that people have not warmed up much to this yet. This may be due to lack of electronic devices available to the poor, who have no option but to use cheap public transit or NMVs. Moreover, patients facing serious danger or needing critical care need to be supervised physically by a medical staff. Table 7 reveals that the preference for pedestrians (188%) and other (100%) options have increased the most when choosing modes for medical trips. Talking with respondents revealed that “other” option includes CNGs (a type of three-wheeler on-demand private vehicle). Choice for telemedicine, private transport, paratransit, and NMVs all increased during COVID-19.

Overall usage reveals that high ridership (38.11%) enjoyed by public transport before pandemic has plummeted by more than half (55%) during pandemic, with people emphasizing more on NMVs and private vehicles now. Online activity (76%), NMVs (135%), and others (100%) have seen the highest increase in overall mode preference. It indicates that people try to avoid public transport now to reduce virus transmission and because of government restrictions.

#### *4.3.2. Regression effect of mode choice*

To assess the effect of mode choice for various trip purposes on overall mode choice, two logistic regression models were analysed considering before pandemic situation (Model-1) and during pandemic situation (Model-2). In Model-1, the dependent variable was “Most used mode before COVID-19” while the independent variables were the most used modes for various trip purposes, as outlined in Table 7. Similarly, Model-2 represents mode usage during COVID-19. Based on the magnitude of the standardized β-coefficient estimates, the six trip purposes are ranked for their influence on mode used for overall trips in Table 5. Rank 1 represents the most influence while Rank 6 represents the least influence. Moreover, the table represents which relations were significant based on p-value.

Table 5 reveals that long distance recreation and green-grocery trips had the greatest and least impact respectively on mode choice before pandemic. During pandemic, work and medical trips had the greatest and least impact respectively. The fall in importance for long-distance trips and the rise in importance of work trips and green-grocery trips (in that order), highlight the increased preference for essential travel. On the other hand, market trips and long distance recreation trips have become less important, which may be considered as non-essential travel. Markets have larger online shopping capa-

**Table 4**
Characteristics related to shopping trip purposes using the contingency test.

| Characteristic | Before COVID-19 (%) | | | | | | During COVID-19 (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Shop (A2) | | | | | | Shop (B2) | | | | | |
| | Monthly trip percentage | | | | | | Monthly trip percentage | | | | | |
| | Online | 1–4 tines | 5–12 times | 13–24 times | 24–30 times | 30 + times | Online | 1–4 tines | 5–12 times | 13–24 times | 24–30 times | 30 + times |
| Gender | | | | | | | | | | | | |
| Male | 5 | 41 | 42 | 9 | 3 | 5 | 14 | 49 | 22 | 8 | 5 | 2 |
| Female | 12 | 41 | 38 | 7 | 2 | 12 | 43 | 19 | 29 | 4 | 1 | 4 |
| Age | | | | | | | | | | | | |
| 0–20 | 8 | 43 | 29 | 14 | 7 | 8 | 10 | 42 | 25 | 12 | 6 | 5 |
| 21–30 | 26 | 19 | 30 | 20 | 5 | 26 | 24 | 24 | 26 | 15 | 4 | 7 |
| 31–40 | 11 | 29 | 45 | 13 | 2 | 11 | 19 | 37 | 22 | 16 | 2 | 4 |
| 41–50 | 14 | 27 | 33 | 13 | 12 | 14 | 16 | 35 | 26 | 11 | 9 | 3 |
| 51–60 | 12 | 33 | 29 | 14 | 11 | 12 | 14 | 38 | 15 | 17 | 10 | 6 |
| 60+ | 24 | 40 | 16 | 10 | 10 | 24 | 22 | 41 | 12 | 10 | 6 | 9 |
| Division | | | | | | | | | | | | |
| Dhaka | 19 | 35 | 33 | 10 | 2 | 19 | 43 | 25 | 16 | 10 | 4 | 2 |
| Khulna | 11 | 30 | 37 | 11 | 10 | 11 | 22 | 22 | 29 | 14 | 9 | 4 |
| Chittagong | 14 | 32 | 29 | 19 | 5 | 14 | 33 | 24 | 20 | 15 | 3 | 5 |
| Barisal | 15 | 29 | 33 | 16 | 6 | 15 | 24 | 20 | 29 | 18 | 2 | 7 |
| Rajshahi | 11 | 37 | 29 | 14 | 8 | 11 | 30 | 26 | 22 | 12 | 7 | 3 |
| Sylhet | 12 | 40 | 25 | 14 | 9 | 12 | 31 | 28 | 22 | 11 | 4 | 4 |
| Region | | | | | | | | | | | | |
| Modern-city | 10 | 21 | 27 | 40 | 2 | 10 | 26 | 15 | 18 | 27 | 7 | 7 |
| Suburban | 11 | 29 | 35 | 14 | 10 | 11 | 14 | 26 | 29 | 17 | 10 | 4 |
| Rural | 14 | 28 | 24 | 26 | 9 | 14 | 10 | 24 | 30 | 24 | 9 | 3 |
| Occupation | | | | | | | | | | | | |
| Student | 5 | 25 | 30 | 30 | 10 | 5 | 24 | 17 | 25 | 18 | 9 | 7 |
| Service-holder | 8 | 24 | 31 | 33 | 4 | 8 | 14 | 17 | 29 | 29 | 7 | 4 |
| Businessman | 7 | 26 | 32 | 32 | 3 | 7 | 16 | 23 | 24 | 29 | 3 | 5 |
| Day laborer | 9 | 23 | 25 | 35 | 9 | 9 | 8 | 28 | 23 | 31 | 8 | 2 |
| Housewife | 10 | 14 | 24 | 29 | 24 | 10 | 26 | 12 | 13 | 26 | 14 | 9 |
| Unemployed | 11 | 34 | 32 | 14 | 9 | 11 | 13 | 34 | 22 | 12 | 15 | 4 |
| Other | 10 | 24 | 33 | 27 | 6 | 10 | 12 | 23 | 31 | 24 | 5 | 5 |
| Monthly Income (BDT) | | | | | | | | | | | | |
| 0–8000 | 13 | 35 | 36 | 10 | 5 | 13 | 24 | 20 | 32 | 14 | 4 | 6 |
| 8001–15000 | 14 | 39 | 30 | 14 | 2 | 14 | 26 | 29 | 25 | 13 | 3 | 4 |
| 15001–25000 | 21 | 28 | 27 | 21 | 4 | 21 | 24 | 25 | 19 | 18 | 5 | 9 |
| 25001–40000 | 24 | 38 | 11 | 23 | 4 | 24 | 25 | 21 | 15 | 25 | 6 | 8 |
| 40000+ | 30 | 26 | 16 | 17 | 10 | 30 | 33 | 26 | 12 | 15 | 10 | 4 |

