PUBLIC TRANSPORTATION IN ISTANBUL AFTER PANDEMIC: IMPACTS, RECOVERY & FUTURE RESILIENCE

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ABSTRACT

PUBLIC TRANSPORTATION IN ISTANBUL AFTER PANDEMIC: IMPACTS, RECOVERY & FUTURE RESILIENCE

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Public transportation has been the mode of transport that was hit hardest by COVID-19. The impact of the pandemic on urban transportation has raised concerns that public transportation was losing ground and that this would be a permanent trend. However, there is a lack of research on the long-lasting impact of the pandemic on different modes of public transportation in developing countries with respect to resilience in the post-COVID-19 period. Therefore, the research questions of whether and how this pandemic permanently changed the demand for public transportation emerge as crucial issues for the planning and operation of urban transport systems in the recovery period. In addition, whether the lessons learned from this health crisis led to a new policy approach for resilience in future crises is another important question. Building on these research questions, this thesis provides a comprehensive review of the literature on the impact of COVID-19 on urban transport with a special focus on public transportation; and it carries out an in-depth analysis of public transport modes during and after the pandemic in Istanbul. The first part of the research is focused on descriptive analysis to demonstrate the change in the number of passengers of each mode of public transportation in Istanbul during

and after the pandemic. In the second part of the research, semi-structured interviews with decision-makers are conducted to inquire about resilience in policy responses to future crises. The key findings indicate the fastest recovery in the urban rail system, with a 16 % increase in ridership in 2022 compared to the ridership level in 2019. In contrast, maritime public transit modes prove to be the most vulnerable modes, remaining approximately 17% below the ridership levels of 2019. Additionally, the results of the semi-structured interviews show that the pandemic led to awareness about resilience in transport practice. The research sheds new light on the policy needs for different modes of transport to adapt to future crises, with a particular emphasis on the most resilient and vulnerable modes of public transport during the pandemic.

Keywords: Public Transportation, Resilience, Transport Policy, Pandemic, Istanbul

ÖZ

PANDEMİ SONRASI İSTANBUL'DA TOPLU TAŞIMA SİSTEMİ: ETKİLERİ, İYİLEŞME SÜRECİ VE DİRENÇLİLİK

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Toplu taşıma, COVID-19'dan en olumsuz etkilenen kentsel ulaşım sistemlerinden biri olmuştur. Salgının toplu taşıma kullanımı üzerindeki olumsuz etkisi, bu durumun kalıcı bir eğilim olacağına dair endişeleri artırmıştır. COVID-19 sonrası dönemde, dirençlilik açısından salgının farklı toplu taşıma sistemleri üzerindeki uzun süreli etkisine ilişkin araştırmalara ihtiyaç vardır. Dolayısıyla, bu salgının toplu taşıma talebini kalıcı olarak değiştirip değiştirmediğine ve nasıl değiştirdiğine dair araştırma soruları, toparlanma döneminde kentsel ulaşım sistemlerinin planlanması ve işletilmesi açısından önemlidir.

Ayrıca, pandemiden çıkarılan derslerin, gelecek krizlerde toplu taşıma sisteminde dirençliliği sağlamak için yeni politika arayışlarına sebep olup olmadığı da bir diğer önemli sorudur. Bu tez, bu araştırma sorularından yola çıkarak, COVID-19'un kentsel ulaşım üzerindeki etkisine ilişkin literatürü toplu taşıma özelinde kapsamlı bir şekilde incelemekte ve İstanbul'da, COVID-19 sırasında ve sonrasında toplu taşıma modlarının derinlemesine bir analizini yapmaktadır.

Araştırmanın ilk bölümünde, pandemi sırasında ve sonrasında İstanbul'daki her bir toplu taşıma sistemi için yolcu sayısındaki değişimi göstermek amacıyla betimsel

analiz yöntemi kullanılmıştır. İkinci bölümde ise karar vericilerle yarı yapılandırılmış mülakatlar gerçekleştirilerek olası krizlere yönelik politika müdahalelerinde, dirençlilik ilkesi sorgulanmıştır. En hızlı toparlanma süreci 2019'daki yolculuk seviyesine kıyasla 2022'de %16'lık bir artışla kentsel raylı sistemlerde gözlenmiştir. Bununla birlikte, 2022'de kentsel deniz ulaşımı yolculuk sayıları, 2019'un yaklaşık %17 altında kalarak pandemiden etkilenen en kırılgan toplu taşıma sistemi olmuştur.

Ayrıca, yarı yapılandırılmış görüşmelerin sonuçları, pandeminin ulaşım politikalarında, dirençlilik konusunda farkındalık yarattığını göstermektedir. Araştırma, en dirençli ve hassas toplu taşıma sistemlerini vurgulayarak, farklı toplu taşıma ulaşım sistemleri için dirençlilik ilkesini benimseyen politika yaklaşımlarına olan ihtiyacı gözler önüne sermiştir.

Anahtar Kelimeler: Toplu Taşıma Sistemi, Dirençlilik, Ulaşım Politikası, Pandemi, İstanbul

To My Family

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CHAPTER 1

INTRODUCTION

1.1 Problem Statement

Public transportation was the mode of urban transport that was hit hardest by COVID-19, which was officially declared a Public Health Emergency of International Concern in 2020. The increase in the COVID-19 cases resulted in a dramatic decline in demand for public transportation during the pandemic. The impact of the pandemic on urban transportation raised concerns that public transportation was losing ground and that this would be a permanent trend (Bort et al., 2022). Moreover, it was seen that public transport systems in developing countries were more vulnerable to the adverse effects of COVID-19 (Semeni et al., 2020). In these countries with insufficient cycling and walking infrastructure, public transportation is the only option especially for those who do not have an access to private modes. Even if the number of cases decrease, the need for a more resilient public transportation system remains a huge challenge for cities. Earley and Newman (2021) clearly adressed these concerns that were raised by COVID-19:

> The impact of COVID-19 on urban transport cannot be underestimated. The question that remains is, what will it take for transport to recover, and when it recovers, how can it be improved to be more resilient and to serve people, their communities, and their economies in a more sustainable and equitable way? (Earley & Newman, 2021, p.111)

The adverse impact of the pandemic on public transportation modes has not been identical. The recovery period of the modes has varied between different modes (see for example, Astroza et al., 2020; Jenelius and Cebecauer, 2020; Tirachini and Cats,

2020; Qi et al., 2023). Therefore, each mode of public transport needs to be analysed separately, and policy requirements need to be defined.

