



Exploring the traveler group-based ridership fluctuations before, during and after the COVID-19 pandemic: A case study of rail transit system in Izmir, Türkiye

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Highlights

- Travel behaviour of adults, students and elderly people were examined
- Travel behaviour of elderly groups has been changed after COVID-19
- Students travel habits seemed to be very similar before pandemic

Abstract

The COVID-19 pandemic has interrupted life around the world. Situations such as the transition of schools to remote education, remote working, and people's fear of becoming infected have had a strong impact on public transport ridership. In this article, rail transit systems ridership data were utilized to examine the impact of the COVID-19 pandemic on the travel behaviour of adults, students and elderly people for the city of Izmir, Türkiye. The rail transit system included one mass rapid transit (MRT) and two light rapid transit (LRT) lines. Due to operational differences of rail transit systems, the analyses were carried out for the ridership of each mode separately. Within the scope of the study, user-based descriptive statistics were determined, and ridership changes were investigated before, during and after the pandemic. The statistical significance in ridership fluctuations were evaluated via one-way analysis of variance (ANOVA) test. The results showed that the pandemic had a negative impact on ridership on all lines and all groups of travelers. Student ridership increased with the opening of schools after pandemic, while travel behaviour of elderly groups after COVID-19 was almost same compared to pandemic duration.

Keywords: COVID-19, ridership, public transportation, rail transit, ANOVA

Information

Received:

09.03.2023

Received in revised:

16.05.2023

Accepted:

30.05.2023

1. Introduction

The COVID-19 pandemic has dramatically affected the use of public transport and all aspects of social life. During the pandemic, there was a substantial decrease in public transportation use worldwide [1,2]. Both the transition to remote working and the closure of schools have led to a significant reduction in daily commute travel. In addition to travels to and from work or school and public transportation made for other purposes, the concern of people being unable to maintain social distance in public transportation and being infected has emerged [3,4]. During the pandemic, people may have preferred private vehicles over public transportation due to these concerns [5]. Cho and Park [6] measured the passenger crowding impedance on public transit in Seoul, consisting of subways and bus lines. They compared the impedances before and after the COVID-19 pandemic and found the crowding impedance nearly 1.04-1.23 times higher before the pandemic. This research used survey data, and the results showed that the fear of being infected on public

transportation increased; furthermore, the travel behaviors differed between the travelers who had experienced crowding and those who did not. Aparicio et al. [7] examined three major public transportation modes in Lisbon (subway, bus, and trams) during the pandemic. Tiikkaja and Viri [8] explored the COVID-19 effects on public transportation in Tampere, Finland. They focused on public transportation ridership, frequency, and fill rates. The results revealed that ridership and frequencies decreased against this; but the fill rates increased during the pandemic. Rasca et al. [9] researched how public transportation ridership was impacted during COVID-19 in European cities. The impact of the first wave of the pandemic on ridership was more substantial than that of the second wave. A similar study has been carried out by Tuydes-Yaman et al. [10] for the city of Konya, Turkey. They found that ridership during the restrictions was one-eighth lower compared to before the pandemic. In all these studies, the impact of the COVID-19 pandemic was searched for the total ridership changes instead of the different traveller groups. Pozo et al. [11] utilized the

