The impacts of COVID-19 on travel behavior and initial perception of public transport measures in Istanbul

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ABSTRACT

The epidemic disease emerged in Wuhan/China in December 2019, which primarily causes acute respiratory syndrome and spread worldwide in a very short time. Although the countries took numerous precautions, the spread of the virus could not be controlled. Furthermore, due to the inability to maintain physical distance and the excess of shared surfaces, public transport services also increase the risk of spreading. This study analyzes the changes in perceptions and behavior of passengers who use public transportation via a survey. The survey is developed to assess the behavioral change of passengers pre and post-pandemic of COVID-19. Outcomes showed a notable shift among transportation modes due to closure of venues, utilization of distance education, partial curfews in Istanbul. A further focal point of the study is the passengers' attitudes towards preventive measures and their perceptions on how well responsible bodies have implemented the measures. Thus, it provides valuable insights into the changes in the traveling habits of city residents, which help the policymakers of public transportation.

1. Introduction

In Wuhan/China, in December 2019 a novel coronavirus (nCoV) is reported by the authorities of China [1]. The reported virus mainly causes an acute respiratory syndrome, and it is named "COVID-19" by the World Health Organization (WHO). The spreading power of COVID-19 was swift, and it was reported in 210 countries (in all continents) in less than five months. Since December 31, 2019, and as of January 6, 2022, 301.539.860 cases and 5.492.836 deaths are reported [2]. Continent-based statistics are provided in Fig. 1.

Because of the severity of the pandemic, several precautions have been taken by almost all countries that suffer from COVID-19. For example, some of the Turkish government's precautions are reported in [3]. Although these protections assisted a lot in preventing the spreading of the virus, later, governments were required to relax these precautions because of economic and social issues. COVID-19 did not only affect health but also affected the economy, environment, and social life. Analyses on the effects of COVID-19 in terms of the abovementioned issues have been studied extensively by researchers. It mainly affected health and the economy. According to the OECD, the shock from COVID-19 is already higher than the financial crisis of 2008, and a recession is expected in many countries. Furthermore, IMF states the recovery is expected to start in 2021 [4]. COVID-19 is already caused

the closure of several businesses, which increases the unemployment rate, and in the end, unfortunately, the supply chain network between countries is at the risk of failure.

Furthermore, COVID-19 caused several changes in the daily life's behaviors of people, i.e., hosting, transportation, traveling, communication, etc. For instance, people do not host several people together for a longer time than the days before COVID-19. One of the most affected behaviors of people is their transportation attitude. Today, in their daily life, people prefer biking or walking for shorter distances and driving private cars for longer distances as transportation modes. It is known that crowded places accelerate the spread of the virus, and public transportation is one of these regions, especially in metropolitans such as Istanbul, Shanghai, Tokyo, New York, etc. Considering the mobility of millions of people via public transportation in a day, the contacts between passengers are unavoidable, and these contacts escalate the spread of the virus if the same behaviors as pre-pandemic are followed. Consequently, several precautions are applied by countries, i.e., Belgium, Portugal, Ireland, Italy, Slovenia, Slovakia [5], and Turkey.

To take the pandemic under control, public transportation management plays a vital role in crowded cities and metropolitans, i.e., Istanbul. With about 17 million residents, Istanbul is the most crowded

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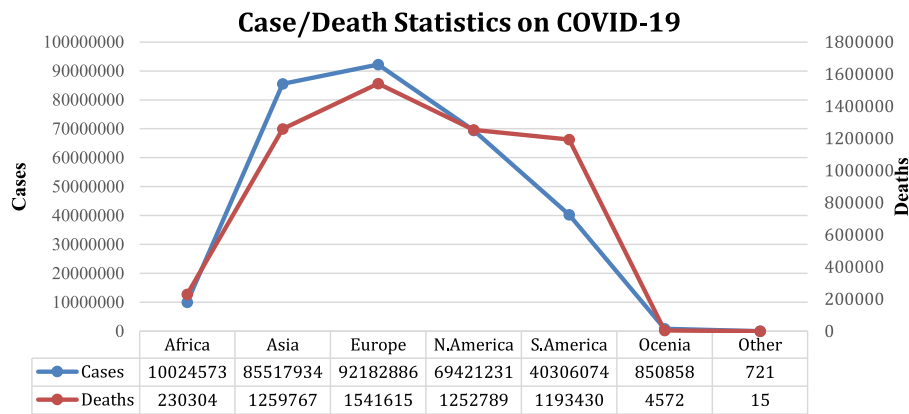
Fig. 1. Number of cases and deaths of COVID-19 between 31/12/19 and 05/01/2022 [2].

city in Turkey [6]. In Istanbul, 12 railways-metros, 8 BRT (Bus Rapid Transit) lines, more than 3000 buses, and hundreds of ferries are in service. As a result, every day, about 15 million trips take place [7].

At the time of conducting this research, the COVID-19 pandemic is still ongoing. Thus, there is a limited number of studies on public transportation during the pandemic [8–22]. Not surprisingly, early examples of research into the topic focus on the change of travel behavior in public transportation. Recent evidence suggests that there have been a significant shift in everyday mobility behavior and transportation mode preferences [13–15,18,19]. To our knowledge, none of the previous studies take into account the behavioral change of travelers before and after the COVID-19 pandemic in Istanbul. Our study analyzes the changes in the perception and behavior of passengers using public transportation vehicles through a questionnaire.

Shakibaei et al. [18] presented the only significant analysis and discussion on the subject in the context of Istanbul. During the early stages of the pandemic, the authors conducted a longitudinal panel data analysis in three phases, total disregard of the virus, raised sensitivity to the virus risk, and actual engagement with pandemic problems. The survey results showed that social/recreational/leisure (SRL) activities have significantly declined during the pandemic. Furthermore, the study proved a remarkable change in transport modes' utilization in Istanbul during the three phases of the concerned time period. The authors also underline the state of constant flux in people's attitudes, which, in turn, shows the need for future research.

One major issue hitherto received scant attention in the context of Istanbul is the perception of measures by passengers and their attitudes towards newly introduced precautionary actions. With this motivation, in this study, we aim to assess the perception of measures by passengers, who use public transportation services in Istanbul, and the shift in their traveling behaviors via a survey tool. The survey is developed in a way to assess and compare the behaviors of passengers pre and post-pandemic of COVID-19. In addition, another important focal point of this study is to measure the personal attitudes of passengers towards precautionary measures. Thus, the present study is one of the very rare attempts [18] in the domain conducted in Istanbul. Thus, the present study contributes to the existing body of knowledge in the following aspects:

- This research measures the changes in travel modes, and in behaviors of passengers because of the effects of COVID-19 in Istanbul.
- This study analyzes the shift in trends of public transport and inter-mode demands during COVID-19.
- The passengers' perceptions of the precautions taken by the authorities and their own attitudes are questioned.
- The study provides valuable insights on the changes in the traveling habits of Istanbulers, which help the policymakers of public transport.

- Using the survey provided in this study, the abovementioned goals can be achieved for any region or metropolitan in the world, given that the city-specific public transportation parameters are used.

The rest of the paper is organized as follows: Section 2 provides a general overview of public transport. The trends in public transport and inter-mode demands during COVID-19 are presented in Section 3. The survey on travel behaviors and data collection is given in Section 4. The findings of the survey are presented in Section 5. Finally, concluding remarks and future research opportunities are given in Section 6. Furthermore, the plain survey is provided in Appendix.