1.2 Aim of The Research and Main Research Questions

The aim of the thesis is to analyze the impact of COVID-19 on the use of public transport systems. In particular, the analysis tries to find out whether there is a long-lasting and permanent impact on the demand for public transport. In doing so, the research also aims to investigate the differences of resilience between different modes of public transportation. In this study, resilience is defined as the ability of public transport modes to recover from the effects of the pandemic on their ridership, and the ability of reaching ridership levels similar to, or above, the pre-pandemic period.

Additionally, the research investigates policy responses to identify effective transportation policies for future resilience. Therefore, in the research, first it is questioned whether and how the demand for public transportation changed. Secondly, it is questioned whether the lessons learned from the crisis led to a new policy approach for resilience for future crisis. In this frame, research questions are formulated as follows:

- Is there a long-lasting impact of COVID-19 on demand for public transportation?
    - Which modes of public transportation recovered fast during the Pandemic and in the post-Pandemic era?
    - What are the most resilient and most vulnerable modes of public transportation?

- Which policy responses and measures have been effective in making Public Transportation more resilient?

- To what extent do the measures determine the mitigation of COVID-19 impacts on public transportation?
- Are there any plans or policies to become resilient for future crises?

1.3 Significance of The Research

Halvorsen et al. (2021) firmly pointed out the necessity of research on the change in the ridership level in the post-pandemic era. They stated that investigating the evolving ridership patterns would be useful for integrating public transportation.

Over the course of the pandemic, the impact of the virus on public transportation in a short time has been investigated by many scholars. However, research on pandemics and public transportation is limited to short-term investigation, which does not rely on discussing post-pandemic effects in the literature (Shakibaei et al., 2021). In other words, there is a lack of research on the long-lasting impact of the pandemic on different modes of public transportation with respect to the resilience in post-COVID-19 era (Shakibaei, et al., 2021; Zhou, et al., 2022). Returning to "business as usual" after the pandemic is not a solution to be prepared for future crises. On the contrary, the pandemic might be a catalyst to reconsider the public transport practice. The long-term change in ridership and the transport policies should be evaluated together to see a significant improvement in resilience of public transport in the future. Otherwise, the lack of adequate policies, along with the tendency to use private modes, can result in an unpromising and unsustainable future (Teixeira et al., 2021). As the public transportation demand is evolving due to the pandemic, it is vital to examine the measures to have better insight to adapt to future crises (Ciuffini et al., 2021).

This research aims at closing the gap by bringing together change in ridership of public transportation modes, and policies to response to crises. To the knowledge of the author, this is the first research which includes an analysis on the change in the ridership of maritime public transportation during and after the pandemic in the

literature. Evaluation of the current public transportation modes with a recovery time could help reshape the transport practice only if considered with policy responses.

1.4 The Structure of The Thesis

This thesis is composed of six main parts. In the first chapter, the framework of the research is explained with an emphasis on the problem statement, research questions and the significance of the study.

The second chapter is built upon the theoretical framework of the research. The health crisis' impact on public transportation is mainly discussed, concerning COVID-19 spread. The factors that influence changing mobility patterns are explained in detail. Subsequently, changing mobility patterns are discussed by comparing different modes of transportation. Following the purpose of the study, a decrease in public transportation usage is explained with the different cases in different cities after pandemic. After discussing prevention and control measures for public transportation during the pandemic, the need for adaptation to crises is highlighted. The newly emerging approaches are explained to have resilient transportation systems in the future.

In the third chapter, the methodology of the research is introduced in a more detailed way with research questions. The methodology which is appropriate for each research question is clarified. The reasons for the selection of the case, that is Istanbul, Turkey, are explained.

The current situation of the public transportation system in Istanbul and measures against COVID-19 are expressed to comprehend the case in the fourth chapter. Each mode of public transportation is examined under three different categories that are urban rail, road-based and maritime public transportation. Afterwards, prevention and control measures imposed on public transportation during the pandemic are demonstrated with the timeline. Additionally, the number of private motorized

modes is analyzed to see the tendency to abstain from public transport and prefer private modes.

Analysis of the usage of different public transportation modes in Istanbul between 2017 and 2022 is conducted in the sixth chapter. The recovery period across different modes of public transport and across different urban rail routes is discussed and compared to find out the resilience and vulnerability of public transportation modes in Istanbul. The reasons for the change in the demand and suggestions for future adaptation from the point of policymakers' view are presented to provide better insights into transport practice. The chapter ends with a brief explanation of the main findings of the analysis.

The last chapter of the thesis includes the summary of the research. Subsequently, a discussion on the main findings is presented together with policy recommendations with a view to provide a policy framework for future resilience. The chapter ends with recommendations for future research.

CHAPTER 2

HEALTH CRISES AND URBAN TRANSPORTATION

2.1 COVID-19 Impacts on Mobility Patterns

COVID-19 has upended the existing mobility patterns worldwide. To prevent and reduce the pandemic, several restrictions, warnings and measures were taken by governments, resulting in severe travel disruption. Besides restrictions, working from home or teleworking, online shopping, and distance education had a great impact on transportation habits during COVID-19.