bilties than green-groceries do. Moreover, food ordered online may not remain fresh by the time order is delivered to the doorstep. Hence market trip mode has become comparatively less important than green-grocer trip mode. Importance of medical trips have decreased because of people's fear of contracting COVID-19 from hospitals. Besides, most hospitals struggled with the influx of COVID-19 patients, and could spare little resources for people with other ailments. Moreover, the growth of telemedicine reduced physical consultation with doctors.

#### *4.3.3. Goodness of fit for logistic regression models*

Suitabilities are assessed and confirmed for Model-1 and Model-2 respectively using the following goodness of fit indicators: Null deviance (394.48 on 599 degrees of freedom, df & 758.15 on 599 df), Residual deviance (384.25 on 593 degrees of freedom & 476.05 on 593 df), AIC (398.25 & 490.05), BIC (429.03 & 490.05), log Likelihood (−192.1256 on 7 df & −238.0273 on 7 df), Pseudo R-square (0.02592 & 0.37209) (Cramer, 1987; Vrieze, 2012).

#### *4.3.4. Inertia analysis for travel modes*

Inertia analysis of travel modes using Sankey diagrams assess the tendency of individual respondents to continue travelling at pre-COVID modes. This is outlined in Fig. 2. Fig. 2 shows greater stickiness in modes of market trips and long distance recreation trips compared to other trip purposes. Interestingly, people who had greater stickiness for private vehicles had the highest income levels. On the other hand, there has been a notable shift in travellers from public transit to other modes like NMVs and private vehicle that offer better physical distancing opportunities. Full inertia have been observed for pedestrian and "Other" modes in Market trips, and for paratransit vehicles in Long distance recreation trips. For work and green-grocery trips, there is a strong tendency to switch to private vehicles and NMVs from other modes during COVID-19.

## 5. Policy implications

The non-therapeutic measures adopted worldwide to mitigate the risk of spread of COVID-19 pandemic has resulted in an unparalleled transformation of urban mobility. As the world traverses through multiple waves of the disease, its impacts can well transcend to a 'new normal', i.e. long-term change in daily travel pattern and mode choices (Bhaduri et al., 2020). The study results highlight two potential aspects of changes in travel behaviour (i) changes in trip frequencies, and (ii) changes in mode preferences for various trip purposes. All these have implications for transport planning and policymaking.

Two themes that have emerged from the results of this study pertain to public transit and NMVs. Transport planners, especially infrastructure operators, need to be cautious about the likely decline in usage of public transport. Public transport has been associated with increased risk of viral transmission. Consequently, the preference for