2. General overview of public transport

2.1. Importance of public transport for sustainable cities

As urbanization rapidly spreads worldwide, transportation becomes more important as an intermediary service required for economic, social, and cultural activities [23]. Performance of the urban transport systems directly affects people's economic and social lives in the cities [24]. One of the biggest problems that developing countries are facing is the issue of transportation. Due to the rapid population increase and urban growth, solving transportation issues has the highest priority in Turkey. In this respect, public transit systems play the most crucial role in supporting urban mobility. However, capacity-related problems and inadequacies of the public transport enterprises create severe problems for the service sector. Cities with ineffective public transportation systems face serious transportation problems that cannot be solved easily.

Urban public transport has become more critical today, as all segments of society have acknowledged that using private vehicles cause severe social and economic problems. In Turkey, urban transportation issues affect one out of two persons directly and all citizens indirectly through allocating resources [25]. Moreover, transportation investments have impacts on the entire city. Thus, the quality of public transport systems is of critical importance for the people living in Turkey, as elsewhere in the world.

Public transport systems with sufficient capacity can reduce private car use and relieve traffic congestion. It also helps to protect the environment by reducing CO_2 emissions from numerous vehicles [26]. In addition, sustainable public transportation systems create more sustainable and livable cities by lowering accident rates, increasing urban mobility for all socioeconomic groups, and reducing fuel consumption [27].
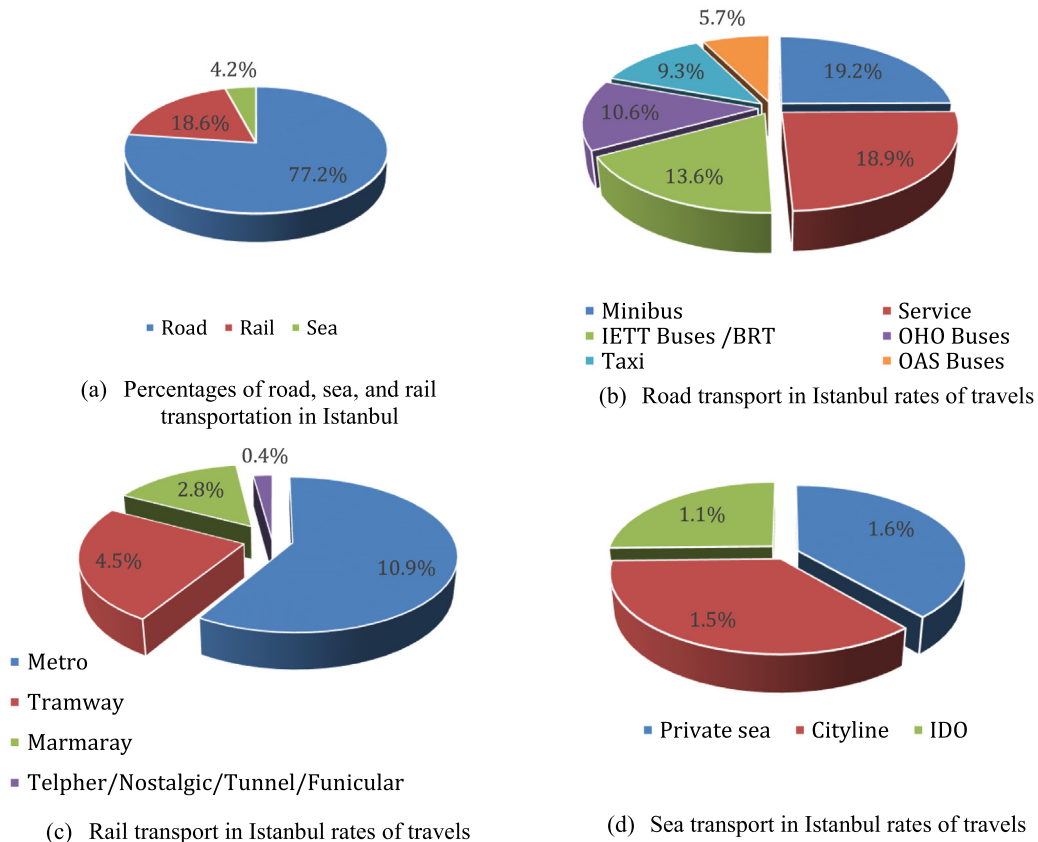
(a) Percentages of road, sea, and rail transportation in Istanbul

(b) Road transport in Istanbul rates of travels

(c) Rail transport in Istanbul rates of travels

(d) Sea transport in Istanbul rates of travels

Fig. 2. Journey distribution by modes of transportation in Istanbul, including land, maritime, and rail transportation.

2.2. Istanbul's public transport

Istanbul is Turkey's economic, cultural, and tourism capital. The metropolitan city has a highly integrated public transport system consisting of public buses, metro, Marmaray (marmarail), light rail, street tram line, ferry, and bus rapid transit (BRT).

More recently, Istanbul has aimed to improve the urban transport system economically, socially, and environmentally by undertaking large-scale investments. IETT (the Municipal Public Bus Company), as the municipal public bus operator of Istanbul, set out a vision to become a pioneer as an environmentally friendly public bus company. IETT has a total fleet of 2560 public buses, 510 of which are used in Bus Rapid Transit (BRT) services, and others are used in regular bus services. BRT has a length of 52 kilometers and covers Istanbul's most crowded road corridors (D-100). It has 45 stations and serves more than one million passengers daily. BRT passenger revenues constitute 64% of IETT's total revenues [7].

Public transport in Istanbul consists of a wide range of transport modes, including road, rail, and sea modes. The road transport mode includes buses, minibuses, shuttle vehicles, and taxis; rail transport covers metro, Marmaray, tramway, and telpher/funicular; maritime transportation incorporates ships, sea buses, and motorboats. The data for 2019 indicate that there were 11.709.602 road passenger journeys on average per day, 2.822.291 rail passenger journeys, and 644.851 sea passenger journeys in Istanbul. Therefore, the total number of trips for all transport modes equals to 15.176.744 on average per day for 2019 [7]. Considering the sheer volume of passengers, it is clear that developing a customer-oriented methodology to address urban transport issues will affect a quite large population. Fig. 2a shows

the journey distribution by modes of transportation. In addition to this, Fig. 2(b, c, and d) shows the journey's percentages by modes of transportation, including land, maritime, and rail transportation.

3. The trends in public transport and inter-modes demands during COVID-19

After COVID-19 became a global problem, Turkey has managed to keep it away for a specified period with the measures taken. However, as the first case was recorded on March 11, 2021, the measures were tightened. The key events and preventive measures taken until the present study carried out can be seen in Fig. 3.

The measures given above have also negatively affected public transportation services. This section compares the trends on the public transport data of Istanbul Metropolitan Municipality (IMM) in 2019 and 2020 of the same period. Not surprisingly, Istanbul residents have started to use public transport less often because of the ongoing coronavirus pandemic. Since the first case of the COVID-19 in Turkey was declared on March 11, 2020, the number of daily passengers using Istanbul's public transportation fell from −5% to −9% [7].

