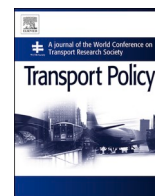Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Transport mode preferences of university students in post-COVID-19 pandemic

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ABSTRACT

The COVID-19 outbreak very quickly disrupted the order of human beings. While many sectors have been trying to cope with the ongoing COVID-19 process, they have also been trying to plan the new process for after the pandemic. Transport is one of the sectors most affected by the pandemic and it is necessary to produce the right political formulations for the post-pandemic period. For this reason, it is necessary to carefully examine the changing user demands in various segments of society due to COVID-19 and reveal effective post-pandemic transport policies. This study contributes to this requirement. Accordingly, this study investigated the transport mode preferences of university students in post-pandemic period in Istanbul, one of the important metropolises of the world, via the use of a survey. The reason for university students were focused on was that the mobility of university students is very high and in addition, they are more flexible than other age groups in using different transport modes. The main findings obtained from the study show that there will be a significant change in demand in transport modes after the pandemic. In particular, while a critical decrease may be observed in the travel demand for public buses, shared minibuses and LRT in public transport in post-pandemic period, a high increase in demand for private car use is highly probable. In addition, the research results indicate that COVID-19 can cause an increase in use of e-scooter/hoverboard and active travel modes. The results obtained through the statistical analysis and the discussions based on these results can make a significant contribution to the post-pandemic transport policies of cities with high university student populations and various transport modes, such as Istanbul.

1. Introduction

The coronavirus outbreak has become one of the largest pandemics encountered by humans (Aaditya and Rahul, 2021). COVID-19 was declared a global pandemic by the World Health Organization on March 11th, 2020. After the declaration of the COVID-19 pandemic, countries around the world began to take unprecedented measures to contain the virus. Governments have limited many activities, and also implemented lockdowns, travel restrictions, and restrictions on business activities, to contain the spread of the virus. These limitations include the cancellation of public events, prohibitions on gathering indoors, closure of many commercial facilities, limitations on business activities, stay-at-home obligations, and orders to wear masks.

In addition to all these, the COVID-19 pandemic has directly affected transport mode preferences. In general, the preference of transport modes is influenced by the travel distance (Cho, 2013), the travel time (Chowdhury and Ceder, 2016), the travel cost (Meng et al., 2018),

income (Ko et al., 2019), education (Liu et al., 2016), gender (Rosenbloom, 2006), age (Almasri and Alraee, 2013), and access to personal vehicle (Chakrabarti, 2017) parameters (Das et al., 2021). However, this extraordinary pandemic process has upset all of the usual balances and has led to a new order for all behaviors. Thus, understanding what transport mode preferences will be after COVID-19 arouses curiosity in terms of determining an effective transport policy. Therefore, it is important to address this issue from different perspectives. In the literature, there are some studies examining what the transport mode preferences will be after the COVID-19 pandemic (Abdullah et al., 2021; Awad-Núñez et al., 2021; Caulfield et al., 2021; Dai et al., 2021; Das et al., 2021; Dong et al., 2021; Vickerman, 2021; Zhang and Zhang, 2021). When these studies were examined, information was obtained about the mode changes that may occur in the post-COVID-19 period. However, it would be useful to address this issue, which is up to date and popular, from various perspectives. This is because this subject is very new and needs to be investigated in many ways. In this study, how the

transport mode preferences of university students will be shaped during the post-COVID-19 period was investigated. The reason for focusing on the transport mode preferences of university students is that the mobility of university students is very high (Cadima et al., 2020) and in addition, they are more flexible than other age groups with regard to different transport modes (Páez and Whalen, 2010; Zhou, 2012; Whalen et al., 2013). In other words, university students are more open and inclined to use different transport modes (Kuhnimhof et al., 2010; Khattak et al., 2011). For this reason, understanding what the preferences of university students will be after COVID-19 can provide important information about urban mode preferences. In their study on this subject, Danaf et al. (2014) stated that understanding the behaviors of university student mobility in developing countries is necessary in setting the transport policy.

In this study, a survey was conducted for university students in Istanbul. The transport mode preferences of university students before and after COVID-19 were investigated. The reason for choosing Istanbul as the study area was that it constitutes approximately 1 in 5.3

(approximately 15.5 million people) of the total population of Turkey. It also has about 1 in 3.5 (57 universities) of the total number of universities in Turkey. In addition, there is a more diverse means of transport (subway, Light Rail Transit (LRT), Bus Rapid Transit (BRT), ferry, bike, e-scooter, bus, etc.) being actively used in Istanbul when compared to other cities in Turkey. For these reasons, this study, conducted on a city of the scale of Istanbul, can make a significant contribution to the literature. In summary, the purpose of this study was to conduct research to understand the travel behaviors of university students in a metropolitan city with a wide range of transport modes and a high population in the post-COVID-19 period and present meaningful ideas for the literature and transport policy makers through the results of this research.

In the second part of the article, information about the ongoing COVID-19 period in Turkey is given. In the third part, literature review is presented. In the fourth part, sample and method used in the study is detailed. In the fifth part, the results of the study are explained. In sixth part, discussions about the results were put forward. In seventh part,
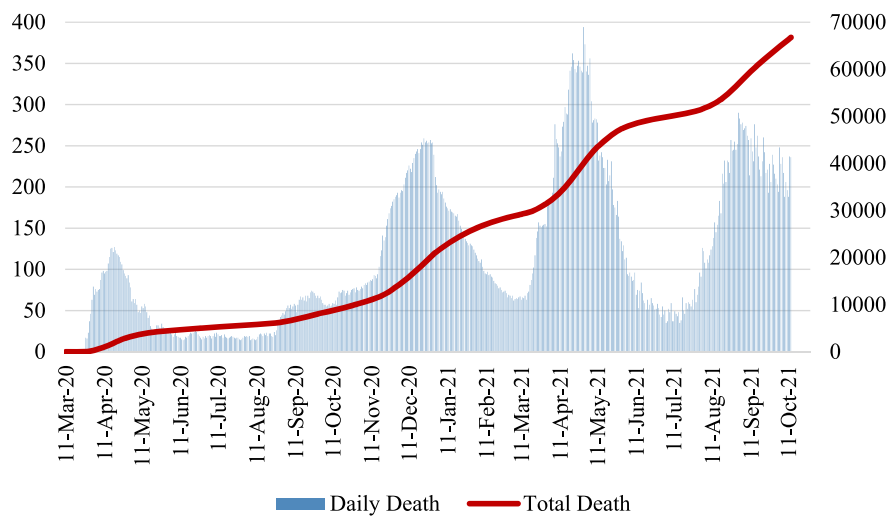
(a)
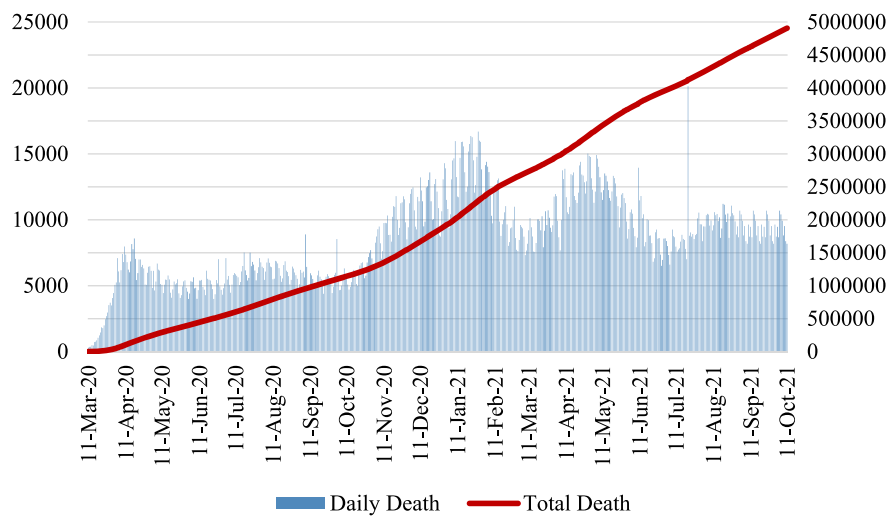
(b)

Fig. 1. Number of deaths due to COVID-19: (a) Turkey (b) World.

conclusion of the study is presented.