**Table 5**
Characteristics related to recreational trip purposes using the contingency test.

| Characteristic | Before COVID-19 (%) | | | | | During COVID-19 (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Recreation (A3) | | | | | Recreation (B3) | | | | |
| | Annual trip percentage | | | | | Annual trip percentage | | | | |
| | No interest | 1–5 tines | 6–12 times | 12–15 times | 15 + times | No interest | 1–5 tines | 6–12 times | 12–15 times | 15 + times |
| Gender | | | | | | | | | | |
| Male | 4 | 42 | 34 | 15 | 5 | 11 | 51 | 28 | 6 | 4 |
| Female | 10 | 40 | 30 | 16 | 4 | 34 | 26 | 15 | 10 | 15 |
| Age | | | | | | | | | | |
| 0–20 | 6 | 44 | 28 | 15 | 7 | 8 | 42 | 35 | 10 | 5 |
| 21–30 | 21 | 25 | 34 | 16 | 4 | 19 | 29 | 35 | 14 | 3 |
| 31–40 | 9 | 27 | 36 | 19 | 9 | 15 | 42 | 29 | 12 | 2 |
| 41–50 | 11 | 32 | 28 | 19 | 10 | 13 | 38 | 23 | 19 | 7 |
| 51–60 | 10 | 37 | 33 | 11 | 9 | 11 | 30 | 27 | 24 | 8 |
| 60 + | 19 | 32 | 23 | 18 | 8 | 17 | 36 | 22 | 18 | 7 |
| Division | | | | | | | | | | |
| Dhaka | 15 | 38 | 26 | 18 | 3 | 34 | 22 | 23 | 18 | 3 |
| Khulna | 9 | 34 | 30 | 19 | 8 | 17 | 32 | 33 | 11 | 7 |
| Chittagong | 11 | 26 | 34 | 25 | 4 | 27 | 23 | 26 | 22 | 2 |
| Barisal | 12 | 34 | 27 | 22 | 5 | 19 | 31 | 34 | 14 | 2 |
| Rajshahi | 9 | 45 | 29 | 11 | 6 | 24 | 34 | 27 | 10 | 5 |
| Sylhet | 10 | 32 | 30 | 21 | 7 | 25 | 35 | 27 | 9 | 4 |
| Region | | | | | | | | | | |
| Modern-city | 8 | 27 | 31 | 32 | 2 | 19 | 23 | 29 | 23 | 6 |
| Suburban | 9 | 34 | 28 | 21 | 8 | 11 | 32 | 35 | 14 | 8 |
| Rural | 11 | 32 | 29 | 21 | 7 | 9 | 34 | 31 | 19 | 7 |
| Occupation | | | | | | | | | | |
| Student | 4 | 35 | 29 | 24 | 8 | 19 | 38 | 21 | 15 | 7 |
| Service-holder | 6 | 29 | 35 | 27 | 3 | 11 | 24 | 36 | 24 | 5 |
| Businessman | 5 | 32 | 33 | 26 | 4 | 13 | 28 | 33 | 24 | 2 |
| Day laborer | 7 | 28 | 30 | 28 | 7 | 6 | 25 | 38 | 25 | 6 |
| Housewife | 8 | 29 | 25 | 24 | 14 | 21 | 22 | 26 | 21 | 10 |
| Unemployed | 9 | 37 | 36 | 11 | 7 | 11 | 37 | 31 | 9 | 12 |
| Other | 8 | 39 | 27 | 21 | 5 | 10 | 33 | 35 | 18 | 4 |
| Monthly Income (BDT) | | | | | | | | | | |
| 0–8000 | 11 | 38 | 28 | 19 | 4 | 19 | 31 | 36 | 11 | 3 |
| 8001–15000 | 11 | 41 | 34 | 12 | 2 | 21 | 37 | 29 | 11 | 2 |
| 15001–25000 | 17 | 32 | 21 | 27 | 3 | 19 | 34 | 23 | 20 | 4 |
| 25001–40000 | 19 | 30 | 31 | 17 | 3 | 20 | 29 | 22 | 24 | 5 |
| 40000 + | 24 | 31 | 23 | 14 | 8 | 27 | 31 | 22 | 12 | 8 |

public transport has decreased markedly across all trip purposes. This can be confirmed by previous studies as well (Bhaduri et al., 2020; de Haas et al., 2020) Moreover, pooled ridesharing has also become unpopular during the pandemic. Although preference for private vehicles has increased significantly in developed countries (de Haas et al., 2020), the rise has been less prominent in Bangladesh. As per Table 3, the share has hovered around 20–25% of respondents for each trip purpose during the pandemic. Moreover, there has been a significant rise in usage of non-motorised vehicles such as bicycles and rickshaws (a traditional paratransit vehicle of Bangladesh). Compared to public buses, both private cars and NMVs offer a greater sense of safety due to greater physical distancing (De Vos, 2020). In fact, NMVs have experienced the largest percentage increase in preference (135% increase in overall mode choice) in Bangladesh. This is because majority of the people are too poor to afford their own private vehicles (Hossain et al., 2019). On the other hand, the increase in usage of NMV may vary with NMV type in different areas. Previous literatures have documented that prospect for bicycle growth is lower in urban than in the rural areas of Bangladesh. One of the reasons for such is relatively weak safety infrastructure for bicyclists in cities (Rahman, 2020b). Moreover, a possible solution proposed by Rahman to increase bicycle ridership through bikesharing (Rahman, 2020b) cannot be implemented now because of increased risk of virus transmission through multiple contacts. Thus it can be inferred that most of the increase in NMV usage can be attributed to rickshaws. However, the problem with rickshaws is that their drivers (called rickshaw-pullers) are usually uneducated and unaware of hygiene practices to be followed during pandemic. Even if they are made conscious of hygiene practices, many rickshaw-pullers cannot financially afford to disinfect their seats everyday and buy proper masks. Moreover, it is not possible to traverse extremely large distances, or traverse quickly in rickshaws. Their slow speeds can aggravate traffic congestion (Anwari et al., 2018). Before pandemic, rickshaws were usually regarded as an inferior alternative to buses. Nevertheless, rickshaws have their role in Dhaka. They are flexible when serving neighborhoods where road width is too narrow to accommodate larger modes of transport. Moreover, women in Muslim countries such as Bangladesh are often reluctant to use public transport because of religious mores. Hence women are more inclined to use rickshaws (Saito, 1993). Thus planners have to pay attention to both public transport and rickshaws to make encourage people to use these modes while shunning private vehicles.

Public transport operators should focus on making public transport a safer way of travelling in times of physical distancing, enabling those without a car or physically disabled to travel around. Although public transport services depend largely on revenues from fares, public transport operators should be encouraged not to drastically reduce public transport frequency or capacity (as a result of lower ridership), but remain at a certain level of service enabling travellers to keep a safe distance from each other (Bhaduri et al., 2020). At the moment, the government has stipulated that public buses in Bangladesh operate