Self-isolation and imperative curfew practices imposed by the government, the impact of COVID-19 on the public transport in Istanbul in terms of ridership was ruinous. Fig. 4 shows the difference between monthly ridership figures for different modes of transport between 2019 and 2020. Demand for Istanbul public transport has fallen by as much as 85 percent during the pandemic. The difference between monthly IETT buses' ridership figures between 2019 and 2020 can be observed in Fig. 4(a). In March, the ridership declined by 33% in 2020 compared to 2019, and the decline went further in April,
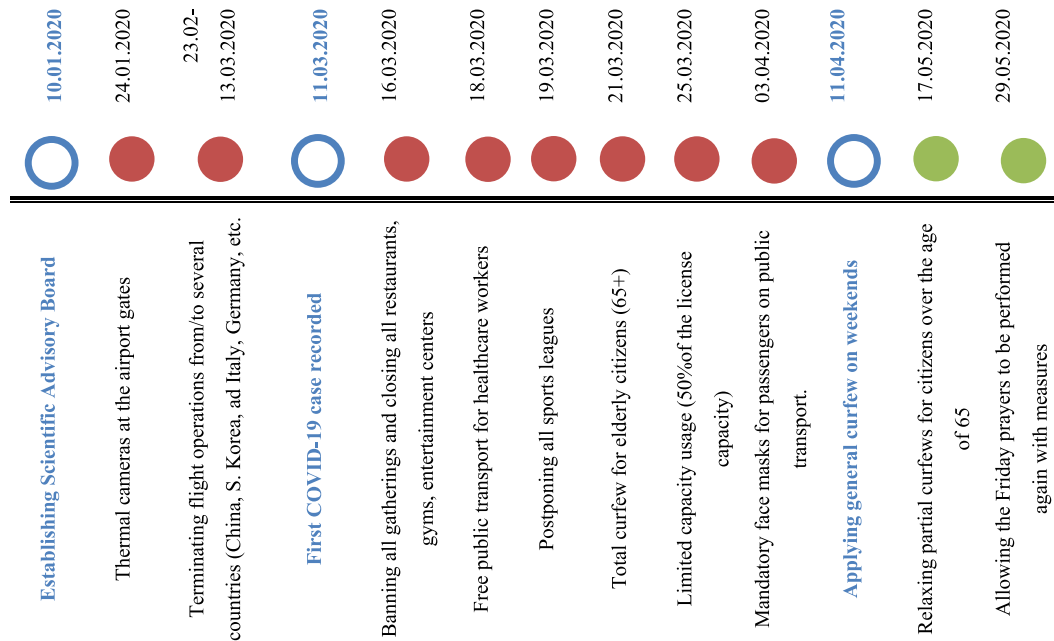
Fig. 3. Key milestones and measures in the initial stage of COVID-19.

reaching an 82% fall. The slide is similar in other modes of transport, and only the funicular and nostalgic tram decline are close to 100%. In addition to this, Fig. 4(b, c, d, e, f, and h) presents the ridership percentages by modes of transport between 2019 and 2020. Istanbul's public transport demand has dropped by as much as 85 to 90 percent during the pandemic.

Fig. 5(a) and (b) show the ridership distribution by modes of transport in Istanbul, including land (IETT Buses, BRT, OHO, and OAS Buses), maritime (Sea Buses), and rail transportation (Metro and Marmaray). The most widely used mode of transport in 2019 was the Istanbul Metro. Similarly, a change in passenger preferences during the COVID-19 period in 2020 was not observed.

Daily demand trend between March 1 and April 30 2020 is shown in Fig. 6. When we zoom into the daily ridership figures starting from March 2020, we see the rapid decline in the third week of March (12nd week of the year). After one week, the ridership got stabilized.

Fig. 7 shows an aggregate of weekday ridership figures as well as Saturday and Sunday shown separately. As is shown in Fig. 7, the decline in Istanbul public transport operations reflects the severity of the COVID-19 pandemic.

According to the Istanbul Metropolitan Municipality, residents of the region have started using private vehicles, cycling, or walking to avoid close contact in overcrowded Istanbul transportation modes during the COVID-19 pandemic.

4. Survey and data collection

To investigate the impact of COVID-19 on travel behavior in Istanbul, an online survey was conducted via email, social media, and professional networks using "Google Forms". Overall, the survey tool aimed to cover the behavioral changes and attitudes towards the measures taken in public transport during the initial three months since the first official case was recorded. It consisted of three major sections and was administered to the residents of Istanbul over two months starting from May 2020.

The first part of the survey contains socio-demographic aspects, such as age, gender, education level, and primary occupation (items 1–4), while the second section questioned the change in traveling habits of the city residents before and during COVID-19 (items 5–12). The last part focuses on the perception of travelers about the safeness of public transport services and their attitudes towards COVID-19 measures taken by transportation authorities. Since the conditions prevailing in public life during the pandemic are very rare, we adopted the survey items from different recently published sources [13,17,28]. In item 13, we questioned the health safety perception of passengers about transportation modes, which is expected to vary due to crowdedness and hygiene standards of different modes. Item 14 aims to obtain the behavioral patterns of passengers on three basic COVID-19 measures, distance, mask, and hand hygiene. The last item in the questionnaire collected the opinions on the COVID-19 related practices in transportation. The authors conducted the questionnaire design based on the current observations and the managers' views from IETT. An initial pilot survey was done to test the questionnaire design. The questionnaire items are presented in Appendix.

5. Case study findings

5.1. Demographic characteristics

In this section, the demographic characteristics of the respondents were examined. The respondents were selected based on convenience sampling due to COVID-19 conditions that complicate the random sampling approach. This questionnaire was filled out by 303 participants which 46.86% were female, and 53.14% were male respondents, as given in Table 1. Most of the respondents were between 21–30 years (65.02%). While the respondents aged 18 or younger were 0.66%, remaining 31.01% and 2.31% had an age range of 35–49 and 50–64 years, respectively. The most significant educational level in respondents was undergraduate students (53.14%). With regard to their occupation, the majority of the respondents (44.55%) was employed in private sectors, and about 34.65% was in public sectors.
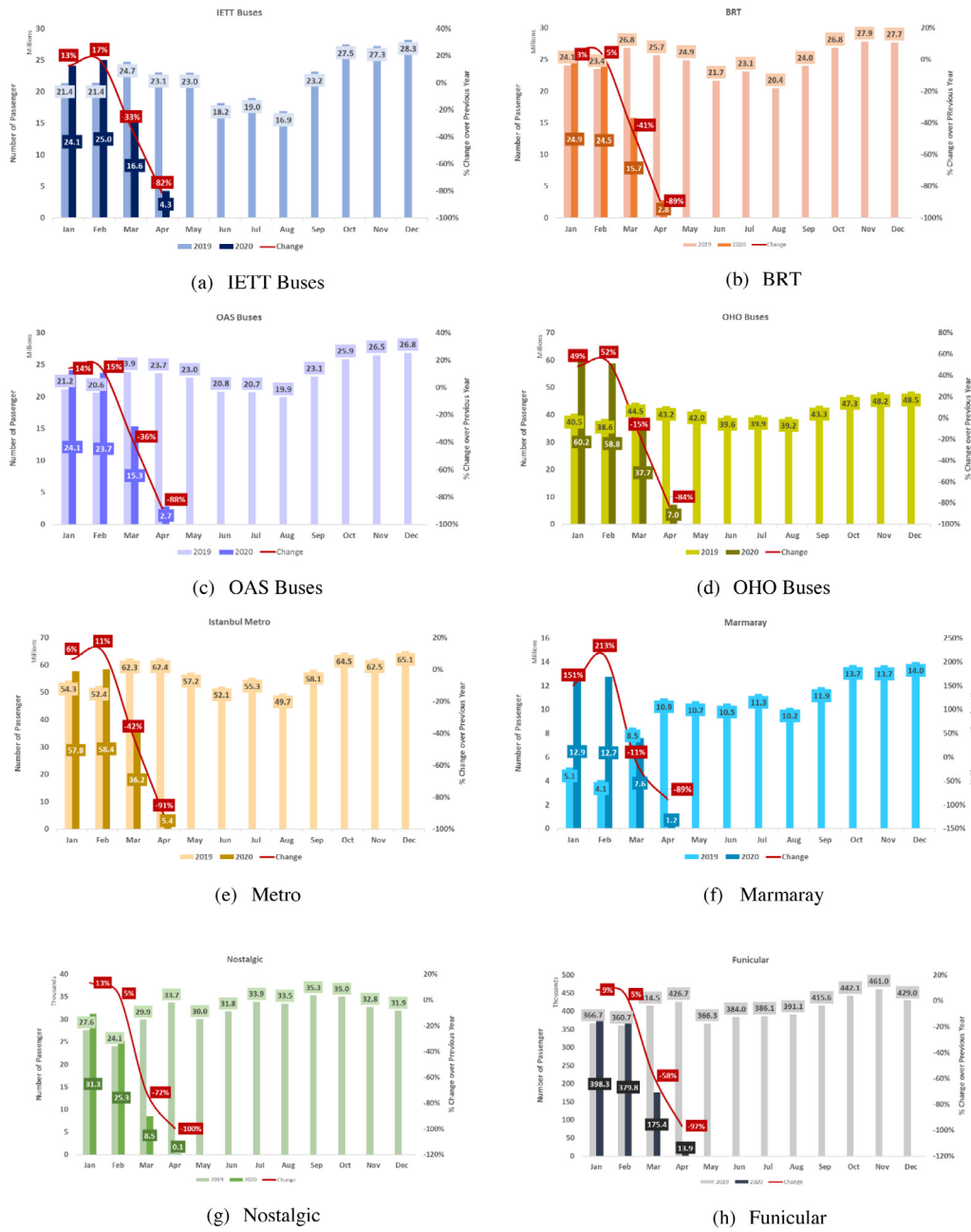
(a) IETT Buses