2. COVID-19 pandemic in Turkey

The first case of COVID-19 in Turkey was recorded on March 11th, 2020, resulting in a cumulative total number of 6,974,541 cases and 62,795 deaths by October 11th, 2021 (TMH, 2021). Fig. 1 shows the number of deaths due to COVID-19 in Turkey and in the World.

As seen in Fig. 1, there is an uncertain fluctuation in the daily death numbers in Turkey due to COVID-19 on the timeline. The reason is that the Turkish government increased and decreased pandemic restrictions, including lockdown from time to time. Similarly, there is also a fluctuation on the timeline in the number of daily deaths in the world. The increase/decrease in pandemic measures in countries and the effect of various variants of the virus caused this fluctuation. In addition, Fig. 1 shows that the cumulative number of deaths in Turkey has a flatter trend in the early stages of the pandemic and a serious upward trend was experienced in the later periods. The cumulative number of deaths in the world has been on a high upward trend since the beginning of the pandemic. The World Health Organization states that this increasing trend in deaths due to COVID-19 can only end with the successful implementation of the vaccination process in countries. When the vaccination data shared by the World Health Organization is examined, approximately 7 billion vaccinations have been carried out worldwide (WHOWorld Health Organization,). In Turkey, about 120 million vaccines have been administered. The numbers of this vaccination, both in Turkey and in the world, are too low for the goal of ending the pandemic. Considering the necessity of administering the second/third doses of the COVID-19 vaccine, the number of these vaccinations should be increased rapidly. According to the data of the Turkish Ministry of Health, until October 2021, approximately 55 million first doses, 50 million second dose vaccines, and 12 million third dose vaccines have been administered in Turkey, which has a population of approximately 84 million (TMH, 2021). According to the data of the World Health Organization, until October 2021, approximately 3 billion people worldwide have been fully vaccinated (WHOWorld Health Organization,). When all these data are evaluated, it is understood that vaccination activities should be continued rapidly by ensuring global vaccine equity.

The following can be said briefly about the pandemic process in Turkey: the Turkish government made some decisions and implemented practices in the early period of the pandemic. As a matter of fact, flights to and from China were stopped on February 3rd, 37 days before the first case occurred in Turkey on March 11th. Turkey's land border with neighboring Iran was also closed on February 23rd, 17 days before the first case was reported. On February 29th, nearly 11 days before the first case, flights to Italy, South Korea, and Iraq were grounded. In addition to these travel restrictions, the critical measures taken for COVID-19 in Turkey in 2020 are listed below: On January 10th, the COVID-19 scientific board was formed. Thermal cameras were installed at airports on January 24th. All flights to and from China were suspended on February 3rd. On February 29th, all flights with Italy and South Korea were suspended. On March 13th, flights were stopped with many countries, such as France, Germany, and Spain. On March 16th, many facilities, such as cinemas, theaters, cafes, sports halls, shopping malls, mosques, and universities were temporarily closed. On March 19th, all sports competitions were suspended. On March 20th, all cultural and scientific contracting activities were stopped. On March 21st, all hairdressers, beauty centers, and restaurants were closed, and it was forbidden to attend or hold barbecues and picnic activities. Additional restrictions, such as lockdown, were imposed on citizens over 65 years of age and patients with chronic illnesses. On March 22nd, the flexible working and remote working process for workplaces began. On April 3rd, a 15-day ban was imposed in Istanbul and 30 major cities. On April 11th, lockdown was implemented across Turkey (Shakibaei et al., 2021). The period when all of these measures were implemented was recorded as

the strictest quarantine period that has ever occurred in Turkey.

In addition to it being a health crisis, COVID-19 has also severely affected many sectors in Turkey, including the transportation industry. This has led to drastic changes in travel patterns and daily activities, and a drastic reduction in road traffic and passenger numbers. As a result of the Turkish government's attempts to prevent the spread of the virus and manage the pandemic, public transport was suspended in many cities. Nowadays, although the virus is relatively under control in Turkey and public transport systems have begun to operate again, a sense of concern for passengers still persists. Due to the fear of COVID-19, there has been a great decrease in public transport mobility. Because public transport modes provide a closed environment in which the passengers sit side by side or stand for a long time, which therefore greatly increases the risk of spreading infectious diseases (Edelson and Phypers, 2011; Wang et al., 2020). Studies in the literature have proven that the transportation sector, especially public transport systems, is a vector in the spread of past pandemics, such as the influenza (Zhang et al., 2011; Aaditya and Rahul, 2021). For these reasons, it can be said that the decrease in the use of public transport is the result of personal preferences, in addition to the government's measures to control the spread of the virus (De Vos et al., 2013). Regarding this issue, a survey conducted in the United Kingdom stated that 72% of respondents would no longer use public transport unless safety and hygiene measures were taken (Transport Focus, 2020; Das et al., 2021). Another study found that 55% of Indian public transport users were more likely to own private cars in the near future. This situation revealed the increase in car ownership in India and the fact that the use of public transport has been decreasing (Pillai, 2020; Das et al., 2021). In fact, this situation is similar all over the world. The demand for urban public transport systems has been greatly affected all over the world due to travel anxiety and fear of infection, and a significant proportion of public transport users has started to turn to private transport modes (De Vos, 2020; Tirachini and Cats, 2020). While the attitudes that people hold towards public transport have become more negative, attitudes towards private transport have started to show a tendency toward being more positive (Beck and Hensher, 2020; de Haas et al., 2020).

3. Literature review

Transport mode preference is shaped by humans' characteristics, travel types, personal attitudes, habits, lifestyle, culture and abilities (Chakrabarti, 2017). Many studies in literature focusing on transport mode preferences have presented that travel time, travel distance, travel cost, traveler features such as gender, age, income, employment and education affect the transport mode preference (Das et al., 2021). With the entry of Covid-19 into our lives, from now on, epidemics and hygiene measures can also be included among these parameters. Because, the fear of being infected with coronavirus is likely to affect the decision whether to use public transport modes. However, the question still remains how COVID-19 might influence all transport mode preferences (Ross, 2021).

Technically, various transport modes have advantages and disadvantages over each other. Public transport and active travel modes have been widely advocated in the literature for sustainable mobility in recent years (Bagchi and White, 2005; Beirão and Cabral, 2007; Grotenhuis et al., 2007; Vandenbulcke et al., 2009; Dell'Olio et al., 2011; Nakamura and Abe, 2014). Furthermore, in practice, young people embrace public transport and active travel modes. Whalen et al. (2013) stated that university students tend to use active travel and public transport modes, more frequently than other population segments. Simons et al. (2014) revealed that travel demands of young adults/college students can easily be diverted to active travel modes by emphasizing the concepts of low cost, flexibility and social activity. Similarly, there are some studies in the literature on determining the transport mode preferences of young people and university students. Some of these rely on multinomial logit, nested logit and cross-nested logit models to

investigate the students' mode preference of public transport and active travel (Rybarczyk and Gallagher 2014; Zhou, 2014, 2016; Danaf et al., 2014; Rotaris and Danielis, 2014; Hasnine et al., 2018; Aaditya and Rahul, 2021; Das et al., 2021). Another part of these studies in the literature is based on various non-parametric methods apart from all these methods (Grimsrud and El-Geneidy, 2013, 2014; Zhan et al., 2016).