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ticket data of different public transport systems of Madrid, Spain during February, and September of 2020. The results indicated a substantial reduction in ridership, especially for tourist tickets reaching up to 95% decrease. Additionally, the authors reported the similar reduction rates of all public modes. Teixeira and Lopes [12] investigated how ridership in the subway and bike sharing system (BSS) in New York was affected by the Covid-19 pandemic. They stated that a greater decrease in ridership was observed in the subway compared to BSS. These results interpreted as the shifting from metro to micromobility modes in New York. According to Park [13] the number of metro users in Seoul infamously decreased in late February, in 2020. Using data from 994 online surveys, Downey et al. [14] sought to determine travelers' preferences and travel behaviours at various points of the COVID-19 epidemic. Users reported that they thought they would use buses and trains less after the epidemic ended. Additionally, 25% of users also believe they will use their cars more frequently going forward because of the epidemic. Jenelius and Cebecauer [15] examined the relative change in 2020 ridership compared to 2019 by using Sweden's 2019–2020 travel data. The most significant ridership drop was observed in Stockholm in spring 2020, at 60%. Eisenmann et al. [16] emphasized that private cars become more important than public transportation for passengers, especially during the mandatory quarantine period. In addition, they stated that 23% of the adult population in Germany used public transportation before the pandemic, while this rate decreased to 13% during the quarantine period. Molloy et al. [17] concluded that there was a 60% decrease in daily transportation distance and that the usage share of bicycle transportation increased among all modes. Shang et al. [18] examined smartcard data from January 1st, 2019, to January 31st, 2021, in Hong Kong and concluded that the pandemic reduced the number of metro passengers by 37.4% for adults, 80.3% for children, 71.6% for students, and 33.5% for elderly persons. In their study of ten cities in the United States, Ahangari et al. [19] examined 2019 and 2020 ridership. Ridership declined in March when restrictions were implemented, reaching its lowest level in April in all ten cities. According to the regression model, the unemployment rate was the only factor influencing the decline in rail ridership. Konecny et al. [20] found that ridership in the Slovak Republic decreased considerably more during the first wave of the pandemic than during the second wave. The demand reduction was most significant among students and pupils under 15 years, with 89.3%, and among children under six years, with 85.7%. Wilbur et al. [21] proved in their study that commuters showed the largest ridership declines. The ridership declined in the highest-income regions with 77% and lowest-income regions with 58% in Nashville. In comparison to a baseline date of January 13, 2020, Lozzi et al. [22] determined that public transit decreased by

76% in April 2020. Hu and Chen [23] find COVID-19 pandemic exerted significant effects on 95% of transit stations, leading to an average 72.4% drop in ridership. Also, according to this study, regions with more jobs in trade, transportation, and utility sectors presented smaller declines. Sahraei et al. [24] reported that public transportation usage dropped up to 90%, while this range was calculated as 80% considering the Ankara and Istanbul public transportation ridership data [25]. Furthermore, the authors measured the air quality index of these cities during the pandemic, which resulted in a 9% and 47% improvement for Ankara and Istanbul, respectively.

Consequently, the impact of the pandemic on public transportation ridership has been the focus of much research. Most of these studies quantified the reduction of daily ridership in percentage. On the other hand, very few studies have considered the impact of the pandemic on the daily ridership of different passenger types as well as different public transportation systems, which are the main motivation and focus of this research. This paper contributes to the literature by conducting traveller group-based research and providing separate analyses for adult, student, and elderly rail transit users with different travel behaviours. The impact of the pandemic on the daily ridership of these travellers was examined over the three rail transit lines, including one mass rapid transit (MRT) and two light rapid transit (LRT) in Izmir, Turkey. The ridership data were taken for the same months (between September 1 and November 9) before, during, and post-pandemic years of 2019, 2020, and 2021, respectively. The methodology covers traveller group-based descriptive evaluation and variance of analysis tests to investigate the ridership fluctuations for the analysis period significantly, which makes our research novel.

2. Study Area and Data

2.1. Case study area: Izmir

Izmir is one of the most important cities in Turkey in terms of economic and socio-cultural aspects. It is the third-most populous city in Turkey, with a population of 4,425,789 (2021 census data). According to 2021 demographic data in the city, 31% of the population is young, 51% is middle-aged, and 18% is elderly (Endeksa, demographic data of Izmir, 2021). As for rail transit lines in Izmir, the mass rapid transit (MRT) system has a length of 20 kilometers, consists of 17 stations, and is in the core city center (Figure 1). Konak tram (LRT-1) serves 19 stations along the 12.8 kilometers and is located on the part of the city's southern coastline. Karsiyaka tram (LRT-2) provides a service at 14 stations along the northern coastline with a line length of 8.8 kilometers.