The evidence of the drastic change in mobility patterns was examined on the global scale. Dingil and Esztergár-Kiss (2021) observed the relationship between COVID-19 and mobility patterns. According to their international survey, 73.6% of public transport commuter passengers and 40.6% public transport leisure tripmakers shifted to other transportation modes; and consequently, a significant decrease was observed in public transport (Dingil & Esztergár-Kiss, 2021, p.437). It can be deduced from the research that the predominance of the private modes over the other modes might be more visible in the near future if these mobility trends continue in the same way (Dingil & Esztergár-Kiss, 2021, p.444). The overall change in mobility patterns, according to the study, can be seen in the Figure 2.1 and Figure 2.2. One of the most noticeable changes was a significant decrease in the use of public transport, such as buses and trains, as people sought to reduce the risk of COVID-19. The decrease in public transport usage was also accompanied by an increase in the use of private cars, as people were looking for ways to maintain social distancing while commuting.

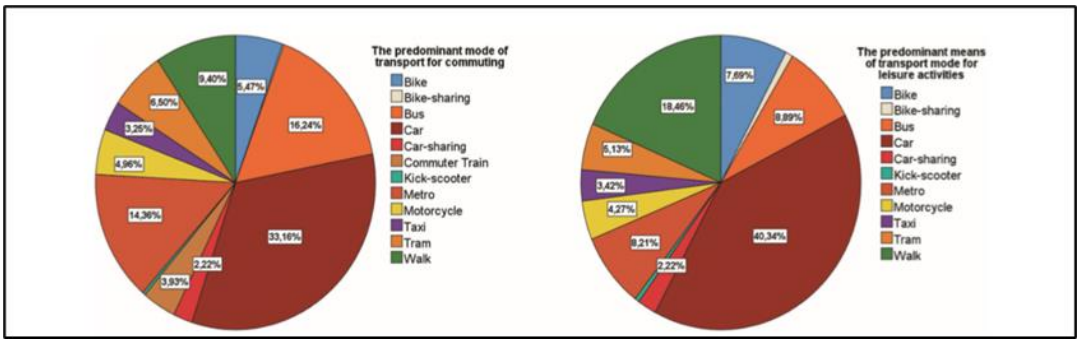


Figure 2.1: The Predominant Mode of Transportation Before COVID-19 (Dingil & Esztergár-Kiss, 2021)

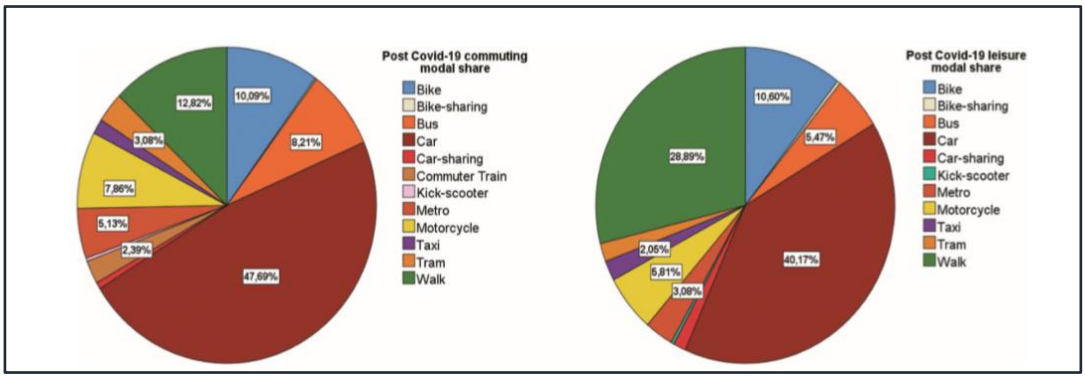


Figure 2.2: The Predominant Mode of Transportation After COVID-19 (Dingil & Esztergár-Kiss, 2021)

Most studies carried out during COVID-19 pointed out similar trends of mobility patterns. A research conducted in ten countries, similar to the previous study, showed that the pandemic led to a significant increase in the usage of private modes of transportation (Monterde-i-Bor, et al., 2022, p. 8). The key point of the research was the prediction that even after the pandemic, the ridership level of public transportation would not return to the pre-pandemic level (Monterde-i-Bor, et al., 2022, p. 5). The dramatic decrease in public transportation usage during COVID-19 had a huge impact on the pre-COVID-19 mobility trends. Therefore, it is crucial to

discuss the changing mobility patterns in order to adapt to future health crisis and post-COVID-19.

2.1.1 Decrease in the Use of Public Transportation

The rapid spread of COVID-19 resulted in passenger loss in public transportation. The view of the high transmission risk in public transportation modes gained ground during this period, and the usage frequency of public transportation declined accordingly (Tirachini & Cats, 2020). The reasons for decrease in the usage of public transportation during the pandemic can be summarized as follows:

- The crowd: exposure in a closed and crowded space is the main contributor to the rapid spread of the pandemic.
- The lack of air filtration: being stranded in a confined space in the vehicle, leads to easy virus transmission.
- Hygiene problems: the surfaces that many passengers come into contact with pave the way for the rapid spread of the pandemic.

As the COVID-19 virus was considered to endure several days on surfaces, public transportation became one of the most vulnerable urban transport modes during the pandemic (Patlins, 2021, p.1399). A study in Brazil compared the number of confirmed cases in buses and the entire city to understand the relationship between COVID-19 and public transportation usage (Ponte et al., 2021). The result of the study revealed that the number of confirmed cases on buses was parallel to the number of cases in the city (Ponte et al., 2021).