Although public transport and active travel modes provide a significant advantage for their cities in terms of sustainable mobility, social distancing, which is an agreed upon measure against the spread of COVID-19, contradicts the principle of public transport (Musselwhite et al., 2020). How this is going to affect transport mode preferences after COVID-19 is a matter of curiosity. Abdullah et al. (2020) conducted research on the effects of COVID-19 on travel behavior through an online survey filled out by participants around the world. The results showed that people are more willing to switch to private transport modes than use public transport due to COVID-19. In their study, Shakibaei et al. (2021) claimed that a significant increase will occur in private car use by men during the post-COVID-19 period when compared to that of women. It was also revealed that there will be a significant decrease in the use of public transport modes. Basu and Ferreira (2021) stated that, while taking advantage of the decrease in vehicle prices since the COVID-19 began, public transport users are likely to discontinue the use of public transport and lean toward private car ownership. Cho and Park (2021) found that bus passengers were more sensitive to travel time and crowds during the post-COVID-19 period. They stressed the importance of sensitivities about travel times and crowding on public transport modes. Molloy et al. (2021) stated that the use of public transport has been decreasing due to COVID-19. In addition, Vickerman (2021) stated that it is highly unlikely that cycling will permanently replace the use of private cars or public transport. Eisenmann et al. (2021) mentioned the increasing positive perception of the cars in society during the pandemic process. All of this information supports the idea that private transport will become widespread during the post-COVID-19 period. For this reason, it is inevitable that the use of public transport will be decreased if no intervention takes place during the post-pandemic period (Dai et al., 2021). In order to prevent passengers from switching to private transport and to increase the decreasing attractiveness of public transport, eliminating the permanent effects of the pandemic on public transport will be one of the most important tasks of the post-COVID-19 period (Dong et al., 2021).

4. Material and method

4.1. Study area

In this study, how the transport mode preferences of university students will be shaped in the post-COVID-19 period was investigated. In this context, a survey was conducted for university students studying at the universities in Istanbul, Turkey's largest metropolitan city. Fig. 2 shows the location of Istanbul in the world and Turkey.

The characteristics of the study area were as follows: according to the data obtained from the Turkish Statistical Institute, the population of Istanbul was 15,462,452 in 2020 and it is a metropolitan city with the highest population density in Turkey (TSI, 2021). Approximately 1 out of every 5.3 people living in Turkey reside in Istanbul. Istanbul is established on a total area of 5461 km^2, some districts of the city are located in Asia and the others are located in Europe, and it is divided by the Bosphorus into two main parts. In addition, the European part of the city is divided in two parts by a natural port called the Golden Horn. These divided parts are connected by bridges that cause significant congestion and delays in urban traffic (Çakmak et al., 2021). There are a total of 4,388,118 motor vehicles in Istanbul traffic and this number constitutes approximately 18% of the total number of vehicles in Turkey. Moreover, 68.6% of the vehicles in Istanbul are cars, 2.2% are minibuses, 0.90% are buses, 16% are trucks, 3.06% are trucks, 8.44% are motorcycles, and the rest are special purpose vehicles and tractors (TSI, 2021). In addition, different systems, such as LRT, BRT, subway and ferryboat provide public transport services in Istanbul. Apart from these, transport vehicles such as bicycles, e-scooters, etc., are also actively used in Istanbul. Istanbul has high potential in terms of higher education opportunities as well as its high population and transport infrastructure. It has been stated that there are a total of 57 universities in Istanbul, 44 of which are private (foundation) and 13 of which are state-owned (CHE, 2021). Thus, Istanbul has approximately 28% of the total number of universities in Turkey. According to the information on the 2019–2020 academic year, there were a total of 1,079,779 students in Istanbul (CHE, 2021). With this number of students, approximately

Fig. 2. Location of the study area.

13.5% of the university students in Turkey are studying in Istanbul. Table 1 shows the statistical information of the universities and university students in Istanbul. In summary, Istanbul is a city with a high population, is home to many universities, and being actively used various transport modes. These features were the reason why Istanbul was chosen as the field of study for this research.

4.2. Survey design

This study focused on university students. This was because university students have high mobility and are open and inclined to use various transport modes (Kuhnimhof et al., 2010; Páez and Whalen, 2010; Khattak et al., 2011; Zhou, 2012; Whalen et al., 2013; Cadima et al., 2020). Due to these characteristic features, the transport mode preferences of university students in the post-COVID-19 period are remarkable, and especially the transport policies of cities with a high university student population are subjects of curiosity. This study can provide information for transport policy makers in this context.

A web-based survey was adopted to collect the data. Since there was a limitation with regard to face-to-face interaction during the pandemic period, the data were collected through an online survey in Istanbul during the period from 14 May to June 9, 2021. Paul et al. (2021) stated that a web-based survey can reach a great number of people within a short time and can be comfortable for the respondents to participate during the pandemic in the survey. Wang et al. (2017) claimed that the web-based survey has great advantages, as it is appropriate for respondents to answer the survey questions without the limitation of time and geographical areas. In addition, Wang et al. (2017) stated that a well-designed of a survey website may assist respondents fully understand the aim of the survey and reply questions appropriately and moreover, the web-based survey minimizes missing answers by suggesting respondents to check all answers. In this study, the survey was conducted through Google Forms. Due to the restrictions, the participants were recruited using convenience sampling through various online forums (i.e., WhatsApp, Facebook, Instagram, Twitter, Telegram) similarly to the studies of Thombre and Agarwal (2021) and Aaditya and Rahul (2021). Etikan et al. (2016) describe that the main purpose of convenience sampling is to collect data from participants who are easily accessible to the researcher and the main assumption related to convenience sampling is that the members of the target population are homogeneous. Young (2015) states that the convenience sampling incorporates the researcher selecting respondents because they are at the center of the study, are easily available in terms of time, are accessible and are willing to participate and contribute to the study. When determining the survey design, it was of importance to cover both, attitudes of university students in transport mode use in pre-pandemic period and their preferences of transport modes in post-COVID-19 period. Therefore, we designed a survey to see demand changes in transport modes before and after the pandemic. The survey consists of three main parts: 1) We identified the demographic characteristics as in similar studies in the literature (Harbering and Schlüter, 2020; Busch-Geertsema et al., 2021). 2) We determined demands in transport mode use in pre-COVID-19 as in similar literature studies (Abdullah et al., 2020; Aaditya and Rahul, 2021; Das et al., 2021; Eisenmann et al., 2021). 3) We investigated transport mode preferences in

post-COVID-19. In this survey, only university students studying in Istanbul participated and a total of 497 questionnaires were collected. After the elimination of ineffective questionnaires, 416 valid questionnaires were obtained for statistical analysis. The effective response rate was 83.7%. The demographic information of the participants is provided in Table 2.

In addition to all these, the following can be said briefly about the ethical consideration of this study: In this study, recruitment of survey participants, collection and protection of their personal information and data, processing and evaluation of data, and textualizing all of these have been executed in accordance with the ethical information and guidelines in the studies of Allen-Schult and Hazard (1982), Kilsby (2006), Belfrage and Hansson (2006), Appleyard et al. (2019).

When Table 2 is examined, it can be seen that 46.6% of the respondents were male and 53.4% were female. Since the survey was conducted for university students, the majority of the participants (75.7%) were between the ages of 18–23. Moreover, 20.2% of the participants were college students, 69.2% were bachelor students, and 10.6% were master students. Additionally, 43.5% of the students studied in private universities, while 56.5% studied in public universities. The students were asked about their total monthly income, and it was understood that the majority (75%) had a total monthly income of 1000–3000 TL. From the survey answers, it was observed that the rate of car ownership of the university students was also low (35.3%). In addition, the participants were asked if they had been previously diagnosed with COVID-19. The reason for this was to investigate whether having this disease had an impact on their transport mode preferences. As a result, 23.3% of the participants stated that they had, while 76.7% stated that they had not.

In addition to the demographic information, there were two more sections on the questionnaire. In the first of these sections, the participants were asked about their frequency of using the transport modes in Istanbul before COVID-19. In the second part, the participants were asked how often they would prefer to use transport modes in Istanbul in the post-COVID-19 period. Answer options were prepared on a 6-point likert-type scale, between 0 and 5, comprising the options: never, occasionally, sometimes, often, always. For example, for the questions "how often did you use the subway for your transport needs before COVID-19?" and "how often do you think you will be using the subway for your transport needs after COVID-19?" The participants answered on a scale of 0–5. Similarly, this question was asked to participants for all transport vehicles in Istanbul (public buses, subways, LRT, BRT, shared

Table 1
Statistics of universities in Istanbul (CHE, 2021).