(b) BRT

(c) OAS Buses

(d) OHO Buses

(e) Metro

(f) Marmaray

(g) Nostalgic

(h) Funicular

Fig. 4. Monthly demand trends for 2019 and 2020 years.

(a) 2019 years
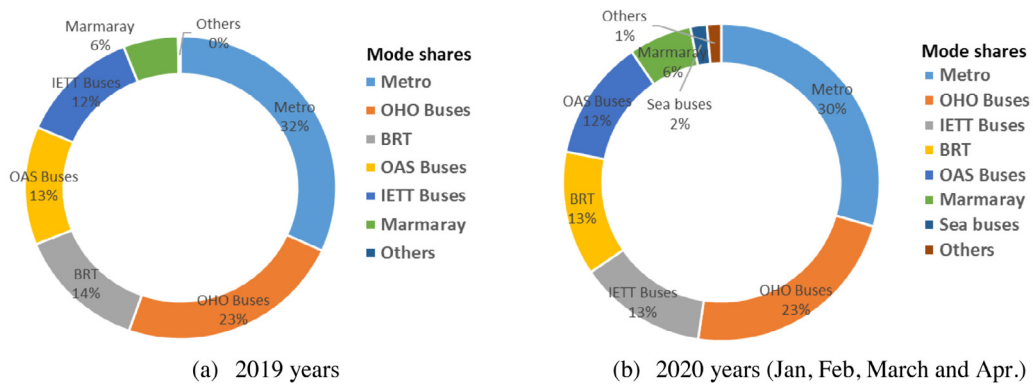
(b) 2020 years (Jan, Feb, March and Apr.)

Fig. 5. Journey distribution by modes of transportation in Istanbul for 2019 and 2020 years.
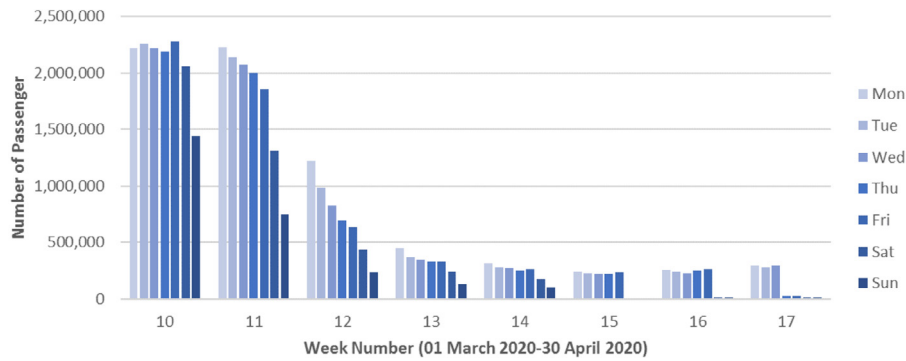
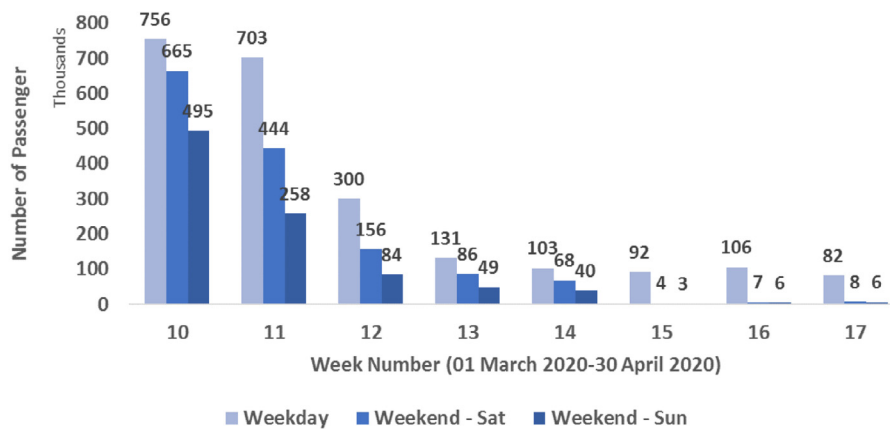**Fig. 6.** Daily demand trend between March 1 and April 30, 2020, during Covid-19.

Fig. 7. Weekdays, Saturdays, and Sundays demand trend between March 1 and April 30, 2020 During Covid-19.

Table 1
Passenger/respondent profiles.

Variables	Sample number	% of total respondents
Gender		
Female	142	46.86%
Male	161	53.14%
Age		
18 or younger	2	0.66%
19–34	197	65.02%
35–49	97	32.01%
50–64	7	2.31%
65 or older	0	0.00%
Education		
No qualifications	0	0.00%
Primary school	5	1.65%
High school	34	11.22%
Two-year college	33	10.89%
Undergraduate	161	53.14%
Graduate	70	23.10%
Occupation		
Student	31	10.23%
Government employee	105	34.65%
Private-sector employee	135	44.55%
Retired	5	1.65%
Others	27	8.91%

5.2. Urban travel behavior characteristics pre- and during COVID-19

This section analyzes the findings of the characteristics of travel behavior pre-COVID-19. It is shown how many people make public transport trips, their primary purpose of travel, how often they do this, and which combinations as intermodal they use. Regarding the characteristics of travel behavior pre-COVID-19, the response sample can be shown in Fig. 8. According to the survey results, the ratio of passengers using public transportation before COVID-19 is 64% (see Fig. 8a). The rate of passengers using private vehicles is 29%. The characteristics of intermodal use of transport modes are examined in Fig. 8(d).

Given the abovementioned reflections of the pandemic on public transportation, it is very likely that travelers will change their habits of using a certain means of transportation. In other words, more intensive use of private cars and other individual solutions, such as biking and walking, is expected compared to the use of public buses, metro, etc. Thus, we first examine if there is a significant change in residents' preferences while choosing the mean of transportation.

Table 2 provides some clues on this expected shift. During the pandemic, more people prefer to use private cars and bikes instead of public transportation modes. To evaluate the significance of this statement, we formulate the following null hypothesis:

H_1: There is no difference in travelers' preferences on the mean of transportation before and during COVID-19.

The hypothesis was tested with the Pearson chi-square test. The test statistics are given in Table 3, which indicates that the null hypothesis can be rejected based on the significance values ($p < 0.05$) reported. Thus, a significant shift exists among the three categories of main transportation habits. Indeed, unsurprisingly, people prefer biking for short distances and private cars to avoid crowded public vehicles while conducting their daily activities in the city. With the results reported above, this observation is also statistically proven.