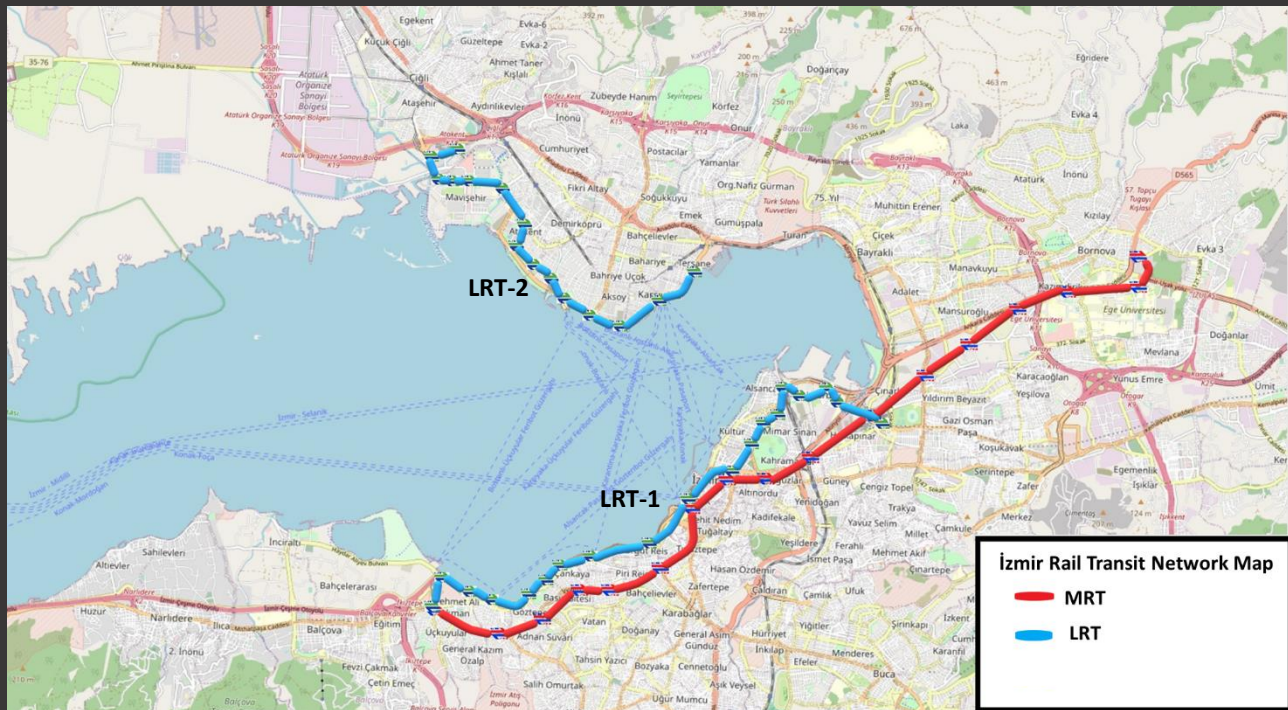


Figure 1. Izmir rail transit network map

Due to operational differences between the rail transit lines, the ridership data of these lines were evaluated separately. There is also the 136-kilometer suburban rail transit line, IZBAN, which connects the north and south counties of the city with 41 stations. In this paper, ridership of MRT and LRTs was considered because of the data availability.

2.2. Smart card data

The "New Normal" after the pandemic started in September 2021 with the reopening of universities and schools. Thus, ridership data for September, October and November were used for the years 2019 (pre-pandemic), 2020 (during the pandemic) and 2021 (new normal after the pandemic) to make more accurate analysis about the traveller ridership. User based daily smart card data obtained from the Izmir Metropolitan Municipality Open Data Portal. The data provides daily ridership for different user groups, such as adults, students, and elderly people. The student users are those who have a student card ID, either a high school or university. Elderly cards are given to people whose ages are over 60. The remaining users are the adults, who constituted most of the travellers. Hence, it could be possible to examine the daily fluctuations of each traveller, which is the focus of this research.

3. Methodology

3.1. Descriptive evaluation

Descriptive statistics of the daily ridership data of adult, student, and elderly traveller groups were determined

before, during, and after the pandemic. The process was carried out for each line separately, and the group-based travel pattern changes were compared according to the years. The impact of COVID-19 on ridership has been determined by comparing the average daily ridership. In addition, how ridership changed with the normalization period was evaluated by comparing ridership during and after the pandemic. Ridership fluctuations before and after the pandemic were also visually presented with graphs based on each group and compared as a percentage change.