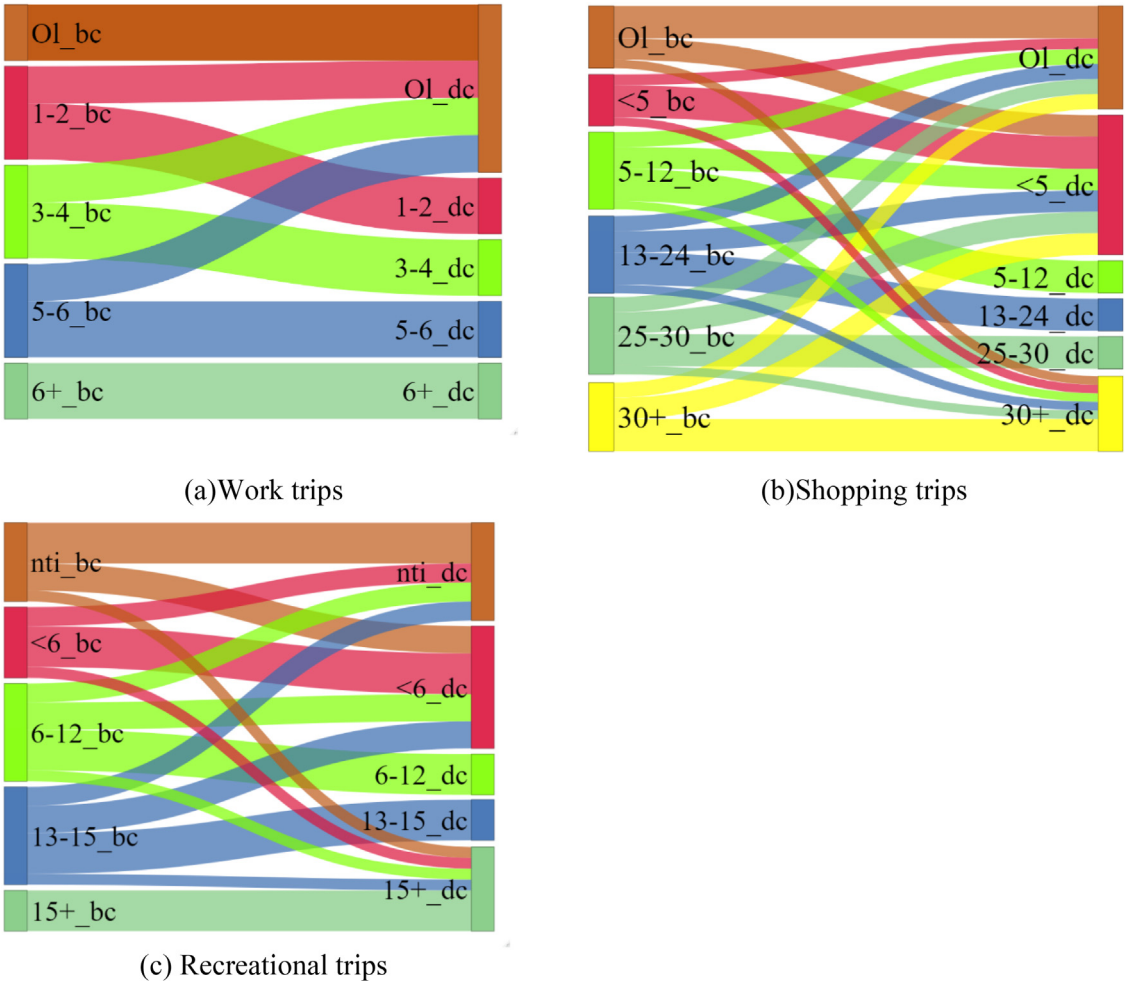



**Fig. 1.** Inertia of various travel frequencies for (a) work trips (b) shopping trips and (c) recreational trips.

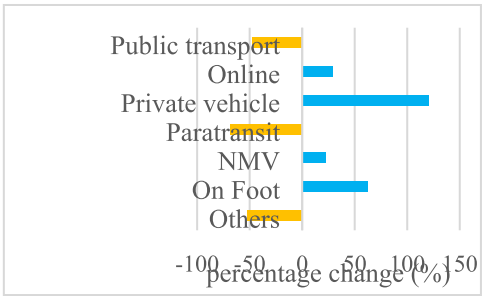
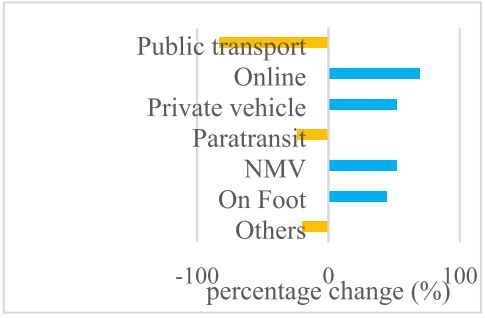
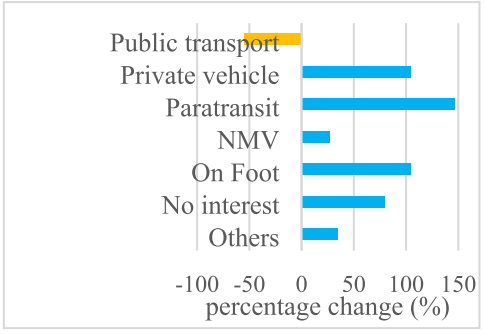
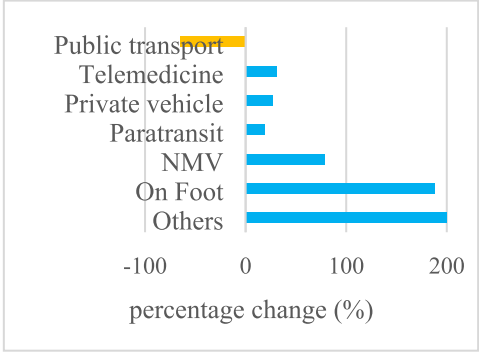
at only 50% carrying capacity. Consequently, to recover losses, many bus operators have increased their fares after being directed by the government (Rahman, 2020a, 2020b). However, such an unpopular move may not be sustainable in the future since income of many job-holders have fallen while others have lost jobs during the pandemic. On the other hand, buses need financial support to enhance hygiene in buses using on-board hand sanitizers, disinfection of buses at transit stops, etc. Even before the pandemic, buses in Bangladesh were considered unhygienic (Islam et al., 2016; Quddus et al., 2019). Thus the government need to subsidise bus operators throughout the pandemic. Public transit operators should also think about rearranging the interiors of buses and train bogeys (e.g., making more separate compartments) to facilitate physical distancing among passengers (Bhaduri et al., 2020).