A second issue worth focusing on is the frequency of using public transportation by travelers. Naturally, we expect a significant change
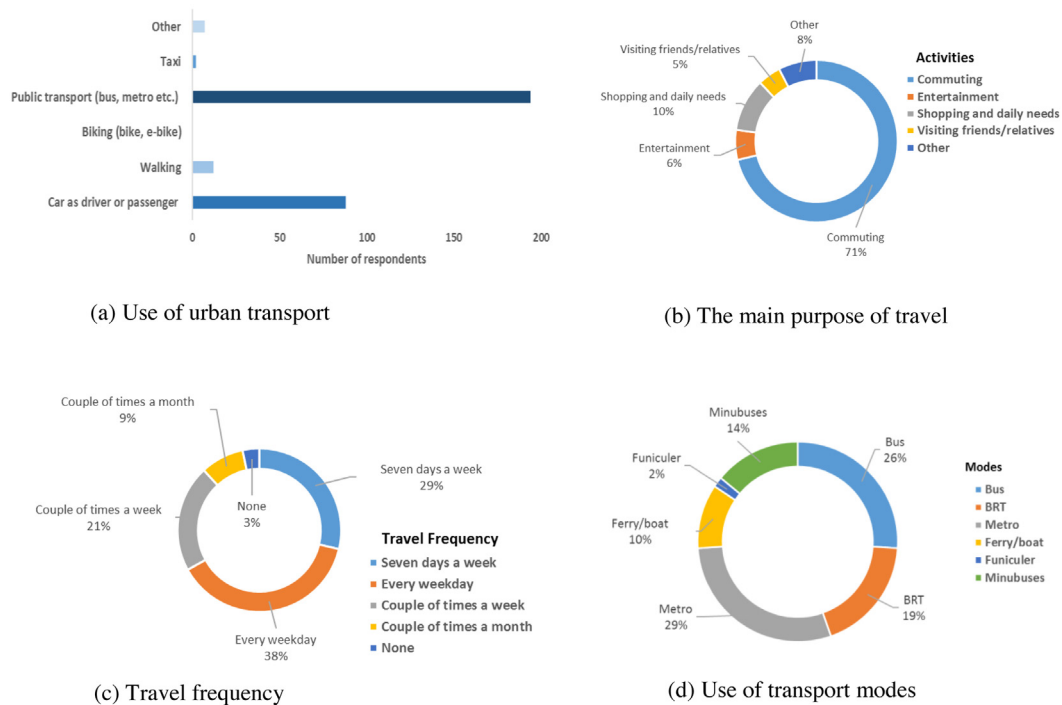
(a) Use of urban transport

(b) The main purpose of travel

(c) Travel frequency

(d) Use of transport modes

Fig. 8. Travel behavior of urban transport users' pre-COVID-19.

Table 2
Comparison of preferences of travelers before and during COVID-19.

		During			Total
		Private car	Public transport	Other (biking, walking)	
Before	**Private car**	84	0	4	88
	Public transport	45	113	36	194
	Other (biking, walking)	8	5	8	21
Total		137	118	48	303

Table 3
Pearson chi-square statistics on the preferences of respondents on transportation means.

	Value	df	Asymptotic significance (2-sided)
Pearson chi-square	138.787[a]	40	.000
Likelihood ratio	164.227	4	.000
Linear-by-linear association	73.441	1	.000
N of valid cases	303	118	48

in this aspect before and during COVID-19. This issue was measured with Q7 and Q11 in the survey. Thus, our next null-hypothesis will be:

H_2: There is no difference in the frequency of using public transportation by travelers before and during COVID-19.

The result of the paired samples t-test proves that the difference between the two samples (the frequency before and during the pandemic) is significant ($p < 0.05$) (see Table 4). Thus, as expected, there is a noticeable decline in travel frequencies of the respondents within the public transportation network in Istanbul.

5.3. Perception of travelers on safeness of public transportation during COVID-19

As in other crowded cities, public transportation vehicles are seen as a vital factor that accelerates the spread of COVID-19 [5]. For this reason, on the one hand, people generally behave more timidly as a natural reflex in using these means of travel; on the other hand, the public authority also takes strict measures on the subject. While

some measures such as more frequent disinfection of vehicles can be implemented more easily, some measures such as following personal hygiene rules take time to become established due to the human factor.

In this section, the level of compliance of passengers with the implemented measures specific to COVID-19 in public transportation vehicles and their perceptions about the attitudes of other passengers towards obeying the rules are questioned. In addition, how safe the passengers find different transportation modes in terms of health and their preference levels have been investigated.

In the literature, there are studies showing that men and women have different approaches to obeying the rules and that the last group internalizes the rules more easily [29,30]. Likewise, the question of whether the attitudes of men and women are different regarding the new measures implemented in public transportation in Istanbul gains importance. Accordingly, we can express our null-hypothesis as follows:

H_3: There is no difference between male and female travelers' compliance levels regarding the individual COVID-19 measures in Istanbul.

To test this hypothesis, the participants were asked how well they followed the commonly used mask, distance, glove, and hand hygiene measures to ensure personal hygiene (Q14). Table 5 provides some clues that there may be some differences between female and male participants on the compliance with COVID-19 measures. The possible difference between the two groups was analyzed with the independent samples t-test.

Given Levene's test statistics where all p-values ($p = 0.806, 0.396, 0429, 0.897$ respectively) are above the critical significance level ($p > 0.05$) for all of the four questions related to mask, gloves, social

Table 4
Paired samples t-test statistics on the frequency of using public transportation before and during COVID-19.

				During				
	Mean	Std. deviation	Std. error mean	95% confidence interval of the difference		T	df	Sig. (2-tailed)
				Lower	Upper			
Frequency before and during the pandemic	.769	1.136	.065	.641	.897	11.782	302	.000

Table 5
Group statistics on individual COVID-19 measures and gender.

Item	Gender	N	Mean	Std. deviation
Mask	**Male**	142	4.67	.638
	Female	161	4.65	.664
Gloves	**Male**	142	2.61	1.294
	Female	161	2.98	1.306
Social distancing	**Male**	142	4.33	.865
	Female	161	4.41	.737
Disinfectant	**Male**	142	3.97	1.038
	Female	161	4.22	1.025

distancing, and hand hygiene, we failed to reject the equal variance assumption. Thus, we only report t-statistics under the equal variance assumption among the two groups. As shown in Table 6, the significance levels of taking the precautions on the use of mask and paying regard to social distance suggest no statistically significant difference between males and females. On the other hand, using gloves and disinfectants were regarded by female travelers with statistically significant differences of means of two sample groups. Finally, Table 6 indicates that the overall compliance of females with the rules is significantly better. Therefore, the general attitudes of female participants were more positive and abiding regarding the individual COVID-19 measures than of the males.

Another interesting point would be the relationship between educational status and compliance with COVID-19 measures. To evaluate this, the surveyed residents were grouped according to three major groups based on their educational backgrounds: high school, undergraduate, and graduate. The next null-hypothesis to be tested states:

H_4: There is no difference between the compliance levels of travelers of different educational statuses regarding the individual COVID-19 measures in Istanbul.

As shown in Table 7, the relevant statistics are above the critical level (0.05) for social distancing, gloves, and the use of disinfectant, whereas the null hypothesis can be rejected for wearing masks. So, the table indicates that travelers equally comply with the measures related to social distancing, gloves, and hand hygiene independent from their educational background. However, there is a significant difference among the groups when it comes to the abidance to mask.

Accordingly, a posthoc analysis was done to determine which group has diverged from the others. The results of Tukey's HSD prove that the mean difference between the compliance of high school graduates the undergraduates is significant at the 0.05 level (see Table 8).