Therefore, it is evident that there is a strong relationship between exposure of staying in a closed environment such as public transportation vehicles and the COVID-19 cases. In other words, the risk of high exposure to the virus in closed environments led to a decrease in the usage of public transportation during COVID-19. This strong relationship between the number of COVID-19 cases and the usage of public

transportation was also evidenced by the research in Italy at national scale (Carteni et al., 2021). The research demonstrated the relationship between the pandemic of COVID-19 and the volume of public transportation passengers, with a 0.87 correlation rate (Carteni et al., 2021).

In addition, Medlock et al. (2021) produced the heat map of COVID-19 cases with public transportation routes covering the U.S metropolitan areas. Higher density of COVID-19 cases concentrated along the public transportation stations and routes (Medlock et al., 2021). According to this map, the main concern was that the decrease in the demand for public transportation because of the "COVID-19 shock" may be permanent.

The decline in the usage of different modes of public transportation such as subway and bus were observed in the literature. For instance, in New York City, heavily affected by COVID-19, the change in the number of bus and subway passengers was examined; and a dramatic decline of up to 95% of both subway and bus usage was observed (Halvorsen et al., 2021, p.13). Moreover, the ridership levels of subway (underground), bus and tramway were measured by a study in Lisbon (Aparicio et al., 2021). The demand around the station before and during the pandemic was mapped in the research. Although the demand level around the station narrowed down, the demand level at the periphery of the city was higher (Aparicio et al., 2021, p.9). It was noted that the demand around the metro station was more than that of the tram and bus stations in Lisbon (Aparicio et al., 2021 p.9). It is deduced from the research that as the number of stops on a public transportation route increased, the impact of COVID-19 on demand decreased (Aparicio et al., 2021, p.9).

Appertaining to the decline of public transportation, according to another research, 64% of former public transportation passengers avoiding public transportation during COVID-19 in Vancouver and Toronto were reported to continue avoiding public transportation for another 18 months after the pandemic (Palm et al., 2021, p.462). Decreasing use of public transportation may therefore become a habit and have irreversible results.

Disruption in the public transportation ridership is reflected in the statistics worldwide. Since a huge number of individuals avoided using public transportation because of COVID-19, a similar issue was experienced all around the world. After the impact of COVID-19 on public transportation, the public road management company in Budapest collected data on the number of public transportation users (Bucsky, 2020). According to the data, COVID-19 led to a reduction in public transportation use by 90% in Budapest (Bucsky, 2020, p.3). To put this percentage into numbers, the number of users decreased from 4.3 million to 430 thousand (Bucsky, 2020, p.3). Of much relevance to the Budapest case, it was found in Taipei/Taiwan that one additional COVID-19 case resulted in a decrease of metro usage by 1.43% (Chang et al., 2021). Similar researches were conducted immediately after the pandemic of COVID-19 all around the world. The percentage of the decrease in the public transportation usage can be seen below (Bernhard, 2021):

- In Berlin, Hamburg and Munich as metropolitan cities in Germany, the decrease rate of public transportation ridership level varied between 40% to 60%.
- In Vienna a dramatic decrease of 80% in the number of public transportation users was observed.
- Even on working days, in Madrid, 75% of former metro passengers avoided using the metro.
- In Paris, decrease rate of metro usage was reported to be between 40% and 60%.

The impact of frequency reduction, curfews and restrictions on public transportation should also be taken into account. These measurements and its impacts are discussed in the later chapters.

It is worth asking if the sharp decline in the use of public transportation led the former public transportation passengers to shift to other modes after the pandemic.

Therefore, besides the former public transportation passengers, the new transportation trends with COVID-19 should be discussed.

2.1.2 Increase in the Use of Private Motorized Modes of Transportation

As mentioned in the previous section, public transportation users tended to change their travel choices during the pandemic. A huge part of the former public transportation users shifted to private modes of transportation. Before COVID-19, travel time, comfort and convenience, and door-to-door access were the key advantages of the travel with a private mode. On the other hand, the cheaper cost of public transportation and accessibility were the advantages of public transportation. However, as individuals chose their health over economy because of COVID-19, hygiene, crowd of the public transportation, fear of contagion risk and lack of air filtration substantially contributed to the increase in the demand of private modes of transportation during the pandemic.

McKinsey Center for Future Mobility (Gresdorf et al., 2020) reported that according to a survey in China, France, Germany, Italy, Japan, UK, and the U.S., the primary reason of the mode choice was risk of infection rather than the time to destination, regarding the private modes of transportation. The comparison among the reasons for choosing private modes pre-COVID-19 and during COVID-19 can be more visible in Figure 2.3.

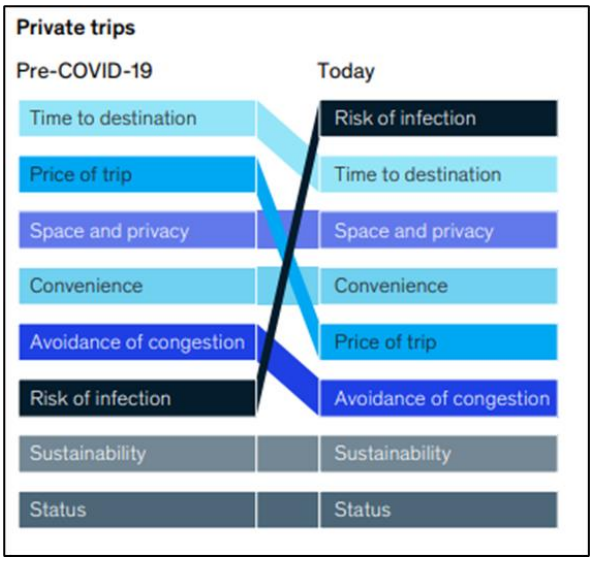


Figure 2.3: The Reasons for Trips by Private Modes of Transport (Gresdof, et al., 2020)