Policymakers should also focus on rickshaw-pullers, who hail from low-income households. The authority should provide financial assistance to rickshaw-pullers to help them maintain hygiene practices for both themselves and the rickshaws. This is because rickshaw is a type of non-motorised paratransit, and may act as potential spreader of COVID-19 when passengers sit on rickshaw seats.

The third theme to emerge from this study pertains to pedestrians. Table 6 reveals that pedestrian activity has increased for majority of the trip purposes during pandemic. However, follow-up conversations with several respondents revealed the presence of suppressed demand for pedestrian travel in urban areas because of lack of adequate pedestrian facilities as well as obstruction on existing pedestrian facilities. This is confirmed by previous studies (Ahmed et al., 2020; Islam et al., 2020). Studies in other countries reveal an increased preference for walking during pandemic (de Haas et al., 2020; Mogaji, 2020). Moreover, well-furnished footpath can encourage people to walk/ jog/ run to improve physical and mental fitness. This will also mitigate the negative effects of physical distancing on people's mental and physical health (De Vos, 2020). Thus, the government needs to improve pedestrian facilities in Bangladesh through allocation of more street space to pedestrians, development of pedestrian infrastructure (such as pedestrian benches, shades, etc.), and improvement of safety and security (automatic pedestrian crossings, grade-separated walkways, etc.) (Bhaduri et al., 2020). After developing pedestrian facilities, and subject to adequate funds, the government can focus on improving bicycle facilities and encourage people to cycle more.

The fourth theme to emerge from this study pertains to the rise in online activities. Work, education and shopping activities have shifted noticeably to online platform, especially in urban areas, as evidenced by Tables 3–5. However, the lack of digital penetration in other areas may create a digital divide (Islam and Tsuji, 2011). This may indicate that urban areas have adapted more to the pandemic compared to rural areas have. Thus, this change is ambiguous in the context of Bangladesh. Consequently, Bangladesh's condition is different from those in developed countries having high ICT literacy and availability, where studies have demonstrated a significant shift in activities online (de Haas et al., 2020). Government should develop ICT infrastructure and train people to shift employment sector from low-skilled blue-collar jobs to high-skilled ICT related jobs, which will help Bangladesh in the long-run.

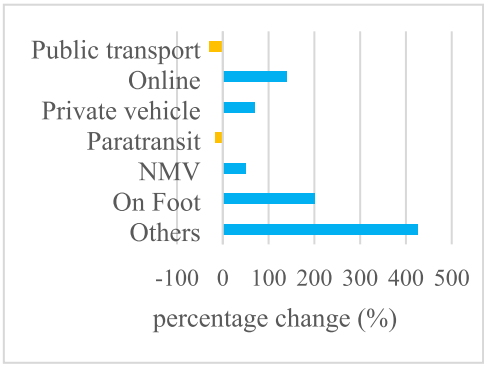
**Table 6**
Temporal comparison of preference for various modes.

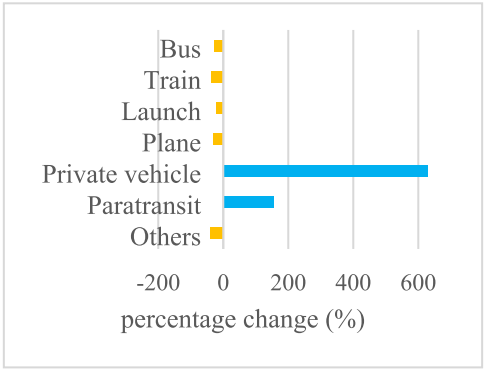
| Mode | Count (%) of Respondents Preferring the Particular Mode | | Percentage Change in Mode Preference During Pandemic with respect to Before Pandemic |
|---|---|---|---|
| Work | | | |
| | Before Pandemic (X1) | During Pandemic (Y1) | |
| Public transport | 212 (37.06) | 112 (19.58) |  |
| Online | 45 (7.87) | 58 (10.14) | |
| Private vehicle | 65 (11.36) | 143 (25.00) | |
| Paratransit | 63 (11.01) | 20 (3.50) | |
| NMVs | 100 (17.48) | 122 (21.33) | |
| On Foot | 66 (11.54) | 107 (18.71) | |
| Others | 21 (3.67) | 10 (1.75) | |
| Green-Grocery | | | |
| | Before Pandemic (X2) | During Pandemic (Y2) | |
| Public transport | 151 (26.40), | 25 (4.37) |  |
| Online | 33 (5.77) | 56 (9.79) | |
| Private vehicle | 69 (12.06) | 105 (18.36) | |
| Paratransit | 117 (20.45) | 89 (15.56) | |
| NMVs | 143 (25.00) | 218 (38.11) | |
| On Foot | 49 (8.57) | 71 (12.41) | |
| Others | 10 (1.75) | 8 (1.40) | |
| Short Distance Recreation | | | |
| | Before Pandemic (X3) | During Pandemic (Y3) | |
| Public transport | 343 (59.97) | 153 (26.75) |  |
| Private vehicle | 65 (11.36) | 133 (23.25) | |
| Paratransit | 28 (4.90) | 69 (12.06) | |
| NMVs | 33 (5.77) | 42 (7.34) | |
| On Foot | 23(4.02) | 47 (8.22) | |
| No interest | 45(7.87) | 81 (14.16) | |
| Others | 35(6.12) | 47 (8.22) | |
| Medical Service | | | |
| | Before Pandemic (X4) | During Pandemic (Y4) | |
| Public transport | 257 (44.93) | 90 (15.73) |  |
| Telemedicine | 48 (8.39) | 63 (11.01) | |
| Private vehicle | 95 (16.61) | 121 (21.15) | |
| Paratransit | 75 (13.11) | 89 (15.56) | |
| NMVs | 65 (11.36) | 116 (20.28) | |
| On Foot | 26 (4.55) | 75 (13.11) | |
| Others | 6 (1.05) | 18 (3.15) | |