Measuring individual perceptions of the travelers on the safeness levels of various transportation modes is another focal point of this study. To analyze this, we use the responses to Q13, which questions the travelers' opinions on the safeness levels of public and private transportation modes during COVID-19. Fig. 9(a–h) depicts the distribution of perceptions of respondents, from unsafe to safe, on different traveling options. As expected, the subfigures (Fig. 9a–h) visualize strong clues about significant differences between public and private transportation modes.

By taking the mean of responses given for public transportation vehicles, bus, BRT, metro, and ferry, as well as for private means of transportation such as taxi, private car, bike, and walking, we conducted

a paired samples t-test. Given a moderately low correlation (0.266) among the two groups, we expect a significant difference between public and private transportation modes. Thus, our next null-hypothesis can be stated as follows:

H_5: There is no difference between the means of safeness perceptions of travelers on public and private transportation modes during COVID-19 in Istanbul.

According to Table 9, the mean difference between public and private transportation modes is −2.057, indicating a clear preference for private modes as respondents found them significantly safer than public ones. Thus, we can reject the null hypothesis of equal means between the groups in terms of safeness perception levels.

Table 10 provides additional insights on the relationship between the frequency of preferring various public transportation modes and safeness perceptions of respondents. Levene's test statistics in the table show that the assumptions for the equality of the variances are valid. Given that these assumptions hold for all public transportation modes, we checked the significance of the mean differences of frequency between two subgroups, those who find public transportation safe and those who consider public transport as unsafe. Significance values for the t-test indicate that the null hypothesis for equality of means of two groups can be rejected. Thus, we can conclude that travelers' perception of safeness is an important factor for the traveling frequency with a particular public transportation mode. As expected, the determination that public transportation vehicles are used less during the pandemic process stated in the previous sections is not only due to the slowdown in economic and production activities. In addition, there is a legitimate perception among people that public transport is less safe due to the pandemic conditions.

A similar issue can also be addressed for private transportation modes, such as taxi, private car, bike, and walking, which are considered relatively safe as the travelers can isolate themselves and more easily conform to the social distancing rule. Table 11 indicates equal variances assumption between the two groups holds. Furthermore, according to reported t-statistics, the differences between means of the groups are not significant for all private transportation modes except walking.

A further set of questions in the survey addresses how the travelers perceive the operational practices of public transportation authorities by giving their levels of agreement with certain statements. In this way, some corrective measures can be taken to increase their safety and satisfaction. Fig. 10(a–e) illustrates the distributions of levels of agreement with five different statement. An interesting finding is that the participants think that the other travelers do not follow the rules as given in Fig. 10(a) with 39.27% (disagree) and 20.79 (totally disagree). Also, the travelers are not well informed about the disinfection practices done by the operator (IETT), which 58.42% of them takes no clear stand on the statement "Vehicles are properly disinfected". Furthermore, two important implications can be generalized regarding the operational decisions. First, many participants agree with the statements on "more frequency of checks" and "more frequent tours", 46.53% and 50.83%, respectively. The drivers' attitudes regarding the COVID-19 measures can be evaluated as proper given that 30.4% of the participants approve. However, IETT, which manages public transportation processes, should effectively explain the measures taken against COVID-19 and enlighten public opinion.

Table 6
Independent samples t-test statistics on the compliance with COVID-19 measures of different genders.

Item	t	Sig. (2-tailed)	Mean difference	Std. error difference	95% confidence interval of the difference	
					Lower	Upper
Mask	.224	.823	.017	.075	−.131	.165
Social distancing	−.858	.392	−.079	.092	−.260	.102
Gloves	−2.510	.013	−.376	.150	−.670	−.081
Disinfectant	−2.122	.035	−.252	.119	−.485	−.018
Overall attitude	−2.189	.029	−.172	.079	−.327	−.017

Table 7
One-way ANOVA statistics on the effect of educational background on compliance with COVID-19 measures.

Item	Sum of squares	df	Mean square	F	Sig.
Mask	2.878	2	1.439	3.451	.033
Social distancing	.923	2	.461	.721	.487
Gloves	1.311	2	.655	.379	.685
Disinfectant	2.532	2	1.266	1.179	.309
Overall attitude	.111	2	.056	.117	.890

Table 8
Posthoc analysis on the effect of educational background on compliance with COVID-19 measures.

Dependent variable	(I) education?	(J) education?	Mean difference (I-J)	Std. error	Sig.	95% confidence interval	
						Lower bound	Upper bound
Mask	**High school**	**Undergraduate**	−.222*	.092	.042	−.44	−.01
		Graduate	−.242	.108	.067	−.50	.01
	Undergraduate	**High school**	.222*	.092	.042	.01	.44
		Graduate	−.020	.092	.973	−.24	.20
	Graduate	**High school**	.242	.108	.067	−.01	.50
		Undergraduate	.020	.092	.973	−.20	.24
	Graduate	**High school**	.056	.116	.880	−.22	.33
		Undergraduate	.028	.099	.956	−.20	.26

*The mean difference is significant at the 0.05 level.

Table 9
Paired samples t-test statistics on the safeness perceptions of travelers (public–private modes).

	Paired differences					t	df	Sig. (2-tailed)
	Mean	Std. deviation	Std. error mean	95% confidence interval of the difference				
				Lower	Upper			
Public–private	−2.057	.942	.0541	−2.164	−1.951	−38.006	302	.000

Table 10
Independent samples t-test statistics on the means of frequency of using different transportation modes by safeness perceptions of travelers (public modes).

	Levene's test		t-test for equality of means					95% confidence interval of the difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	Lower	Upper
Frequency of using buses	1.134	.288	−5.312	301	.000	−.967	.182	−1.326	−.609
Frequency of using BRT	.845	.359	−3.324	301	.001	−.539	.162	−.858	−.220
Frequency of using metro	.002	.964	−5.410	301	.000	−.981	.181	−1.338	−.624
Frequency of using ferry	.139	.709	−2.561	301	.011	−.364	.142	−.644	−.084

Table 11
Independent samples t-test statistics on the means of frequency of using different transportation modes by safeness perceptions of travelers (private modes).