It can be inferred that the change in priorities resulted in individuals refraining from the use of public transportation and turning to private vehicles (see Figure 2.3). In Seoul, while the use of metro and railways declined from 44% to 41% and from 12% to 10%, the use of private vehicles rose from 41% to 46% (Ku et al., 2021). In other words, it is evidence of a transition from public transportation to private transportation during the pandemic process (Ku et al., 2021, p.12). Furthermore, the observed rise in car sales was associated with the demand for the use of private vehicles (Ku et al., 2021, p.15). In addition, while 42 out of 54 public transportation passengers preferred to use private vehicles for short-distance journeys, 117 out of 150 passengers preferred private vehicles for long-distance journeys in Pakistan (Abdullah, 2021). It should be noted that contrary to the developed countries, slow recovery from the alarming increase in the rates of private mode usage was predictable because of the poorly equipped public transportation (Lee et al., 2021, p.13).

Not only was there an increase in private car ownership, but also an increase in car-sharing services. In a survey conducted in Madrid, all of the respondents, as car-

sharing service users, agreed that car-sharing provided individuals with easy access to private motorized modes (Alonso-Almeida, 2022, p.8). Moreover, all the respondents reported that they preferred using car-sharing over public transportation services during the pandemic (Alonso-Almeida, 2022, p.11).

A spatial model of mode choices in 2019 and 2020 was produced in a study in Vienna (Sinko et al., 2021). According to the research, in Vienna, about 43% of increase in the use of private vehicles was observed in spite of the low rate of car ownership before COVID-19 (Sinko et al., 2021, p.11). However, this increase was observed in areas close to the periphery and over long distances between origin and destination (Sinko, et al., 2021, p.11). The map of the shift from bike and public transportation to automobile in Vienna can be seen in Figure 2.4.

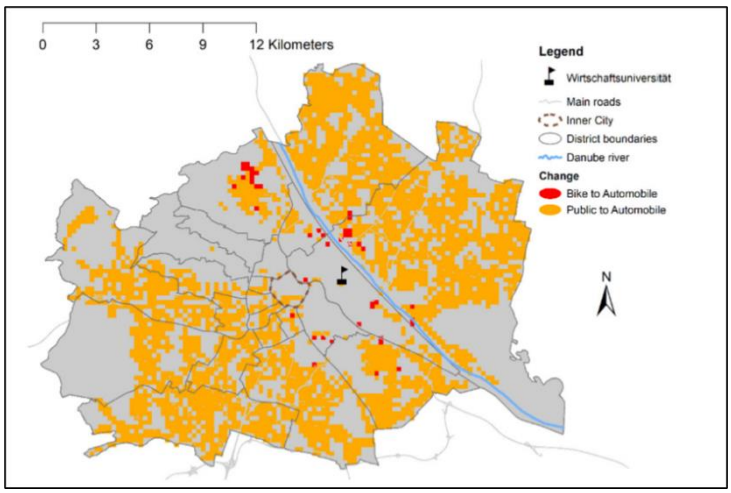


Figure 2.4: Mode Changes in Vienna in 2021 (Sinko et.al, 2021, p.12)

Additionally, rise in the intention of car purchase was observed during COVID-19. The perceived value of car ownership during COVID-19 was measured in a study in the U.S (Moody et al., 2021). The striking point of the research was the increase of value perception of the use of private vehicles by 260% compared to 2019 (Moody et al., 2021). That is to say, private vehicles provided flexibility and comfort in

transportation, especially when public transportation was avoided due to the fear of contagion risk (Moody et al., 2021). Moreover, the research in China estimated the intention of the car purchase by comparing the first wave and the second wave of COVID-19 (Luan et al., 2022). According to the results of the research, although the number of cases almost declined to zero, about 46% of the carless participants had the intention of car purchase (Luan et al., 2022). The underlined reason of this intention was the necessity of a private car ownership in the face of the restriction of public transport (Luan et al., 2022).

Unfortunately, urban transportation system may come under pressure due to the increasing number of private vehicles (Luan, et al., 2022). Although the mode of choice varied regarding different cities or countries, the pandemic of COVID-19 was the global driver of the increase in the use of private cars (Babalık, 2020).

If this trend continues with the alarming increase and the necessary precautions are not taken, it is possible that the long-lasting effect on mobility patterns may be permanent.

2.1.3 Impact on Active Modes of Transportation

As described in further detail in the upcoming sections, disruptive events, from sports events to pandemics, are the primary catalyst for the changing travel behavior (Buchel et al., 2022, p.145). COVID-19 can be regarded as “a window for opportunity” for active modes of travel especially for cycling (Buchel et al., 2022, p.145). Several factors influence the behavioral change towards cycling; and the reasons for the propensity towards cycling were summarized in a study investigating cycling during COVID-19 (Budi, et al., 2021). The reasons can be seen in Table 2.1. Four main categories are shown in the table. During the pandemic, health was one of the main factors which had an influence on active modes of transportation.

Table 2.1: The Reasons for Using Active Modes (Author, 2022)

Factors	*Reasons*
Health:	In accordance with the principle of Physical Distancing The desire to maintain health and body immunity Types of exercise recommended by health experts
Environment:	Environmentally efficient and environmentally friendly supports the go green program Acquire fresh and clean air
Media:	The influence of social media content and hashtags about cycling
Lifestyle:	Lifestyle Following the latest trends Overcoming stress The price of a bicycle shows social status Conformity in social groups

As COVID-19 is transmitted through the surfaces and with close contact, traveling with bikes provides individuals with a safe option and the least contact experience. To illustrate, the motivations for using bike-sharing system were explained with the maintenance of the social distance and considering this system as an alternative to public transportation during COVID-19, according to research in Lisbon (Teixeira et al., 2021, p.393). In addition, a case study in London showed that the demand for bike was higher in the high risky neighborhoods than the less risky ones (Li et al., 2021, p.151). The research claimed that low-income neighborhoods may have higher demand for bike as an alternative to public transportation (Li et al., 2021, p.152).