		N
University	Private	44
	State	13
University Students	Male	495442
	Female	584337
	College	257762
	Bachelor	737901
	Master	84116

Table 2
Respondent demographics.

Characteristic	Description	N	%
Gender	Male	194	46.6
	Female	222	53.4
Age	18–20	160	38.2
	21–23	156	37.5
	24–26	59	14.2
	Over 27	42	10.1
Education	College	84	20.2
	Bachelor	288	69.2
	Master	44	10.6
University Type	Private	181	43.5
	State	235	56.5
Income per month ([a]TL)	1000–2000	215	51.7
	2000–3000	97	23.3
	3000–4000	66	15.9
	4000–5000	16	3.8
	5000–6000	3	0.7
	Over 6000	19	4.6
Car ownership	Yes	147	35.3
	No	269	64.7
Have you been sick of COVID-19?	Yes	97	23.3
	No	319	76.7

[a] TL: Turkish Lira.

minibuses, cabs, ferryboats, bikes, e-scooters/hoverboards, private cars, motorcycles, roller skates/skateboards, car-sharing, etc.) Information on the frequency of use before and after COVID-19 was obtained.

4.3. Statistical approach

In the analysis phase after the collection of the data, first, two-sample Z tests were performed for the proportions to determine the statistical significance of transport mode preferences before and after COVID-19. This test checks whether there is a significant difference in transport mode preferences between before and after COVID-19. The null hypothesis of the test assumes that there is no significant difference between the proportions, and the other hypothesis assumes that there is a significant difference between the proportions. The Z test statistic used in the analysis can be expressed as in Equation (1):

$$Z = \frac{P_{pre} - P_{post}}{\sqrt{P_t \times (1 - P_t) \times \left(\frac{1}{N_{pre}} + \frac{1}{N_{post}}\right)}} \quad (1)$$

Here, P_{pre} is the proportion of participants who chose a specific mode before the pandemic, P_{post} is the proportion of people who intend to choose the same mode after the pandemic, P_t is the proportion of people who chose the mode in the total sample, N_{pre} is the sample size for the pre-pandemic and N is the sample size for the post-pandemic.

In addition, the logistic regression method was applied in order to comprehend the change in demand in the transport modes after COVID-19. In the analysis, in addition to the effects of the demographic characteristics, also investigated were the effects of being disease of COVID-19 on the post-pandemic transport mode preferences. We asked the question, "In this context, the question "Did you become sick with COVID-19 during the pandemic?" This information served as one of the independent variables in the regression model. The logistic regression method was used as a logistic function in the study to model the binary dependent variable, which means that 0 was stable (i.e. there was no demand change in the transport mode) and 1 was unstable (i.e. there was a demand change in the transport mode). For the independent variables, there was no limitation and it could be continuous numerical, discrete numerical, sequential, or unordered categorical. Predictively, the logistic model with X and Y as binary response variables could be written as in Equation (2).

$$p = P(Y = 1 | X = x) = \frac{e^{\beta_0 + \beta_1 x}}{1 + e^{\beta_0 + \beta_1 x}} \quad (2)$$

Here, β_i are the parameters of the model. The relationship, called the logistic function, can be transformed into the form in Equation (3):

$$g(x) = ln\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 x \quad (3)$$

Logistic regression using IBM SPSS Statistics for Windows 24.0 was applied separately for the public buses, subways, LRT, BRT, shared minibuses, ferryboats, and private cars, car-sharing, cabs, motorcycles, bikes, e-scooters/hoverboards, roller skates/skateboards, and walking, representing "Public Transport" in Istanbul.

5. Results

The results obtained provided comprehensive information about the changes in the use of transport modes in the post-pandemic period.

In line with the information obtained from the 416 university students in Istanbul, the distribution of the use of transport mode before the pandemic to demographic information is given in Table 3. When Table 3 is examined, it is seen that 47.1% of the university students using public buses were male and 52.9% were female. Again, 38.1% of the university students using public buses were between the ages of 18 and 20, 37.8% were between the ages of 21 and 23, 14.3% were between the ages of 24

Table 3
Distribution of use of transport modes in pre-pandemic period.

Variables		Public Transport (%)						Individual Transport (%)									
		Public Bus	Subway	LRT	BRT	Shared Minibus	Ferryboat	Private Car	Car-sharing	Cab	Motorcycle	Bike	e-scooter/ hoverboard	Roller Skate/ Skateboard	Walking
Gender	Male	47.1	48.3	49.0	42.3	45.4	47.3	55.7	41.5	41.1	43.9	45.0	56.2	32.8	45.2
	Female	52.9	51.7	51.0	57.7	54.6	52.7	44.3	58.5	58.9	56.1	55.0	43.8	67.2	54.8
Age	18–20	38.1	38.5	37.2	39.1	39.6	35.6	36.6	43.1	42.4	48.0	38.6	38.0	55.2	37.0
	21–23	37.8	37.7	37.2	40.9	36.9	38.6	37.4	31.6	35.1	33.3	38.2	42.1	29.3	38.6
	24–26	14.3	14.3	15.3	15.3	14.0	14.1	9.9	14.2	13.7	16.3	13.7	13.2	15.5	14.2
	Over 27	9.8	9.5	10.3	4.7	9.5	11.7	16.1	11.1	8.8	2.4	9.5	6.7	0.0	10.2
Education	College	19.6	21.0	21.4	22.3	20.1	16.1	16.0	24.5	20.4	39.0	21.7	29.7	48.3	18.9
	Bachelor	70.4	69.0	67.2	68.8	69.5	72.5	71.0	66.0	68.4	52.0	67.2	55.4	37.9	71.1
	Master	10.0	10.0	11.4	8.9	10.4	11.4	13.0	9.5	11.2	9.0	11.1	14.9	13.8	10.0
University Type	Private	41.8	43.0	41.1	40.0	41.5	43.6	50.4	42.3	48.8	48.8	47.1	50.4	37.9	42.8
	State	58.2	57.0	58.9	60.0	58.5	56.4	49.6	57.7	51.2	51.2	52.9	49.6	62.1	57.2
Income per month (ªTL)	1000–2000	53.2	52.2	49.6	54.4	51.8	48.7	40.5	51.4	49.8	43.1	50.3	50.4	51.7	51.4
	2000–3000	23.8	23.9	24.6	26.5	24.7	23.5	23.7	19.0	22.4	23.6	22.2	21.5	17.2	24.9
	3000–4000	15.9	16.2	17.9	16.3	15.9	18.8	19.8	18.2	16.5	20.3	14.8	16.5	20.7	15.5
	4000–5000	3.9	3.7	3.8	2.8	4.3	3.0	4.6	5.1	4.6	6.5	5.3	4.1	1.7	4.2
	5000–6000	0.8	0.8	0.8	0.0	0.9	1.0	11.4	1.2	1.1	0.8	1.6	1.7	1.8	0.8
	Over 6000	2.4	3.2	3.3	0.0	2.4	5.0	0.0	5.1	5.6	5.7	5.8	5.8	6.9	3.2
Car ownership	Yes	33.6	34.0	36.1	3.7	32.6	36.6	100.0	41.9	39.3	39.8	38.6	33.9	24.2	34.6
	No	66.4	66.0	63.9	96.3	67.4	63.4	0.0	58.1	60.7	60.2	61.4	66.1	75.8	65.4

and 26, and 9.8% were over the age of 27. Other information can be read similarly in Table 3.

In the survey, the university students were asked what their transport mode preferences would be after the pandemic. In line with the answers obtained, the distribution of the transport mode preferences to the demographic information is given in Table 4. When Table 4 is examined, it is seen that 48.3% of the university students who prefer public buses after the pandemic are male and 51.7% are female. Again, 38.5% of the university students who prefer public buses after the pandemic are between the ages of 18 and 20, 37.6% are between the ages of 21 and 23, 14.6% are between the ages of 24 and 26, and 9.3% are over the age of 27. Other preferences can be read similarly in Table 4.