|	Levene's test		t-test for equality of means					95% confidence interval of the difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	Lower	Upper
Frequency of using taxi	.651	.420	−.159	301	.874	−.024	.150	−.320	.272
Frequency of using private car	1.876	.172	−.493	301	.623	−.101	.204	−.503	.302
Frequency of using bike	.328	.567	−.597	301	.551	−.104	.174	−.447	.239
Frequency of walking	1.454	.229	−2.040	301	.042	−.346	.169	−.679	−.012
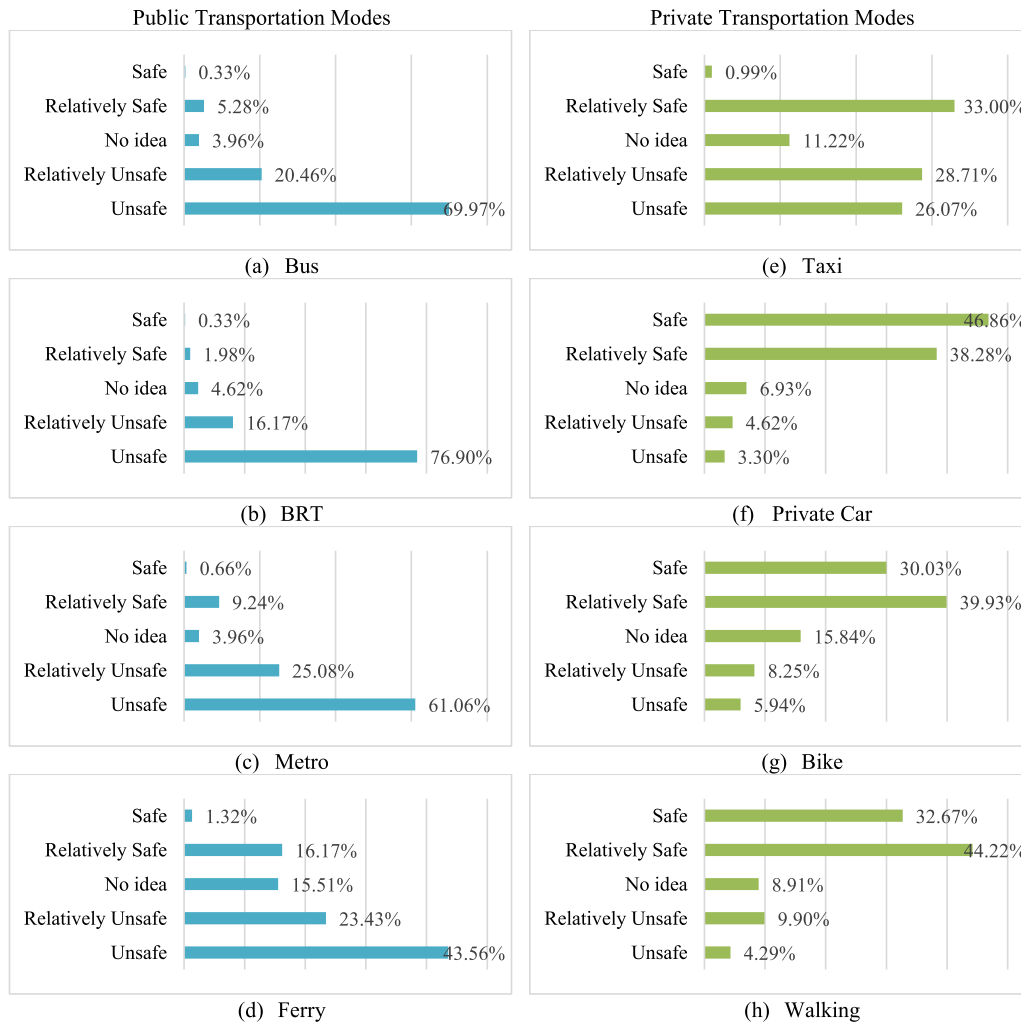
Fig. 9. Safeness perception on public vs. private transportation modes during COVID-19.

5.4. Policy implications

Public transport is one of the most important operations, which mostly is conducted by the governments and municipalities, in taking the pandemics under control, especially in crowded metropolitans such as Istanbul. Istanbul has a wide range of public transportation modes such as railways-metros, BRT lines, buses, minibuses, and ferries. Furthermore, as a business city, Istanbul's residents mainly prefer public transportation for several reasons, i.e., traffic congestion and cost. In this study, the perception of passengers, who use public transportation in Istanbul, and the shift in their traveling behaviors are measured.

Based on the analysis, several discussion points were raised. First, a significant shift among transportation modes is detected. In other words, passengers prefer more biking and private cars compared to their pre-pandemic behavior. As an expected result, which is supportive and helpful to the governments in taking the pandemic under control, people aim to secure themselves from the areas where the contamination risk is high. However, managers should be aware of the fact that the pandemic may continue during the winter season. Accordingly, some transportation alternatives, biking and walking, may not be feasible due to weather conditions. Therefore, fewer options will be available, which will make the combat against pandemic more challenging.

Second, a high difference in the usage frequency of public transportation, which is supportive and indirectly related to the first observation, is measured. It is evident that passengers prefer not to use public transportation if it is not a need or obligation. However, we note that the survey is conducted during semi-curfew in Turkey. Therefore, to determine the effect of the curfew, we measure passengers' perception on the safeness of different transportation modes. The majority of the respondents find public transport risky.

On the other hand, the passengers find private car usage much safer than public transportation. Thus, it can be concluded that the passengers' perception of safeness is an important issue for traveling frequency with a certain public transportation mode. Furthermore, it can be highlighted that the decrement in public transportation mode is not only due to the slowdown in economic and production activities or curfew. In addition, a legitimate perception has formed among people that public transport is less safe due to the pandemic conditions. The permanent transformation of this perception into a behavior stands in front of decision makers as an essential problem. That is, people may permanently change their preferred transportation modes, which may lead hampering economic sustainability of public transportation services. Another significant side effect would be a higher traffic load on the city's road network as more personal vehicles will be on the roads. The recent increase in traffic density in Istanbul may be associated with
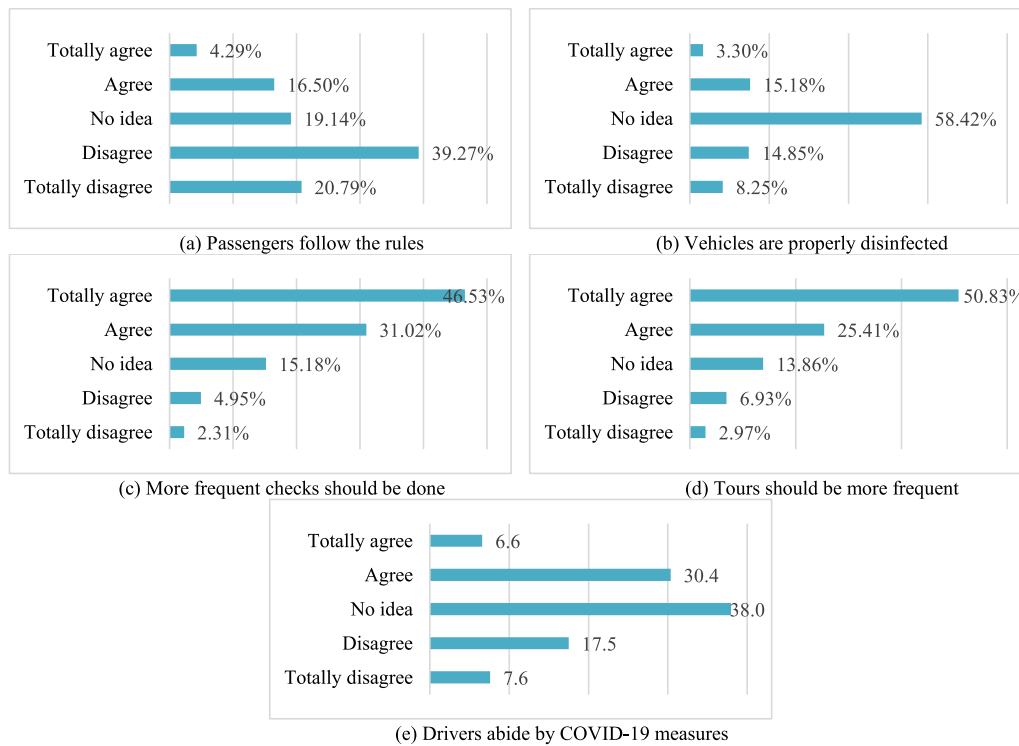
(a) Passengers follow the rules

(b) Vehicles are properly disinfected

(c) More frequent checks should be done

(d) Tours should be more frequent

(e) Drivers abide by COVID-19 measures

Fig. 10. Levels of agreement on suggestions to improve the operational practices.

this fact. So, the responsible authorities should accelerate investments in road infrastructure to ease the traffic jam in the city's main arteries. New investments may also support employment ratios and economic activity that has become more fragile since the beginning of COVID-19.

Furthermore, as metro is perceived less riskier than any other transportation modes (43,56% finds it unsafe) in Istanbul, the city's authorities may push the planned investments in the rail systems forward. This can provide an alternative to personal vehicles, leading to less CO_2 emissions. Lastly, the management of IETT should take the challenge seriously and make sure that the shift in transportation modes is not permanent. To do this, they have to consider the psychological dimension of the problem and convince the public transportation users that the vehicles and the entire system are well disinfected and safe.