3.2. Analysis of Variance (ANOVA)

An ANOVA was performed to determine whether the changes in daily ridership were significantly different for the analysis years. The differences in daily ridership in the pre-pandemic, during the pandemic and post-pandemic years were determined by ANOVA. For this purpose, the fluctuations in ridership for each rail transit line were evaluated separately. Statistical significance exists when the independent variable makes a difference over the mean of the dependent variables at the 95% confidence interval. With one-way ANOVA, it is determined from the p-value whether COVID-19 restrictions and the new normal cause a statistically significant difference in daily ridership. If the p-value is less than 0.05, it is in the 95% confidence interval, and a significant difference is observed. If statistical significance is found as a result of the ANOVA analysis, pairwise comparison tests (Post-Hoc) was performed to determine the statistical difference between the groups under 95% confidence interval. Among the several methods for performing pairwise comparison, Bonferroni method was chosen in this study.

All statistical analyses have been made in the IBM SPSS program.

4. Results and Discussion

4.1. Descriptive Evaluation of Rail Transit Ridership Data

The descriptive evaluation of the daily ridership of adults, students, and elderly travelers is given in Table 1. Significant drops were observed for each traveler group during the pandemic. On MRT, while the average daily ridership was 193914.2 in 2019, this was only 107863.7 in 2020, which corresponds to a 44.4% reduction for adults. This reduction was found to be 61.2% for students compared to pre-pandemic days. This significant reduction is expected due to the switch to remote education in 2020. The reduction in the elderly group was around 55.11% on average. For the post-pandemic year, the average daily ridership of each traveler increased compared to the pandemic condition. A significant increase in ridership was observed for student travelers, rising from 33785.7 to 70927.2 on average, corresponding to a 109.9% increase. Furthermore, average adult ridership increased by almost 43%, rising from 107863.7 to 154612.9. However, a very slight increase was observed for the elderly (15.5%). This showed that the most affected group was the elderly, who were considered to be the riskiest group in the COVID-19 epidemic.

Figure 2 shows daily MRT ridership changes for each traveler category over the years before, during, and after the pandemic. The average daily ridership for adult travelers fell from 54538.4 to 27868.2 during pandemic, a 49% decline. After the pandemic, it rose by 44% over the pandemic level, averaging 40231.7 ridership/day. Looking at the group of student travelers, the pandemic's effects caused the daily average ridership to fall by 85%, from 20873.7 to 10273.1. After the pandemic, the daily ridership increased to 19015.9, almost identical to the pre-pandemic level. This suggests that during the period of normalization, students resumed their pre-pandemic

travel habits as schools switched to face-to-face. The daily average ridership for the elderly was reduced by 60% from 2325.4 to 922.8 during the pandemic. A 17% increase was observed after the pandemic.

The impact of pandemic on ridership was also clearly observed for LRT-1, significant drops were captured (Figure 3). Adults were the major passenger types like MRT, but the daily ridership values were between 30,000 and 60,000 in general. The ridership of the elderly during and after the pandemic is quite similar, as can be seen in Figure 3. Figure 4 displays daily variations in LRT-2 ridership for adults, students, and elderly passengers. It is possible to see periodic jumps for all three user groups, especially prior to pandemic. This was due to the fact that every Wednesday, a very large public market called Bostanlı Pazar was set up near the tram route. Daily ridership after the pandemic is deficient compared to the pre-pandemic level for adults. If these are expressed with descriptive statistics, the average daily adult ridership was down 53% during the pandemic, with 10371.3 ridership compared to 22244.6 ridership before the pandemic. After the pandemic, the average daily adult ridership increased by 51% and reached 15625. It is observed that the daily student ridership fluctuations on LRT-2 are almost the same in 2019 and 2021. The average daily student ridership fell from 6689.3 to 3994.4, a decrease of 40% during the pandemic period compared to the pre-pandemic period. After the pandemic, it increased by 59% compared to during the pandemic and increased to 6345.5. It can be seen that there is not much of a difference between the daily trips made by the student user group on LRT-2 before and after the pandemic. Only a 5% reduction was observed. This allows us to infer that, out of all the modes of transportation we looked at, LRT-2 is the one that the student user group has adapted to the "new normal" the best. Finally, the elderly passengers ridership decreased by 71% (from 1205.9 to 344.3) during the pandemic. Despite a 33% increase in the average daily ridership of elderly after the pandemic, there was a nearly 62% decrease in daily ridership compared to pre- and post-pandemic conditions.