In order to comprehend the demand for all transport modes in Istanbul, the students were asked how often they used each transport mode before the pandemic and how often do they envisage using each mode of transport after the pandemic. Answers were recorded on a 6-point likert-type scale, between 0 and 5, comprising the options: none, too few, few, mid, much, too much. The percentage of the distributions of the answers obtained are seen in Table 5. Fig. 3 and Fig. 4 illustrate the frequency of use of transport modes in pre- and post-pandemic period using values in Table 5.

The mean values of the demand for transport modes before and after the pandemic are given in Table 6 with standard deviation values. When Table 6 is examined, it can be seen that there was a general decrease in demand for public transport modes after the pandemic, while there was an increase in demand in individual transport modes. However, to determine the statistical significance of the change in the transport modes, two-sample z-tests were performed for pre- and post-pandemic preferences. In this study, the z-test checked whether there was a significant difference between pre-pandemic and post-pandemic preferences. The null hypothesis of the test assumed that there was no significant difference between the proportions. The alternative hypothesis assumed that there is a significant difference between the proportions. When the z-test results in Table 6 are examined, public buses, subways, LRT, and shared minibuses showed a significant change in public transport. While a significant change was observed in private cars, motorcycles, bikes, and e-scooters/hoverboards in individual transport, a small change in walking was observed. The z-test results showed that the COVID-19 pandemic negatively affected the use of public transport modes and there may be an increase in demand in the use of individual transport modes. While the increase in the use of private cars in the individual transport mode had a negative effect on sustainable transport, the increase in the demand for bicycle and e-scooter/hoverboard use can be interpreted as a positive effect. Figs. 5 and 6 illustrate the demand changes in the transport modes before and after the pandemic using the values in Table 6. When Fig. 5 is examined, it can be seen that there was a general decrease in demand in public transport modes. When Fig. 6 is examined, a remarkable increase in demand can be seen in some individual transport modes.

In order to better understand the demand change in each transport mode, the logistic regression method was applied, because this method can address the research goal of determining the explanatory variables that affect the post-pandemic demand change in each transport mode. In this study, while the demand change tended to decrease in public transport, it tended to increase in individual transport. As a result of the logistic regression application, associating a variable with a positive coefficient meant that the variable had a positive effect on the probability of a demand change in the transport mode. This probability increased with the value of this variable. Conversely, if a variable had a negative coefficient, it adversely affected the probability of demand change in the transport mode of the variable.

When Table 7 is examined, the points that draw attention are as follows: it is seen that having COVID-19 caused demand changes in public transport modes, such as public buses, subways, and shared minibuses, at rates of 1.94, 2.63, and 3.92, respectively. It is observed that having COVID-19 caused demand changes in individual transport

Table 4
Distribution of preferences of transport mode in post-pandemic period.

Variables		Public Transport (%)						Individual Transport (%)							
		Public Bus	Subway	LRT	BRT	Shared Minibus	Ferryboat	Private Car	Car-sharing	Cab	Motorcycle	Bike	e-scooter/ hoverboard	Roller Skate/ Skateboard	Walking
Gender	Male	48.3	47.5	48.1	43.1	44.4	46.8	50.3	60.1	41.5	42.9	44.6	51.1	35.8	45.3
	Female	51.7	52.5	51.9	56.9	55.6	53.2	49.7	39.9	58.5	57.1	55.4	48.9	64.2	54.7
Age	18–20	38.5	38.3	38.6	39.2	39.7	34.2	40.0	38.6	40.1	46.8	38.5	36.9	50.9	38.1
	21–23	37.6	37.2	36.7	40.7	36.1	38.6	35.2	34.9	37.5	37.3	39.7	42.0	34.0	37.9
	24–26	14.6	15.0	15.8	15.2	16.6	15.4	10.3	14.3	15.4	13.5	12.9	13.6	15.1	13.9
	Over 27	9.3	9.5	8.9	4.9	7.6	11.8	14.5	12.2	7.0	2.4	8.9	7.5	0.0	10.1
Education	College	19.8	20.6	20.9	21.6	21.3	15.6	18.8	23.1	22.4	38.1	21.9	26.7	49.1	20.3
	Bachelor	70.7	69.7	69.3	69.6	67.1	73.2	70.3	67.6	67.3	50.8	66.5	61.9	37.7	69.8
	Master	9.5	9.7	9.8	8.8	11.6	11.2	10.9	9.3	10.3	11.1	11.6	11.4	13.2	9.9
University Type	Private	40.8	42.2	39.6	39.7	40.1	42.7	50.3	42.4	44.8	48.4	46.0	50.0	37.7	42.9
	State	59.2	57.8	60.4	60.3	59.9	57.3	49.7	57.6	55.2	51.6	54.0	50.0	62.3	57.1
Income per month (ᵃTL)	1000–2000	54.9	53.9	52.5	54.9	55.2	50.2	40.6	48.7	48.9	41.3	52.7	47.7	54.7	52.3
	2000–3000	24.4	24.2	24.4	26.4	22.7	22.7	21.8	20.2	25.0	27.0	21.4	25.0	13.2	24.0
	3000–4000	15.5	15.8	17.1	15.8	16.7	18.6	18.8	19.3	18.4	22.2	15.2	15.3	24.5	15.2
	4000–5000	3.4	3.6	3.5	2.9	4.0	3.1	5.5	5.0	4.8	4.7	4.9	4.0	1.9	4.0
	5000–6000	0.9	0.6	0.6	0.0	0.7	1.0	1.8	1.3	1.1	1.6	1.3	1.7	3.8	0.5
	Over 6000	0.9	1.9	1.9	0.0	0.7	4.4	11.5	5.5	1.8	3.2	4.5	6.3	1.9	4.0
Car ownership	Yes	31.3	32.2	29.7	2.5	28.5	34.6	79.4	38.2	33.1	28.6	36.2	34.7	22.6	34.1
	No	68.7	67.8	70.3	97.5	71.5	65.4	20.6	61.8	66.9	71.4	63.8	65.3	77.4	65.9

ᵃ TL: Turkish Lira.

Table 5
Demands on the transport modes.