Even though no difference was observed in using a mask and paying attention to social distance, a significant difference in using gloves and disinfectants is determined between female and male passengers. In this sense, female passengers are more careful in taking precautions.

Fifth, no significant difference is measured between the passengers who have a different level of education in using disinfectant and gloves and paying attention to social distancing, while the opposite is observed in using the masks—the use of masks increases as the education level increases. Therefore, the significance of using masks in combating the disease should be explained better to people. Free masks can be offered in the buses to the passengers in case they do not wear a mask until people get used to using it, and the mask becomes an integral item of any trip.

Lastly, in order to include the voice of the passengers in the measures to be taken by the authorities, we questioned their perceptions on the practices taken by the decision makers. Passengers usually think that other travelers do not follow the rules and they are not well informed about the disinfection practices done by the operators. They demand more frequent tours and controls. Therefore, the operators

should effectively explain the measures taken against COVID-19 and enlighten the public. Specific communication channels should be defined and effectively used by public authorities.

Overall, while COVID-19 increased the private car usage rate, directly it caused a decrease in public transportation use during the early stages of the pandemic. Based on the analysis, the behavior of passengers significantly shifts towards using private cars and biking/walking, which brings an important issue and an advantage to the decision-makers; the increment in personal car usage might cause traffic congestion if appropriate precautions are not taken by the authorities. On the other hand, preferring biking and walking are essential to public health and well-being. Accordingly, municipal authorities may invest more on personalized public transportation means, such as scooters, bikes, etc., which are empowered with new internet of things (IoT) technologies [31]. Furthermore, the new hygiene perception of passengers on public transportation necessitates defining new hygiene standards by the policy makers. This should be even born in mind during the design stage of public transportation vehicles. Namely, COVID-19 will have some implications on the product design [32]

6. Conclusion

The pandemic started in Wuhan/China in December 2019, which mainly causes acute respiratory syndrome and spreads worldwide in a brief time period. Even though the countries took several precautions, these protection measures must be relaxed due to the economic and social shocks following the pandemic. The spread severity is mainly related to the disease's transmission rate, virulence, immune status of people, person-to-person contact, transportation modes, healthcare services, and climate [33]. Therefore, as one of the main issues that cause the spread of the pandemic, public transportation is the main topic of this study. Consequently, we analyzed passengers' perceptions

and behavior via a survey. The Metropolitan city of Istanbul represents a good sample for analyzing the modal share shifts because it has a wide range of public transportation modes such as railway metros, BRT lines, buses, minibuses, and ferries. In addition, the usage percentage of public transportation in Istanbul is high because of some important reasons such as traffic congestion and increasing cost of fuel during the pandemic.

In particular, the perception of passengers in Istanbul and the shift in their traveling behaviors are measured. The survey is developed to assess and compare the behaviors of passengers' pre and post-pandemic of COVID-19. Once the demographic information is asked, answers are gathered by directing 11 questions. Outcomes showed that a noteworthy shift among transportation modes is detected. Particularly, passengers prefer more biking, walking, and private cars compared to their pre-pandemic choice, and they find them safer than using public transportation. In a parallel manner, the usage frequency of public transportation is decreased compared to pre-pandemic rates. Furthermore, it is determined that while the education level does not have a significant impact on taking personal precautions, female individuals are more careful than male passengers. Moreover, passengers think that the informing system of the operators is not enough and people do not follow the rules correctly.

Even though this study has some limitations, such as the number of surveys and the period it covers, it is the first research conducted on measuring the changes in behaviors of passengers because of COVID-19 and their perceptions of the precautions taken by the authorities and people who use public transportation in Istanbul. Thus, it may provide valuable insights into the changes in traveling habits of city residents, which help the policymakers of public transport.

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.

Appendix. Survey

Demographics

1 Please specify your **gender**.
- ○ Female
- ○ Male

2 Please specify your **age** range.
- ○ 18 or younger
- ○ 18 to 35
- ○ 35 to 50
- ○ 50 to 65
- ○ 65 or older

3 Please specify your **education level**?
- ○ No qualifications
- ○ Primary school
- ○ High school
- ○ Two-year collage
- ○ Undergraduate
- ○ Postgraduate (Masters or above)

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4 Please specify your **occupation** status?
- ○ Student
- ○ Employee in public sector
- ○ Employee in private sector
- ○ Retired
- ○ Other

Travel Behavior

5 Which modes of transportation were you using **before COVID-19**?
- ○ Private car as driver or passenger (carpooling)
- ○ Walking
- ○ Biking (bike, e-bike)
- ○ Public transportation (bus, BRT, metro, ferry, tram, minibus)
- ○ Taxi
- ○ Other

6 What was your main purpose of traveling by public transportation **before COVID-19**?
- ○ Commuting
- ○ Entertainment
- ○ Shopping and daily needs
- ○ Visiting friends/relatives
- ○ Other

7 Please specify your travel frequency by public transportation **before COVID-19**.
- ○ Seven days a week
- ○ Every weekday
- ○ Couple of times a week
- ○ Couple of times a month
- ○ None

8 If you were using public transportation, which mode(s) of transportation were you using **before COVID-19**?
- ○ Bus
- ○ BRT
- ○ Metro
- ○ Ferry/boat
- ○ Funicular
- ○ Minibus

9 Which modes of transportation do you prefer in public transportation **during COVID-19**? Car as driver or passenger (carpooling)
- ○ Walking
- ○ Biking (bike, e-bike)
- ○ Public transport (bus, BRT, metro, ferry, tram, minibus)
- ○ Taxi
- ○ Other

10 What is your main purpose of traveling by public transportation **during COVID-19**?
- ○ Commuting
- ○ Entertainment
- ○ Shopping and daily needs
- ○ Visiting friends/relatives
- ○ Other

11 Please specify your travel frequency by public transportation **during COVID-19**.
- ○ Seven days a week
- ○ Every weekday
- ○ Couple of times a week
- ○ Couple of times a month
- ○ None

12 Please indicate your preference level for the following modes of transportations **during COVID-19**?

Modes	Never	Rarely	Sometimes	Often	Always
Bus	○	○	○	○	○
BRT	○	○	○	○	○
Metro	○	○	○	○	○
Ferry/boat	○	○	○	○	○
Minibus	○	○	○	○	○
Taxi	○	○	○	○	○
Private Car	○	○	○	○	○
Biking (bike, e-bike)	○	○	○	○	○
Walking	○	○	○	○	○

Passenger Perceptions

13 Could you please rate the following transportation modes in terms of health safety against COVID-19?

Modes	Dangerous	Relatively dangerous	No idea	Relatively safe	Very safe
Bus	○	○	○	○	○
BRT	○	○	○	○	○
Metro	○	○	○	○	○
Ferry/boat	○	○	○	○	○
Minibus	○	○	○	○	○
Taxi	○	○	○	○	○
Private Car	○	○	○	○	○
Biking (bike, e-bike)	○	○	○	○	○
Walking	○	○	○	○	○

14 How often do you follow the health measures on public transport against COVID-19?

Measure	Never	Rarely	Sometimes	Often	Always
Mask	○	○	○	○	○
Social Distancing	○	○	○	○	○
	○	○	○	○	○
	○	○	○	○	○
Gloves					
Hand sanitizer					

15 Please indicate your level of agreement with the following statements regarding to the public transportation in Istanbul?

Measures	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Passengers do not follow the rules	○	○	○	○	○
Vehicles are properly disinfected	○	○	○	○	○
More frequent controls should be done	○	○	○	○	○
More frequent trips are needed	○	○	○	○	○
Drivers comply with the COVID-19 measures	○	○	○	○	○

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