According to the research in Nanjing, China, contrary to a 90% decrease in public transportation, a 39% of increase in bicycle use was observed for the added 11 000 bicycles (Hua et al., 2021). Clearly, increasing the supply of bikes and the view that traveling by bike is less risky for COVID-19 had a positive effect on the bike use.

In the U.S.A, the impact of COVID-19 on non-motorized transportation was measured in a study by Zhang and Fricker (2021). The research was conducted in 11 urban areas with different population density. COVID-19 resulted in an increase in

the walking and cycling activities in the less-dense cities including Indianapolis, Tallahassee, Clovis and Charlotte (Zhang & Fricker, 2021, p.14). On the other hand, walking and cycling activities were negatively affected in denser cities, such as San Francisco, Long Beach, New York City, and Boston (Zhang & Fricker, 2021, p.14) Although the rate of walking and cycling activities increased at first in Washington D.C., a decrease was observed with the announcement of the State about the number of COVID-19 cases (Zhang & Fricker, 2021, p.17). Despite this decline, the walking and cycling activities were observed to be higher compared to the pre-pandemic period (Zhang & Fricker, 2021, p.17).

Another research analyzed Chicago, focusing on the changing patterns in the usage of bike-sharing (Hu et al., 2021, p.9). According to the research, all modes of transportation dropped abruptly in mid-March 2020 and reached their lowest levels in April (Hu, et al., 2021, p.9). Afterward, a slow recovery was observed (Hu et al., 2021, p.9). However, the fastest recovery was examined by the end of July in bike-share Chicago, where the total number of trips increased by 284% (Hu, et al., 2021, p.9). The research concluded that cycling during COVID-19 period emerged as a resilient option providing healthy and safe travel (Hu et al., 2021, p.13). Similarly, another research indicated that the rapid spread of COVID-19 prompted individuals to buy and use bicycles (Bergantino & Tangari, 2021, p.8). Moreover, it was argued that a 50% increase in the number of public bicycles led more than 40% of individuals to use bicycles during COVID-19 (Bergantino & Tangari, 2021, p.10).

The environment and the infrastructure are the key determinants of cycling activities. Promoting cycling is highly associated with the facilitating level of the environment. For instance, the availability of the bike paths, respect for the cyclers, and the condition of the traffic are the primary reasons for the increase in the level of bike use (Bergantino & Tangari, 2021, p.6). Thanks to the suitable infrastructure for cycling in Hannover, the observed response to the dramatic decrease in public transportation was accompanied by a slightly higher increase in use of bikes than that of cars (Schaefer et al., 2021, p.208). Similarly, in Vienna while public transportation usage together with walking and cycling diminished approximately by

60%, the number of districts where cycling was the first choice increased by approximately 200% (Sinko et.al, 2021, p.10). Most of the population used public transport in 2019, while in 2021, bicycles replaced public transport in the city center (Sinko et.al, 2021, p.10).

On the other hand, it was confirmed by the respondents in a survey conducted in Liverpool, a city that lacks a cycling infrastructure, that a city dominated by vehicles aroused negative feelings about cycling (Buck & Nurse, 2021). It is evident that the shift between transportation modes was heavily depending on the availability of the proper environment especially for the active modes of transportation. For instance, in developing countries, the active modes of transportation may not be as attractive as in developed countries. Although during COVID-19, the number of bicycle users surged, the overall share of the bicycle modes remained quite low in Pakistan (Abdullah et al., 2021, p.30). Moreover, 67% of the respondents in a survey in Pakistan declared that if the pedestrian friendly environment was enhanced, they would substitute private modes of transportation for walking (Abdullah et al., 2021, p.30). Furthermore, as a striking case, in a study in Istanbul, the shift from public transportation to active modes was not observed (Shakibaei et al., 2021, p.15). Inadequate infrastructure for walking and cycling can be the fundamental reason for this (Shakibaei et al., 2021, p.15).

Research in Italy claimed that an additional 25% of the increase in bicycle lanes attracted approximately 10% more passengers during COVID-19 (Scorrano & Danielis, 2021, p.13). The slight increase in cycling was because cycling replaced walking thanks to the additional lanes (Scorrano & Danielis, 2021, p.13). The study revealed that the built environment should promote active mobility but private motorized modes should be discouraged (Scorrano & Danielis, 2021, p.14). The overall rate of the cycling thanks to the additional lanes can be higher in a city which lacked a sufficient pedestrian-friendly environment.

Active transportation modes gained importance as an alternative to public transportation during the pandemic. However, the need for the appropriate

infrastructure for the active modes became even more evident with the rapid spread of the pandemic. Moreover, active transportation modes might be the key substitute for public transportation for short distances. On the other hand, active transportation modes may not meet the demand for travel for longer distances. Therefore, providing a pedestrian friendly environment for short trips and promoting public transportation despite negative attributes such as crowds, hygiene, etc., have been the main challenges during COVID-19.

In this section, the changing mobility patterns because of COVID-19 have been discussed. The reasons behind the shift in mobility patterns should be explained in more detail to identify the challenges faced by public transportation systems during crises, as well as the opportunities for improvement. Therefore, the factors affecting public transportation usage during pandemic will be discussed the next section.