How often did/will you use?		Pre-pandemic (%)						Post-pandemic (%)					
		none (0)	too few (1)	few (2)	mid (3)	much (4)	too much (5)	none (0)	too few (1)	few (2)	mid (3)	much (4)	too much (5)
Public Transport	Public Bus	9.2	9.4	13.9	20.4	26.7	20.4	16.3	13.9	17.5	23.6	18.0	10.7
	Subway	9.4	13.2	14.9	17.1	23.6	21.8	13.5	16.3	16.1	19.7	18.8	15.6
	LRT	18.0	21.2	17.3	17.1	15.6	10.8	24.0	22.1	19.5	15.6	10.6	8.2
	BRT	48.3	17.8	20.4	5.1	4.8	3.6	51.0	18.8	19.7	4.8	5.0	0.7
	Shared Minibus	21.2	23.8	20.9	15.9	11.5	6.7	33.4	24.0	16.6	14.2	8.2	3.6
	Ferryboat	28.4	27.6	17.8	11.8	8.4	6.0	29.1	25.2	19.3	12.7	8.4	5.3
Individual Transport	Private Car	68.5	4.8	4.6	7.7	7.9	6.5	60.3	3.6	6.7	9.1	10.4	9.9
	Car-sharing	39.2	29.6	14.6	7.9	6.3	2.4	42.8	23.8	13.2	11.5	5.1	3.6
	Cab	31.5	27.6	16.3	15.1	8.3	1.2	34.6	25.7	15.4	13.2	6.5	4.6
	Motorcycle	70.4	18.8	5.5	2.6	1.7	1.0	69.7	12.5	5.8	7.2	3.6	1.2
	Bike	54.6	23.6	9.9	6.5	4.3	1.2	46.2	23.5	13.2	9.9	6.3	0.9
	e-scooter/ hoverboard	70.9	14.7	6.0	4.1	3.1	1.2	57.7	20.9	10.6	5.5	4.1	1.2
	Roller Skate/ Skateboard	86.1	9.6	1.4	1.4	1.0	0.5	87.3	8.4	1.0	1.2	1.9	0.2
	Walking	8.4	18.8	19.5	18.7	19.7	14.9	9.8	12.3	16.8	20.0	22.3	18.8
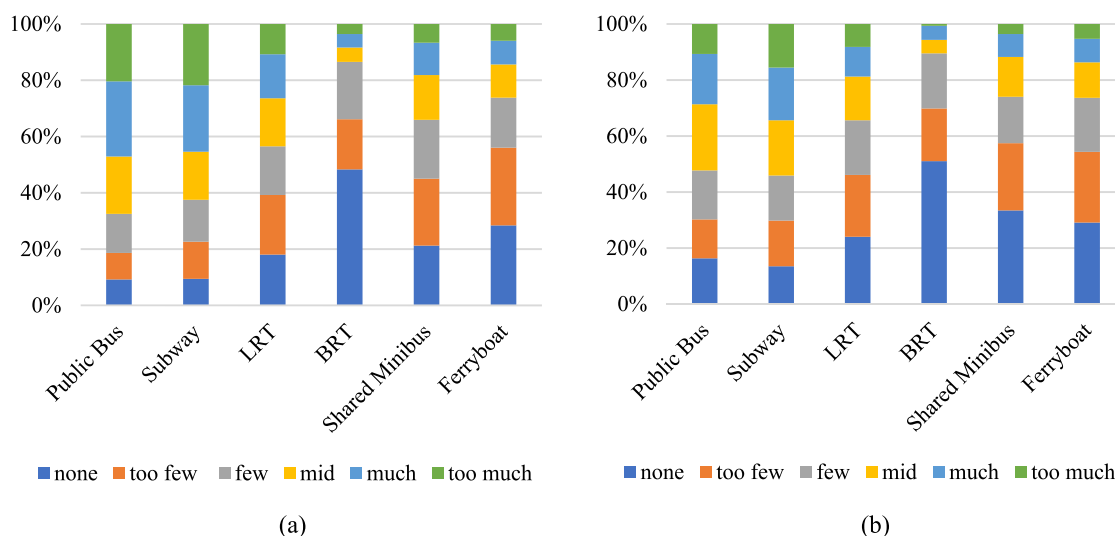
Fig. 3. Frequency of use of public transport modes: (a) pre-pandemic (b) post-pandemic.

modes, such as private cars, bikes, e-scooters/hoverboards, and walking, at rates of 2.78, 5.82, 5.14, and 2.21, respectively. This situation draw attention to the effect of having had the disease on the change in demand in the transport modes. This change in demand in the university students may have been triggered by the fear of contracting COVID-19 again, because COVID-19 is a disease with severe symptoms. As it contains uncertainties in terms of symptoms due to its various variants, societies continue to experience anxiety about this disease (Beck and Hensher, 2020). This may be resulting in behavioral changes, especially in people who have had COVID-19 disease. In addition, another issue was that, for university students, having a car was seen as a parameter that affected the demand changes in the transport modes. This was an expected situation. In addition, the fact that students who own cars caused an increase in demand in private car use, at a rate of 3.09, revealed that there will be a significant increase in private car use due to the pandemic. This situation may negatively affect sustainable urban life. Another issue was that men contributed 1.75 times more to the demand change than women with regard to the use of bicycles. The increase in demand in active travel modes is a significant gain for cities. Due to the pandemic, it was seen that male students would contribute more to this achievement.

6. Discussion

Public transport modes appear to be the form of travel that has been most impacted by the COVID-19 pandemic. For this reason, this situation points to three possible scenarios with the progress of the pandemic: 1) People can completely avoid using public transport modes and this situation may never recover. This may force societies to use cabs and motorcycles, and especially private cars. 2) In the long term, people can prefer e-scooters/hoverboards, and active travel modes, as well as private cars, instead of public transport. 3) As soon as the pandemic and the fear of the pandemic disappear, people can continue to use public transport modes (Abdullah et al., 2021).

When these scenarios were examined, some studies supported the first scenario, showing that public transport could not recover in the near future and travel demands would be largely directed towards the use of private cars, cabs, and motorcycles (Zhang et al., 2011; Chen et al., 2021). However, based on the experience gained from past epidemics, some studies supported the second scenario, showing that people can prefer travel modes such as bicycles, e-scooters/hoverboards, and walking among individual transport, as well as using private cars instead of public transport modes. (Conway et al., 2020; Moslem et al., 2020; Buehler and Pucher, 2021; Echaniz et al., 2021; Kazemzadeh and
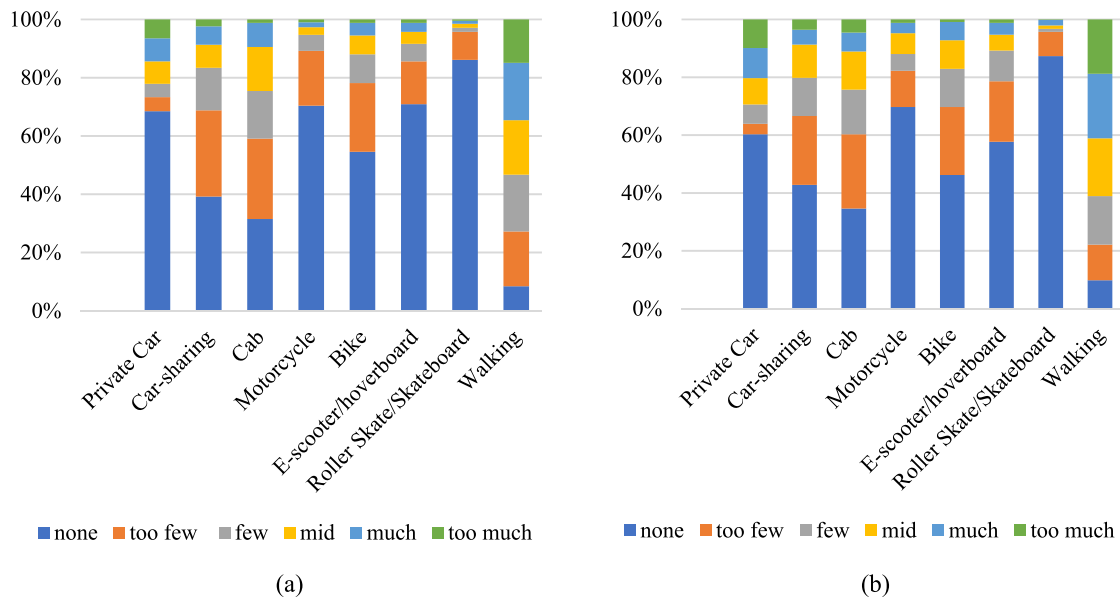
Fig. 4. Frequency of use of individual transport modes: (a) pre-pandemic (b) post-pandemic.

Table 6
Mean values and z-tests for pre- and post-pandemic.

		Pre-pandemic		Post-pandemic		Z-value	Z-critical
		Mean	Std. Dev.	Mean	Std. Dev.		
Public Transport	Public Bus	3.07	1.56	2.45	1.58	5.75	1.96
	Subway	2.98	1.62	2.61	1.64	3.27	1.96
	LRT	2.24	1.63	1.91	1.58	2.92	1.96
	BRT	1.11	1.36	0.96	1.21	1.63	1.96
	Shared Minibus	1.93	1.52	1.50	1.46	4.09	1.96
	Ferryboat	1.62	1.51	1.62	1.49	0.02	1.96
Individual Transport	Private Car	1.01	1.67	1.35	1.85	−2.75	1.96
	Car-sharing	1.20	1.33	1.23	1.42	−0.30	1.96
	Cab	1.44	1.35	1.45	1.47	−0.05	1.96
	Motorcycle	0.49	0.96	0.66	1.20	−2.20	1.96
	Bike	0.86	1.21	1.09	1.30	−2.65	1.96
	E-scooter/hoverboard	0.57	1.11	0.81	1.20	−2.89	1.96
	Roller Skate/Skateboard	0.23	0.71	0.22	0.74	0.14	1.96
	Walking	2.67	1.55	2.89	1.59	−1.99	1.96

Koglin, 2021). Apart from these, the third scenario is related to the permanence of the fear caused by COVID-19 in societies. In order to better understand whether this scenario will occur, the effects of psychological factors affecting the fear of COVID-19 in societies should be measured and evaluated by long-term analysis.