Table 1. Descriptive statistics of rail transit ridership for different passenger types

Years	MRT			LRT-1			LRT-2		
	2019	2020	2021	2019	2020	2021	2019	2020	2021
Adult									
max	245044	132346	190419	81868	33355	57551	32706	14908	23449
min	99782	49616	75024	29581	12319	20712	12501	5650	9922
mean	193914.2	107863.7	154612.9	54538.4	27868.2	40231.7	22244.6	10371.3	15625
Student									
max	117227	43825	114710	33890	13566	31327	12290	5586	9266
min	28593	14438	31288	9224	4412	9784	4067	1884	4178
mean	86975.1	33785.7	70927.2	20873.7	10273.1	19015.9	6689.3	3994.4	6345.5
Elderly									
max	9348	4390	5260	3387	1233	1560	2139	621	912
min	3114	1274	1498	1010	280	391	426	140	185
mean	7504.5	3368.4	3891.1	2325.4	922.8	1076.1	1205.9	344.3	456.7

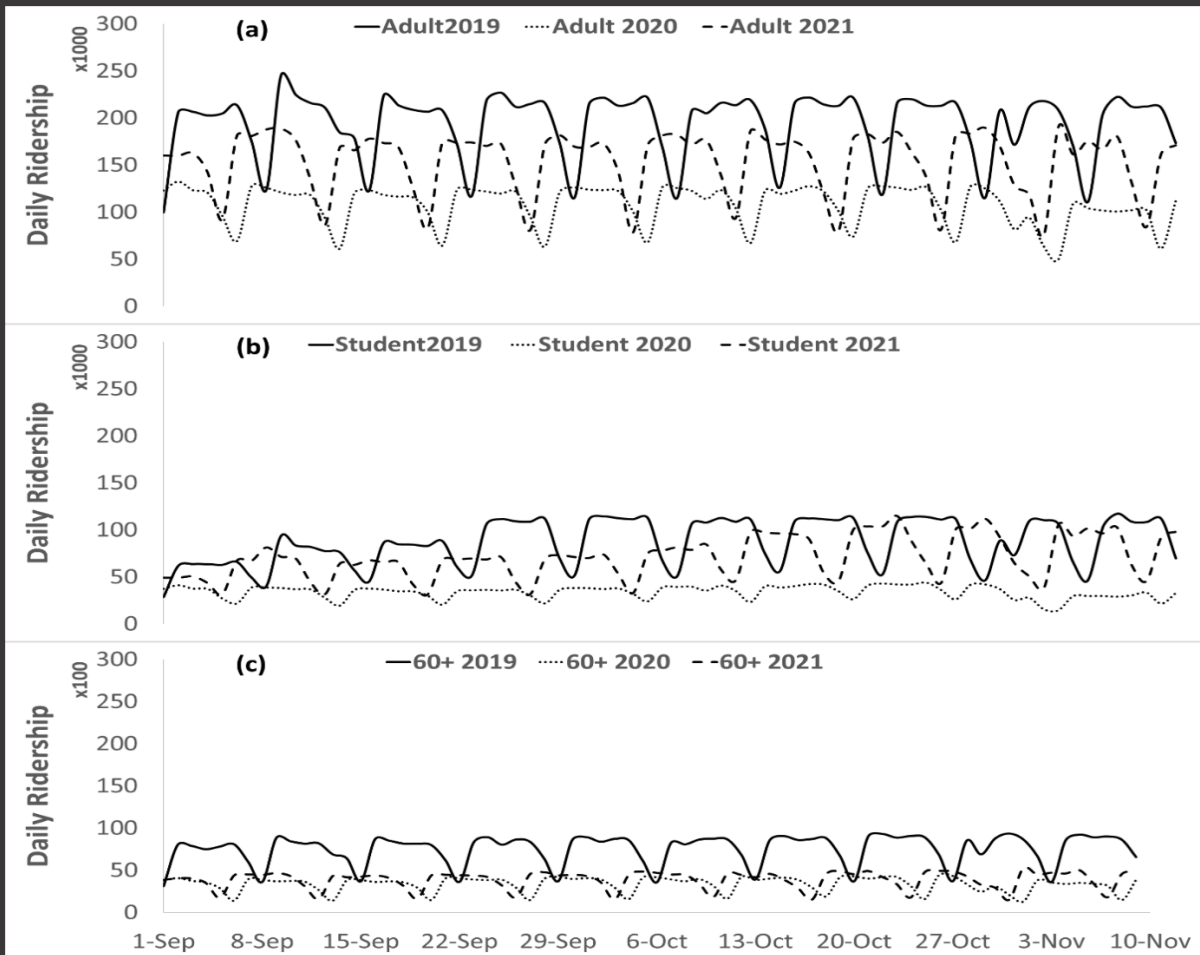


Figure 2. Daily ridership fluctuations for a) adults, b) students, c) elderly passengers for MRT