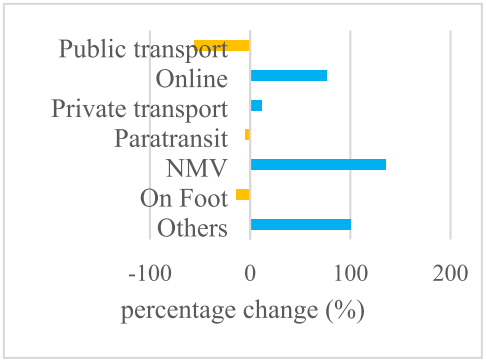
(*continued on next page*)

**Table 6** (*continued*)

| Mode | Count (%) of Respondents Preferring the Particular Mode | | Percentage Change in Mode Preference During Pandemic with respect to Before Pandemic |
|---|---|---|---|
| Work | | | |
| | Before Pandemic (X1) | During Pandemic (Y1) | |
| Market | | | |
| | Before Pandemic (X5) | During Pandemic (Y5) | |
| Public transport | 354 (61.89) | 247 (43.18) | |
| Online | 28 (4.90) | 67 (11.71) | |
| Private vehicle | 39 (6.82) | 66 (11.54) | |
| Paratransit | 97 (16.96) | 81 (14.16) | |
| NMVs | 40 (6.99) | 60 (10.49) | |
| On Foot | 10 (1.75) | 30 (5.24) | |
| Others | 4 (0.70) | 21 (3.67) | |
| Long Distance Recreation | | | |
| | Before Pandemic (X6) | During Pandemic (Y6) | |
| Bus | 286 (50.00) | 204 (35.66) | |
| Train | 87 (15.21) | 54 (9.44) | |
| Launch | 89 (15.56) | 71 (12.41) | |
| Plane | 28 (4.90) | 19 (3.32) | |
| Private vehicle | 10 (1.75) | 73 (12.76) | |
| Paratransit | 55 (9.62) | 141 (24.65) | |
| Others | 17 (2.97) | 10 (1.75) | |
| Most used Mode | | | |
| | Before Pandemic (X) | During Pandemic (Y) | |
| Public transport | 218 (38.11) | 97 (16.96) | |
| Online | 17 (2.97) | 30 (5.24) | |
| Private vehicle | 102 (17.83) | 114 (19.93) | |
| Paratransit | 64 (11.19) | 61 (10.66) | |
| NMVs | 80 (13.99) | 188 (32.87) | |
| On Foot | 88 (15.3) | 76 (13.29) | |
| Others | 3 (0.52) | 6 (1.05) | |




The fifth theme to emerge from this study pertains to disproportionately larger exposure faced by the male population from COVID-19 in Bangladesh. Tables 3 and 4 reveal that a significantly larger share of women compared to that of men have adapted to online work and shopping. In many families in Bangladesh, males are the sole breadwinners for their families while females do household chores. Besides, males play a larger role in shopping and taking care of issues outside the house. Thus they have to travel more. Besides, Table 5 reveals that a larger share of females compared to that of males do not wish to travel for recreation during the pandemic. Such recreation involves, but is not limited to, visits to ancestral homes where male members have to maintain their extended families. Thus in majority of cases, males in Bangladesh have to take care of both their own family (wife and children) and their extended family (parents), where both families may be separated by large distances. In addition, some people maintaining families in urban areas cultivate farm produce in rural areas, which they harvest/collect every few months. This reduces their dependency on shopping to some extent. Since males have a disproportionately greater travel tendencies compared to females during the pandemic, they are at more risk in being infected. Consequently, males have larger infection and death percentages in Bangladesh (Directorate General of Health Services, 2020). The situation is aggravated if the male person is the sole breadwinner of his family. Considering the socio-economic context of Bangladesh, males will continue to

**Table 7**
Ranking of Trip purposes on most used mode for overall trip based on Standardized Coefficients.

| Before COVID-19 | | | | During COVID-19 | | | |
|---|---|---|---|---|---|---|---|
| Most used mode for trip purpose | Estimate (β) | Pr(>\|z\|) | Rank | Most used mode for trip purpose | Estimate (β) | Pr(>\|z\|) | Rank |
| X1:Work | 0.11641 | 0.495 | 4 | Y1:Work | 1.20475 | 8.63e-07 *** | 1 |
| X2:Green-Grocery | 0.05527 | 0.648 | 6 | Y2: Green-Grocery | 0.98956 | 1.05e-07 *** | 2 |
| X3:Short Distance Recreational Trip | −0.07365 | 0.413 | 5 | Y3: Short Distance Recreational Trip | −0.50665 | 0.000205 *** | 5 |
| X4:Medical Service | −0.11797 | 0.323 | 3 | Y4:Medical Service | −0.37965 | 0.004340 ** | 6 |
| X5:Market | −0.12029 | 0.127 | 2 | Y5:Market | −0.7876 | 2.22e-09 *** | 3 |
| X6:Long Distance Recreational Trip | −0.16519 | 0.39 | 1 | Y6:Long Distance Recreational Trip | −0.57296 | 3.11e-09 *** | 4 |