2.2 The Reasons for the Changing Mobility Patterns During COVID-19

COVID-19 had a massive impact on the way of daily life. One of the critical challenges of daily life routine became deciding on the travel mode for commuting to work, school or leisure time activities. The changing mobility patterns were discussed in the previous section. The severity of the rapid spread enforced individuals to think over their travel choices and decisions (Büchel et al., 2022, p.144). Although transportation habits are difficult to change, the events such as contagious diseases trigger individuals to question their previous transportation mode decisions (Thomas et al., 2021, p.1). In this section, the reasons for the changing mobility patterns are discussed.

Several factors contributes to changing travel habits. Before COVID-19, in the literature, structural factors, demographic factors, travel-related factors, and psychosocial factors were discussed to understand the parameters associated with transportation behavior (Pawar, 2021, p.47). However, during COVID-19, the need for new parameters emerged in order to understand changing travel behaviour. The

existing literature may not be sufficient to explain the changing transportation behaviors, so additional parameters should be discussed such as personal safety and the need to avoid potential interaction (Pawar, 2021, p.47).

In the literature, it is discussed that several factors that are associated with demand and supply have an influence on the changing mobility behavior (Qi et al., 2021, p.2). All the factors mentioned above can be categorized under the demand and supply reason. The newly emerging factor during pandemic, such as the fear of the contagion and the need to keep safe distance in the face of crowded public transportation vehicles, can also be related to the demand and supply side factors. Socio-demographic factors including age, income, and education level of individuals can be associated with the demand side reasons, while travel related factors such as trip purpose, length of the trip and availability of the modes can be discussed under the supply side reasons. The categories of the reasons and factors can be seen below.

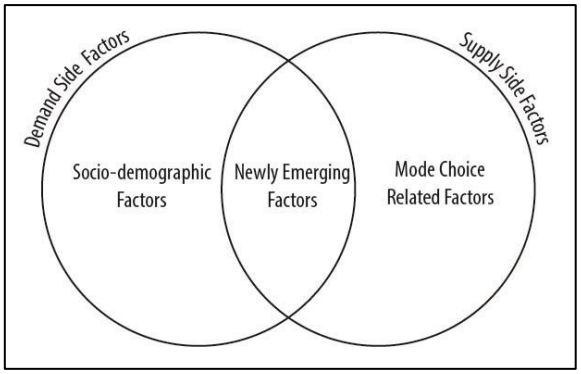


Figure 2.5: The Classification of Reasons (Author)

2.2.1 Socio-Demographic Factors That Affected Travel Behavior During COVID-19

Socio-demographic factors can be discussed under the parameters such as gender, age, income, education level and household size related to travel behavior (Zafri et al., 2021, p.6). The existing literature investigates the motivation underlying

changing travel behaviour by measuring the influence of aforemenitoned parameters. Some of them are particularly related to COVID-19. For instance, according to WHO (World Health Organization), people who are over the age of 60 are one of the most sensitive groups severely affected by the virus. Therefore, it is crucial to investigate the socio-demographic factors to find out the parameters associated with travel behavior.

A study conducted in Washington between February and April 2020 examined the travel behavior with respect to the socio-economic status as a response to COVID-19 (Brough et al., 2021). In the study, it was observed that individuals who had the opportunity to work remotely responded faster to COVID-19 situation by preferring a private vehicle or remote-working instead of commuting to work by public transport. The study showed that when public transport passengers decreased by 74%, the transportation mode choice of less educated and low-income individuals slightly changed. Differences in travel behavior may be due to the lack of opportunities for low-income and less-educated individuals to perform their work remotely (Brough, 2021). Aligned to the Washington study, Parker et al. (2021) examined the transit ridership travel behavior in COVID-19 across the United States. The study found that individuals with higher incomes tended to choose alternative modes of transportation over public transportation, even with the availability of free-fare policies. In contrast, lower-income groups were less able to reduce their use of public transportation, despite the existence of free-fare policies. Although the lower-income groups had concerns similar to those of the high-income groups related to COVID-19, lower-income passengers could not change their travel habits. The study explained this difference with access to cars in high-income groups. In other words, high-income groups have option to substitute public transportation with private cars. On the other hand, lower-income groups are heavily dependent on public transportation since they are more likely to have limited alternatives to public transportation.

Parallel to studies in the United States, Habib et al. (2021) measured the impact of COVID-19 on travel behavior in Greater Toronto Area (GTA) during the lockdown

through socio-demographic factors. Individuals, working full-time in essential sectors such as health, reported that they continued their work even in lockdown period. Since most of the workers including essential workers had lack of opportunity to perform their work remotely, the maintenance of transportation services was the main challenge during COVID-19. On the other hand, the study revealed that the daily travel activites of the older and female population decreased significantly compared to the different age and gender groups. In addition, according to the study, individuals who had a driving license and access to a car tended to do more out of home activities even in during the complete lock-down stage. The study emphasized the importance of socio-demographic factors on travel behavior during COVID-19.

As a contrast to previous studies, a study conducted in Istanbul revealed that socio-demographic factors such as age, gender, income level and car ownership were not the most important factors in commuting to work during the pandemic (Shakibaei et al.,2021, p.7). Instead, occupation type was the most influential factor in commuting travel behavior during this period. For instance, the commute of individuals working in educational institutions minimized thanks to distance education (Shakibaei et al., 2021, p.7). However, parallel to the case in the United States, the study also noted that high-income groups inclined to use their private car for their trips. In addition, according to the study, public transportation passengers with mid-high-income tended to replace the mode of transportation with private car. Furthermore, Shakibaei et al. (2021) revealed that since the teleworking system was more common for women compared to men, males preferred private cars more than females in Istanbul.

In this section, the effects of socio-demographic factors on travel behavior have been discussed. Apparently, although the travel behaviors are robust to change, the pandemic of the COVID-19 is a crucial trigger to changing habits. Income level, gender and age are the leading factors that cause changes in travel behavior. Owing to the changing daily life routines and new ways of life such as distance education and teleworking during COVID-19, commuting activities and modes of travel choice have been heavily affected.