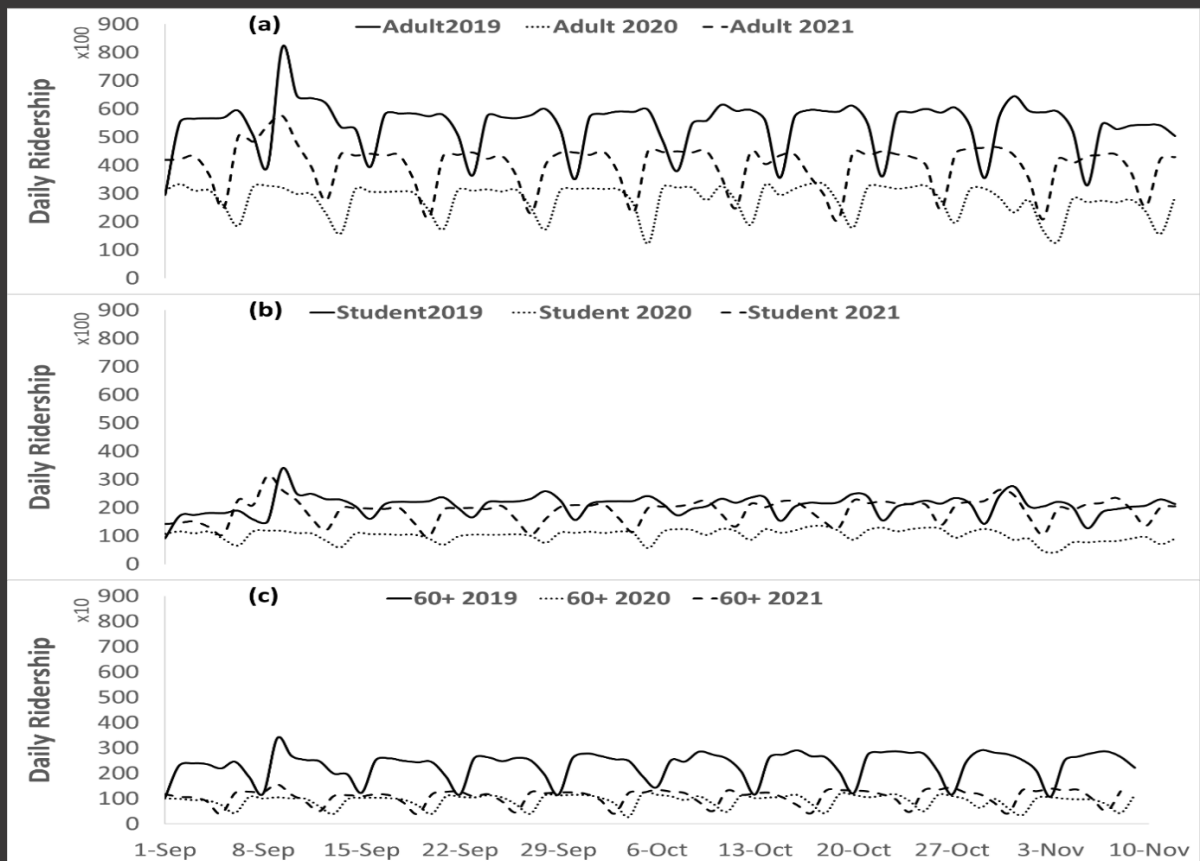


Figure 3. Daily ridership fluctuations for a) adults, b) students, c) elderly passengers for LRT-1