Significant codes: '***' 0.001; '**' 0.01; '*' 0.05

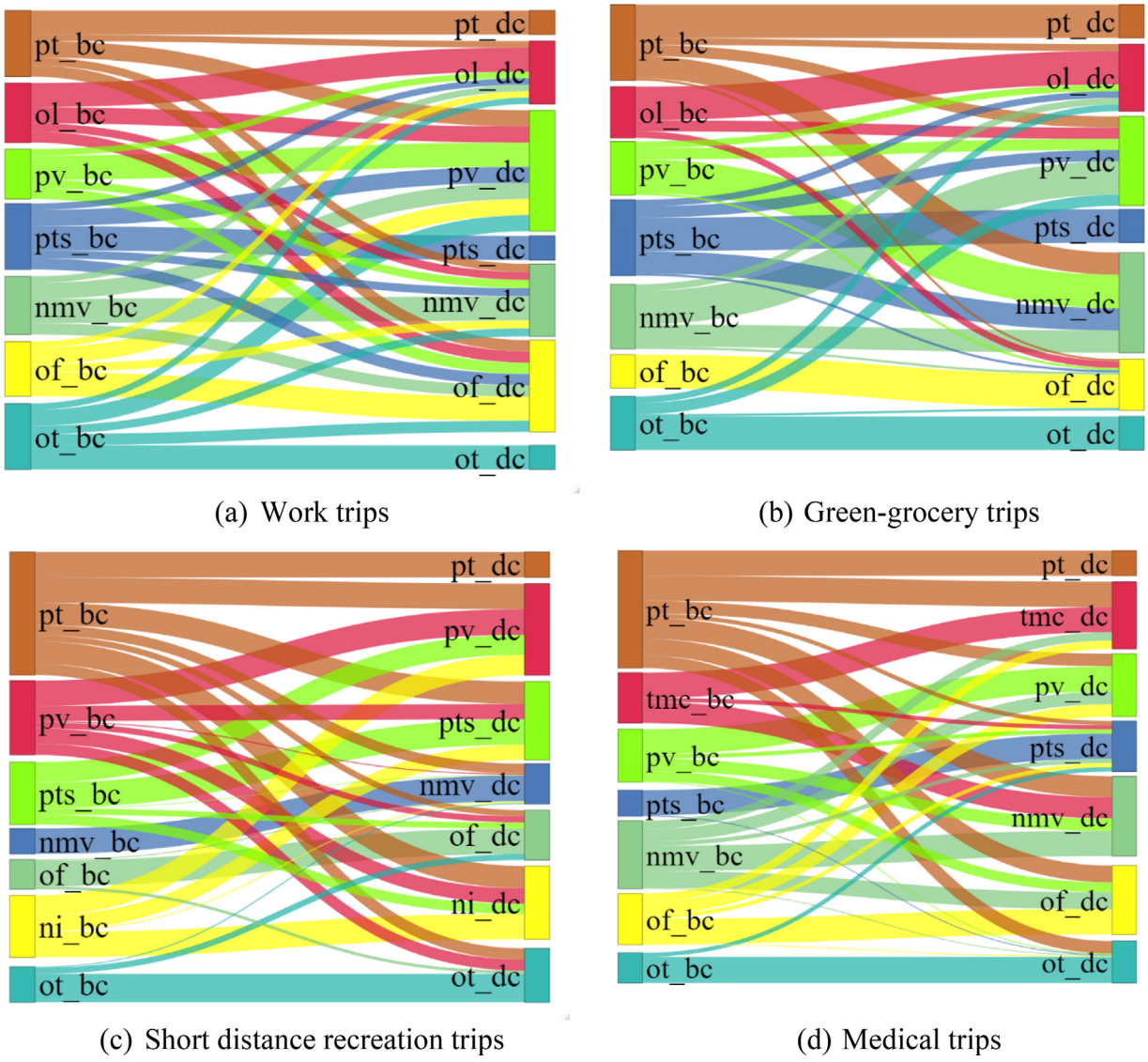
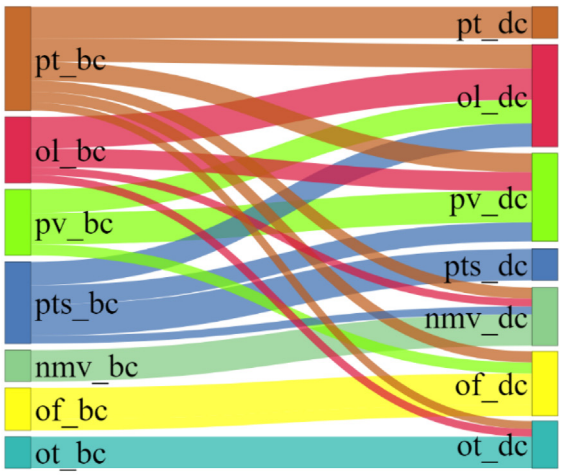