To discuss the possible consequences of these scenarios, it is clear that the realization of the first scenario will adversely affect city life. In addition to the negative environmental effects, such as exhaust emissions and noise pollution, the increase in fuel consumption, the costs of time losses caused by additional delays due to congestion and the increase in public transport costs that need to be subsidized will also reveal negative economic effects. In addition, increased stress on the drivers will trigger accident risks and cause negative social effects. Thus, this possible scenario arising from the COVID-19 pandemic can be considered as the worst scenario for urban transport (Abdullah et al., 2020). In the case of the realization of the second scenario, the decreasing demand in public transport modes will be directed toward bicycles, e-scooters/hoverboards, and walking, as well as increasing private car use. Although the decrease in demand in public transport modes is undesirable, the increase in the demand of e-scooters/hoverboards and active travel modes will contribute positively to a sustainable urban life (Hosseinzadeh et al., 2021). For this reason, this scenario is one that

transport authorities should focus on the most. E-scooters/hoverboards and active travel modes should be strengthened by transport authorities with physical and technological infrastructures, and the use of these modes should be encouraged by various campaigns. Otherwise, possible dissatisfactions that may arise in the use of these modes may direct the users of these modes to use private cars (Das et al., 2021). As a result of this, transport authorities may miss this possible opportunity that may arise due to the pandemic. For this reason, bicycle, walking, and e-scooter/hoverboard path networks should be expanded in cities without wasting time, and these paths should be equipped with geometric improvements and smart systems.

In addition to the general policy implications, the following can be said about the post-pandemic transport mode preferences of university students and the policies that can be followed for them: especially in cities with a high number of universities and/or a high university student population, transport mode preferences of students are important for policy makers (Limanond et al., 2011; Nordfjærn et al., 2019). For example, there are currently 57 universities and 1,079,779 university students in the city of Istanbul, where the field research was conducted in this study (CHE, 2021). These numbers are quite high and are remarkable for transport policy makers. This is because this mobile population directly affects urban mobility (Nash and Mitra, 2019). In
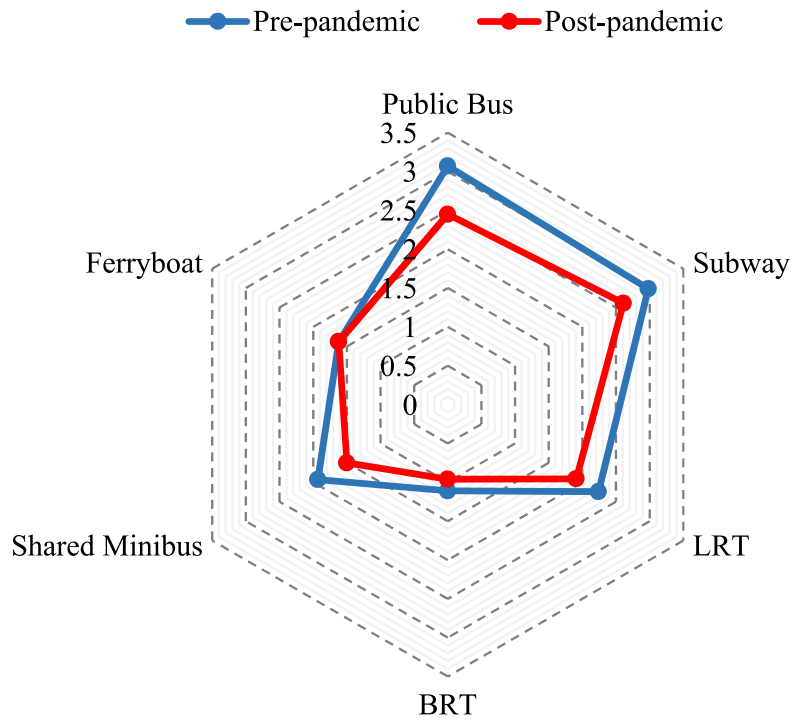
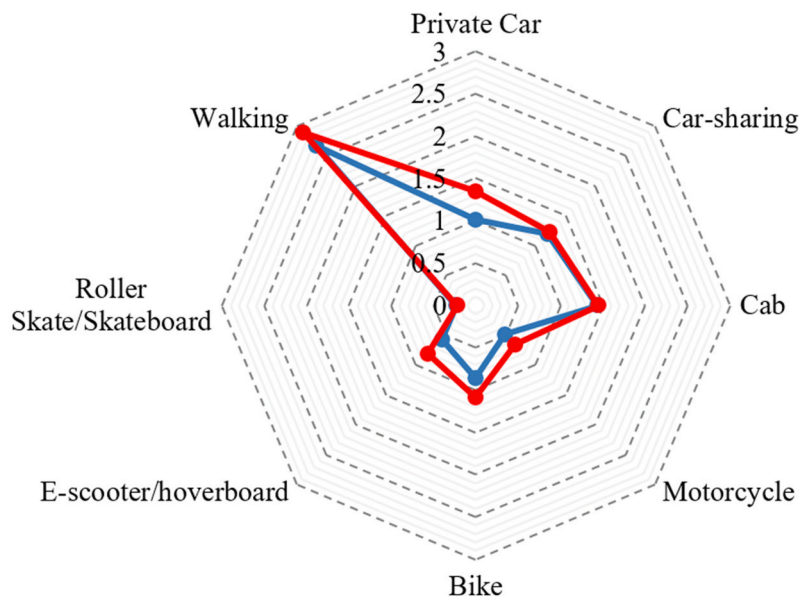**Fig. 5.** Demand changes in public transport.

Fig. 6. Demand changes in individual transport.

addition, university students are more open and inclined to use different transport modes (Kuhnimhof et al., 2010; Khattak et al., 2011). Due to these characteristics, it is a high probability that the transport mode preferences of university students will be more greatly affected by the

COVID-19 pandemic. In this study, this situation was quantified and revealed.

The results obtained in this study can be discussed as follows: in particular, students who owned cars were found to be more inclined to

Table 7
Binary logistic regression for demand changes in transport modes.

		B	Std. Error	Sig. (p-value)	Odds Ratio	95% CI (lower)	95% CI (upper)
Public Bus	Intercept	−0.226	0.138	0.102	0.798		
	COVID-19 (ref: yes)	0.664	0.245	0.007	1.942	1.202	3.139
	Univ. Type (ref: private)	0.400	0.203	0.049	1.491	1.001	2.222
Subway	Intercept	−0.939	0.143	<0.001	0.391		
	Car ownership (ref: yes)	0.967	0.216	<0.001	2.630	1.723	4.013
	COVID-19 (ref: yes)	0.713	0.243	0.003	2.040	1.267	3.285
LRT	Intercept	−0.677	0.129	<0.001	0.508		
	Car ownership (ref: yes)	1.209	0.214	<0.001	3.351	2.201	5.101
Shared Minibus	Intercept	−0.108	0.396	0.786	0.898		
	Education	−0.557	0.206	0.007	0.573	0.383	0.857
	Car ownership (ref: yes)	0.617	0.229	0.007	1.854	1.183	2.904
	COVID-19 (ref: yes)	1.367	0.249	<0.001	3.924	2.407	6.396
Private Car	Intercept	−2.373	0.222	<0.001	0.093		
	Car ownership (ref: yes)	1.130	0.264	<0.001	3.094	1.845	5.188
	COVID-19 (ref: yes)	1.023	0.274	<0.001	2.780	1.624	4.759
	Income	0.215	0.092	0.020	1.240	1.035	1.485
Motorcycle	Intercept	−0.786	0.290	0.007	0.456		
	Income	0.342	0.095	<0.001	1.407	1.168	1.696
	Age	−0.556	0.155	<0.001	0.574	0.424	0.777
Bike	Intercept	−1.871	0.207	<0.001	0.154		
	Gender (ref: male)	0.561	0.246	0.023	1.753	1.082	2.841
	COVID-19 (ref: yes)	1.762	0.259	<0.001	5.827	3.507	9.681
E-scooter/hoverboard	Intercept	−1.748	0.174	<0.001	0.174		
	Income	0.171	0.088	0.053	1.186	0.998	1.411
	COVID-19 (ref: yes)	1.638	0.255	<0.001	5.143	3.123	8.471
Walking	Intercept	−0.858	0.122	<0.001	0.424		
	COVID-19 (ref: yes)	0.796	0.237	0.001	2.216	1.392	3.528