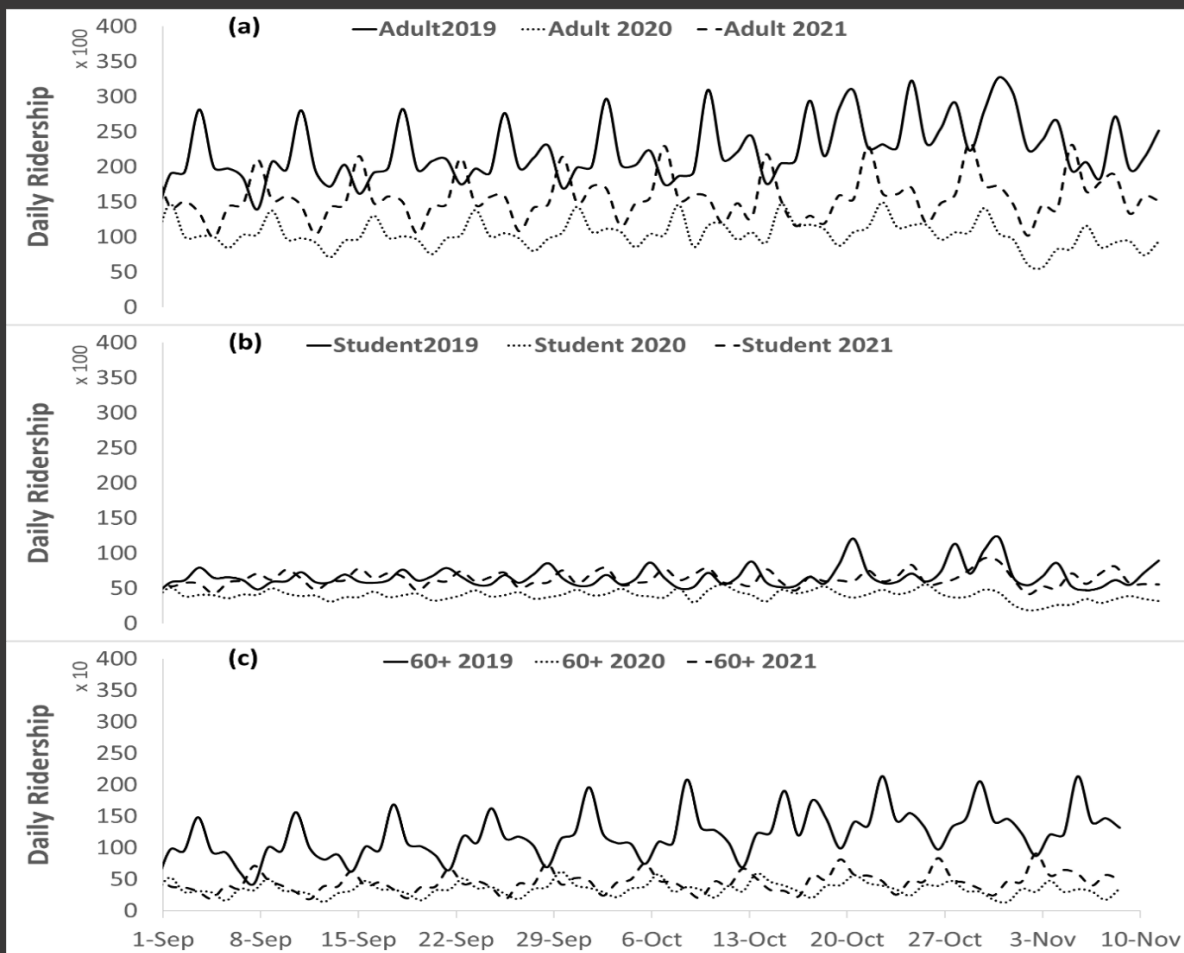


Figure 4. Daily ridership fluctuations for a) adults, b) students, c) elderly passengers for LRT-2

4.2. ANOVA results

ANOVA revealed that there was a statistically significant difference in ridership at least between two years, with F-statistics of 133,815 and a p-value of 0,000 for adults, F-statistics of 132,002 and a p-value of 0,000 for students, and F-statistics of 206,163 and a p-value of 0,000 for the elderly (Table 2). Just by comparing the F-statistics value, it is evident that the change in ridership for the elderly was the largest. Bonferroni's Post-Hoc Test for multiple comparisons was performed to examine the comparisons before-during, during-after, and before-after pandemic. According to multiple comparison results, there was statistically significant difference between before pandemic and during pandemic ridership for all traveler groups (see Table 2). Also, there was statistically significant difference before pandemic and after pandemic ridership. There was a statistically significant change between before and after the pandemic ridership for adults and students, but not for the elderly. For the elderly group, during the pandemic and after the pandemic ridership was very same. Thus, it can be said that elderly groups' travel behavior changed with the pandemic, and it became permanent even in the "new normal". As for LRT-1, there was statistically significant difference in ridership between 3 periods for all traveler groups: adult (F-statistics= 216,880, p-value= 0,000), student (F-statistics= 195,237, p-value= 0,000) and elderly