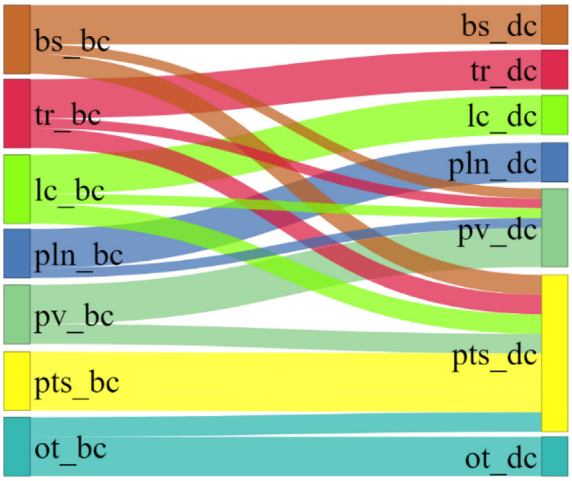

**Fig. 2.** Inertia of various mode preferences for trips involving (a) work (b) green-grocery (c) short distance recreation (d) Medical services (e) Market (f) Long distance recreation, and (g) Overall Mode choice. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

travel more than females will. Hence, government needs to increase awareness among males to make them extra vigil regarding safety practices during the pandemic.

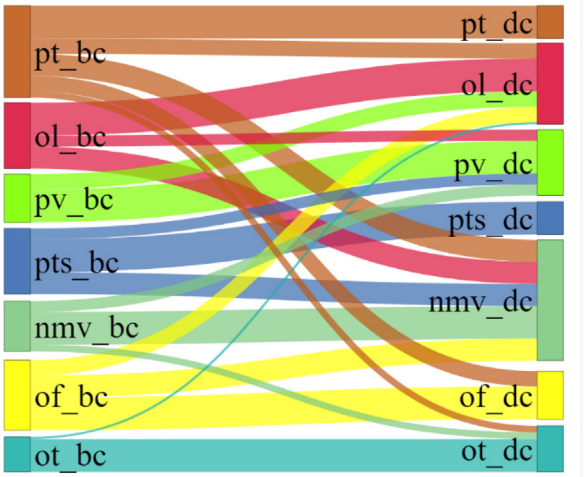
The last, but not the least, key takeaway is that even though mode preferences have shifted noticeably, trip frequencies have not varied much during the pandemic. Although online work and shopping have increased dramatically, the percentages of people preferring online work and shopping during pandemic have varied between only 10–30% of respondents across most sub-categories of demographic groups (Tables 2–5). On the other hand, there have been only slight reductions in travel for other trip frequencies. This is also confirmed by inertia analyses of trip frequencies (Fig. 1) and mode preferences (Fig. 2), where respondents show greater stickiness to maintain trip frequencies than to maintain mode preferences. This can be attributed




(e) Market trips




(f) Long distance recreation trips




(g) Overall Mode Choice

**Fig. 2** (*continued*)

to low digital penetration in many places and jobs in the country, which has already been discussed previously. Thus, since people could not substitute their physical travel by ICT, they have adapted to the pandemic instead by shifting to vehicle modes that offer more physical distancing. Consequently, as discussed before, there has been a decrease in preference for public transport. A small segment of the respondents is the rich who can afford cars, and hence have increased their reliance on cars. The majority of respondents are to poor to maintain cars, and instead opt for NMVs or walking. However, the poor still rely on buses for travelling large distances. Thus, it is of paramount importance to maintain hygienic practices in public transport to reduce virus transmission. While essential trips like work and shopping have remained nearly unchanged, recreational trips have decreased significantly. However, this is to be expected as many such recreational trips are non-essential. This has also been confirmed by previous studies (Bhaduri et al., 2020; de Haas et al., 2020).

Based on these discussions, the government should give top priority to immediately improve hygiene practices in public transit and rickshaws. In the medium-term, the government should focus on improving pedestrian and bicycle facilities. In the long-run, the government should try to upgrade its ICT infrastructure while encouraging people to improve their ICT literacy and application.

## 6. Conclusion

This study has evaluated the travel pattern changes during COVID-19 pandemic with respect to pre-pandemic situation for a developing country. The two main themes of assessment included (i) evaluation of trip frequency changes and (ii) evaluation of shifts in mode preferences. The evaluation was performed across a variety of demographic characteristics, and for a variety of trip purposes. Both virtual and conventional modes of transport were investigated. The policy implications of the results have been highlighted in Section 4.

The results obtained in this study provide useful policy insights for policymakers in Bangladesh. Though travel behaviour, particularly behaviour during an unusual situation as in the COVID-19 pandemic, is unlikely to be transferable to other countries, the findings provide some insights which may be useful to other countries. In particular, our results indicate the distrust faced by public transport during the pandemic, and an increased preference for more secluded forms of transport. It is thus vital to ensure proper hygiene practices in public transport and help it regain the trust of the general public.

The online survey – only safe option during the pandemic – prevented us from getting a fully representative sample. It is true that lack of internet availability can hamper most online activities such as par-

ticipation in video-enabled meetings, online shopping, sending large files, etc. However, many people have mobile phones or know someone who has a phone in order to carry out extremely minimal internet activities such as browsing in social media platforms to check text-based writing and messages. Mobile and social media penetration stood at 99% and 22% respectively in January 2020 (Kemp, 2020). Throughout the pandemic, social media presence continued to rise, sitting at 24% during May-June 2020, the period of our study (NapoleonCat, 2020). The authors tried to reach such people through social media platforms and using their personal and professional connections. Thus, the authors tried their level best to increase the circulation of the questionnaire survey. Accessing the questionnaire survey requires minimum bandwidth. Even so, some people were interviewed over telephone to reduce bias among respondents.

Since this study mainly analysed data in an exploratory way, future studies can deal with more advanced modelling techniques, such as discrete choice models. Moreover, subsequent studies can cover later study periods to compare among trends established in this study.

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