have a reduced demand for public transport modes due to the pandemic. This decrease in demand in public transport modes showed that students who own cars will increase their use of private cars. This will have a negative result on urban life. However, what should be noted here is that 64.9% of the university students who answered the questionnaires in this study did not own a car. In addition, 75% of these university students had a monthly income of 1000–3000 TL, that is, low income (see Table 2). Therefore, the transport mode preferences of students who refuse to use public transport modes and do not own a car can include bicycles, e-scooters/hoverboards, and walking. In other words, the second of the three scenarios expected for the aforementioned pandemic can be realized specifically for university students. This is an important opportunity that should not be missed by the transport authorities. Transport authorities should seize this opportunity with necessary arrangements and physical/technological infrastructures without delay. As an example, the Ministry of Transport and Infrastructure, the Ministry of Environment, Urbanization and Climate Change and the Ministry of Interior jointly published the e-scooter regulation on April 14, 2021 in Turkey (AuthorAnonymous, 2021). Thereafter, the Istanbul Metropolitan Municipality Transport Coordination Centre (UKOME) announced a number of regulations for the safe use of e-scooters on August 28, 2021 (IMM, 2021). This arrangement, which includes issues such as speed limit, parking, and the fee policy of e-scooters, can be seen as a good gain. However, it is insufficient. All instruments that support e-scooters/hoverboards and active travel modes should be quickly activated by transport authorities during the pandemic process. Otherwise, a dissatisfaction that may arise due to insufficient regulation and infrastructure can direct middle-/high-income users from e-scooters/hoverboards and active travel mode users to private cars, and middle-/low-income users to cabs and motorcycles.

A discussion about the results obtained in this study can be expressed as: having COVID-19 seems to be a factor that reduces demand in public transport modes. This may be due to the fear of COVID-19, which has severe symptoms and still contains uncertainties in terms of symptoms due to its various variants (Parker et al., 2021). It is not yet clear how long the permanence of this fear will continue in societies (Martínez-Lorca et al., 2020). However, as a result of the decrease or absence of the effect of this fear by the end of the pandemic, some of the passengers

who have turned away from public transport modes may try to use public transport modes again (Abdullah et al., 2021). It is very important to make some improvements in public transport modes in order not to lose these passengers who return to public transport modes after the pandemic (Eisenmann et al., 2021). These improvements in public transport modes are well known to all of us, reducing the occupancy rate of passengers in vehicles, reducing the crowds at stops, social distancing, good ventilation, and hygiene measures (Tirachini and Cats, 2020). With these improvements, demands for public transport modes can become permanent again. Das et al. (2021) stated in their study that the most effective strategy to protect the demands on public transport after the pandemic was the strategy of "reducing the stops in regions attracting large crowds". Cashless and contactless payment was the next priority, followed by alternative seating arrangements with appropriate social distancing measures, the provision of personal protective equipment kits, real-time information on seat availability, limitations in the number of passengers, and regular disinfection of public transport modes. When Das et al. (2021) asked passengers about their probability of using public transport modes if these strategies were applied, 25.6% of the participants answered yes, and 53.6%, 16.7%, 3.6%, and 0.5% of the participants answered probably yes, probably no, no, and absolutely no, respectively. The implementation of such policy measures that guarantees the health safety of public transport users shows that the demand for public transport modes in a post-COVID-19 world can still be maintained.

As can be seen from the above discussions, the transport authorities have a lot of needs to meet. In the most general framework, these include: 1) supporting the demand for e-scooters/hoverboards, bicycles, and walking with physical/technological infrastructures and encouraging society to use these modes through a series of campaigns; and 2) making permanent improvements that are common expectations of everyone for public transport modes. The negative impact of the pandemic on transport modes can be reduced only if the transport authorities can successfully meet these needs.

7. Conclusion

Transport policy makers face countless challenges to produce new

solutions within the constraints caused by ongoing pandemic conditions. Formulating new policies that support sustainable urban life, especially for the post-COVID-19 world, appears to be a complex task for transport policy makers. Because of the COVID-19 pandemic, there is an unprecedented radical change in demand in societies. This change has been strongly felt in many issues, such as shopping, social life, and travel. While this shift in demand is alarming for policy makers, it can also hold opportunities for a post-COVID-19 world. For this reason, restructuring the transport policy vision and formulating new policies that take into account users' expectations and transport mode preferences are the most important tasks of transport policy makers in the ongoing pandemic process.

In this study, useful findings that will shed light for transport policy makers for a post-pandemic world were obtained. For this purpose, the pandemic-based transport mode demand changes of university students, who have adapted quickly to changes when compared to other parts of society, were examined. In summary, the reasons for examining the behaviors of university students were: 1) Understanding the transport mode demand changes of university students can provide information about the future demand changes of other segments of society, because all segments of society do not adapt to new practices simultaneously, and some segments of society may take time to adapt to changes and new practices. In this context, university student behaviors can be considered as the pioneer of change. 2) For cities with a large university student population, the transport mode demand changes of university students may directly affect the transport system in the city. For these reasons, this transport mode preference study focused on university students can provide a useful perspective to transport policy makers.

The following can be concluded as a result of the discussions of the findings and findings obtained from this study: public transport includes transport modes in which passenger demands are easily affected by negative effects, even though they are cheaper, provide better accessibility, and are efficient. Due to this fragile structure, a modal shift from public transport modes to private car use is inevitable as a result of a possible negative effect. Since the COVID-19 pandemic has had a very negative effect on public transport, the shift scenario of transport demands to private car use is seen as the strongest scenario if no intervention is made. This scenario, which is the strongest, is also the worst scenario for the post-pandemic. As seen in this study and other recent studies in the literature, it is highly probable that a demand shift from public transport modes due to COVID-19 will occur. Effective intervention by transport authorities is crucial to ensure that this demand shift does not take place entirely toward private car use and that a significant part of this demand shift takes place toward e-scooters/hoverboards and active travel modes. In this study, it was seen that there will be an increase in demand for bicycles, e-scooters/hoverboards, and walking, as well as the use of private cars, after the pandemic. This is an important opportunity. In order not to miss out on this opportunity, the demand shifting to e-scooters/hoverboards and active travel modes should be supported by physical and technological infrastructures by transport authorities. In addition, the integration of these modes into public transport modes should be strengthened. Otherwise, the realization of the worst-case scenario will be inevitable and after the pandemic, much more private car ownership and use will be witnessed in cities. In addition to all these, hygiene, ventilation, social distancing, and in-vehicle and stop occupancy issues should be meticulously addressed by transport authorities in order to reduce the shift from public transport modes and increase the return to public transport modes after the pandemic, and these improvements should be maintained after the pandemic.

One of the issues mentioned, but not detailed in this study was the fear of COVID-19. It is quite remarkable how long this fear will continue after the pandemic and the change in its effect on transport mode preferences over time. In the future, a transport mode preference study, in which the relationship between the fear of COVID-19 and the post-pandemic period is also taken into consideration, may be useful and expand the results of this study.

CRediT authorship contribution statement

Muhammed Emin Cihangir Bagdatli: Conceptualization, Visualization, Methodology, Validation, Resources, Investigation, Writing - Original Draft. **Fatima Ipek:** Methodology, Resources, Investigation, Writing - Original Draft.

Declaration of competing interest

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

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