(F-statistics= 275,185, p-value= 0,000). Bonferroni's Post-Hoc multiple comparison test showed that there was a significant difference between before and during the pandemic ridership as well as before and after pandemic for all traveler groups. Although there was statistically significant difference in ridership between during and after pandemic for adults and students; there was no statistically significant difference in elderly group (p-value= 0,061). This situation was similar with travel behavior of elderly users on MRT. For LRT-2, there was a remarkable point about students, different from other modes. All of the results of ANOVA were same as others for adults and elderly but there was not statistically significant difference between before and after pandemic ridership for student traveler group (p-value= 0,262). This means; students who use LRT-2, have returned to the travel behaviors they used to have before the pandemic, with the post-pandemic normalization. This result was not found in any other user group or travel mode. It is possible to explain that students use LRT-2 after the pandemic as before the pandemic by the fact that the curfews applied for youths during the pandemic are completely lifted, and most importantly, there are compulsory trips to and from the school in the new normal. Other details about one-way ANOVA and Bonferroni's Post-Hoc multiple comparison tests are shown in Table 2.

Table 2. ANOVA results

Mode	MRT			LRT-1			LRT-2		
User Group	Adult	Student	Elderly	Adult	Student	Elderly	Adult	Student	Elderly
F-statistic	133,815	131,002	206,163	216,880	195,237	275,185	219,644	107,330	252,305
(p-value)	(0,000)	(0,000)	(0,000)	(0,000)	(0,000)	(0,000)	(0,000)	(0,000)	(0,000)
Multiple Comparison	Post Hoc Test (p-values)								
2019-2020	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
2020-2021	0,000	0,000	0,058	0,000	0,000	0,061	0,000	0,000	0,023
2019-2021	0,000	0,000	0,000	0,000	0,004	0,000	0,000	0,262	0,000

5. Conclusion

In this study, ridership fluctuations in Izmir rail transit system were investigated before, during and after the COVID-19 pandemic. Conducting traveler group-based analysis for each rail transit system separately makes our research novel. First, information about daily ridership averages, maximum daily ridership and minimum ridership were given with descriptive statistics. In addition, the 70-day ridership averages between September 1 and November 9 for the years 2019, 2020 and 2021 were compared as a percentage between the years for each traveler group. Based on these statistics, the following comments can be made on a user basis:

- Adult daily ridership has nearly halved across all rail systems during the pandemic in 2020. This decrease can be explained by changes in social life, such as people using public transport for compulsory reasons only for fear of being infected, and the opportunity to work remotely. When the pre-pandemic and new normal were compared, a one-day ridership reduction was observed in the range of 20-30%. Within the possibility of owning a car; adult users prefer their private vehicles instead of public transport, may justify the decrease in ridership in the new normal, where the effect of the pandemic is still seen and the fear of infection continues.
- For students, although a decrease of up to 110% was observed for MRT during the pandemic compared to the pre-pandemic period, the difference in daily ridership between the pre-pandemic and the new normal is a prominent result. Most students use public transport, and their travel behavior has reverted to the way schools have switched to face-to-face education.
- In the elderly traveler group, the situation was much different. Considering the ridership fluctuations in this group, it was seen that the travel behavior that changed with the pandemic continues in the new normal. It is obvious that the COVID-19 epidemic has created travel changes in the elderly user group even after the pandemic.
- When the statistical significance of these ridership changes was examined, no significant

difference was found between the elderly ridership on MRT and LRT-1 during and after the pandemic. Another outstanding result is that there was no significant difference between pre-pandemic and post-pandemic student ridership on LRT-2.

Declaration of Interest Statement

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.

Author Contribution Statement

D. Guzel: Formal Analysis, Investigation, Methodology, Resources, Visualization, Writing – Original Draft, Writing – Review&Editing; **O. Altintasi:** Conceptualization, Formal Analysis, Methodology, Resources, Supervision, Visualization, Writing – Review&Editing

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