2.2.2 Mode Choice Related Factors During COVID-19

In the existing literature, mode choice related factors are composed of the vehicle ownership patterns, availability, price and timetable of transportation modes. Mobility choice related factors are not only specific to COVID-19 but were also mentioned in several pre-Covid studies under different categories. These categories are listed in Table 2.2.

Ortuzar and Willumsen (2011) investigated the mode choice related factors under three sub-categories. Characteristic of trip maker, characteristic of the journey and characteristic of transportation facility are the main determinants of travel behavior. The characteristics of a trip maker are discussed as socio-demographic factors with extended parameters in the previous section. Therefore, mode choice related factors are regarded as the combination of characteristics of the journey and transportation facility during COVID-19.

Table 2.2: Mode Choice Related Factors (Author,2022)

Categories	
Characteristic of Trip Maker:	Age, Income, Household structure, Residential density
Characteristic of The Journey:	Trip Purpose, Time of the trip day, trip with family, alone.
Characteristic of The Transportation Facility:	Availability and cost of mode, reliability of travel time

The characteristics of a trip maker have been discussed with regards to socio-demographic factors with extended parameters in the previous section. Therefore, mode choice related factors are regarded as the combination of characteristics of the journey and transportation facility during COVID-19.

Zafri et al. (2021) investigated the change in mobility patterns by comparing the pre-COVID-19 and New Normal Situation in Bangladesh. In the study, travel related factors were explained with motorcycle and car ownership, trip frequency and virtual activity frequency. According to the result of the study, individuals who had motorcycle or car were less likely to shift to a public or active mode of transportation. On the other hand, public transportation passengers had more tendency to substitute public transportation with active transportation mode. Unfortunately, just a limited number of individuals preferred cycling owing to the insufficient infrastructure for cycling. The similar situation was observed for walking. Due to the unfriendly and unattractive pedestrian environment, the number of individuals choosing to walk during COVID-19 were rather limited. According to the study, if the infrastructure was provided, the pedestrian-friendly environment could appeal to private vehicle owners to switch to active modes. Most importantly, the availability of an alternative mode of transportation was the key determinant of shifting transportation mode of choice (Palm et al., 2021, p.463). Individuals living in a pedestrian friendly neighborhood with essential needs within a walking distance coped more easily with COVID-19 and lockdown period (Palm et al., 2021, p.466)**.** This was because there were other transportation options when a mode of transportation was unavailable.

A study conducted in Ghana investigated the features of public transportation facility influencing mode choice by comparing the before and during COVID-19 (Sogbe, 2021). The cost of fare, availability of buses and access to seats were the most influential factors before COVID-19. On the other hand, cleanliness of the vehicle and physical distancing became the most significant factors during COVID-19.

Moreover, the influence of vehicle ownership situation and trip characteristics such as travel time, cost and safety on mode choice were measured in a study in India (Dasa et al., 2021). As regards to this study, 59% of public transportation passengers in pre-COVID-19 shifted to another mode of transportation. In addition, 18% of passengers shifting their travel mode were interested in driving a private car. The study reported that the underlying reason for this change may be caused by the availability of vehicle ownership and public transportation accessibility.

With the onset of COVID-19, the purpose of the trips was severely affected. A study in Canada investigated the adjustment of trip purposes (Fatmi, 2020, p.271) and observed a reduction of more than 50% in the commute to out-of-home activities. Besides, the highest share in the trip purpose was shopping and work-related activities. At this point, it is noted that work-related travel activities were concentrated on health, government and services sectors (Fatmi, 2020, p.272). Moreover, in the literature, the purposes of trip are categorized in two groups during COVID-19. Like in the former study, work-related and non-work-related activities are the primary categories. Besides, non-work-related activities are divided into essential trips regarded as shopping for groceries and non-essential trips like intercity travel or restaurant trips (Pawar et al., 2021 p.48). A study in India demonstrated that an individual who traveled more than 5 days a week for work-related purposes was almost 84% less likely to switch to non-travel than an individual who traveled less than five days a week (Pawar et al., 2021, p.50). In other words, working days in a week had a significant effect on adjusting travel frequency. In addition, looking at the non-work-based trips, essential trips were vaguely diminished, while a serious decrease in the non-essential trips was observed (Pawar et al., 2021, p.50).

The mode choice-related factors were prevailing in pre-COVID-19. Along the same line, these factors were effective on the travel behavior during COVID-19. Ownership patterns and alternative mode of transportation are the main triggers for switching to different mode of transportation. The existence of alternative modes of transportation provides the opportunity to decide between different modes. Alternative modes of transportation and providing proper infrastructure are strongly associated with each other. For instance, individuals who avoided using public transportation during COVID-19, can prefer cycling or walking if appropriate infrastructure or pedestrian-friendly environments are provided. Likewise, ownership of a private vehicle offers individuals an alternative mode of transportation, especially when there is no public transportation mode and there is no active mode of transportation.

2.2.3 Newly Emerging Factors in Travel Behavior Change during the COVID-19

Up to this point, numerous factors which were also effective before the COVID-19 on travel behavior have been discussed. However, together with COVID-19, new parameters begun to be discussed to examine the travel behavior. As close contact was the main contributor to transmitting COVID-19, the crowding level of public transportation modes was one of the main causes for adjusting the mode choices (Abdullah et al., 2021). Therefore, the fear of the contagion of COVID-19 compelled individuals to alter the mode choices in their daily lives. For this reason, ignoring pandemic-related factors can be misleading to understand the changes in travel behavior. Hygiene, overcrowding, and fear of contagion of COVID-19 were the leading parameters that have an inevitable effect on mode choices during the COVID-19.

As a newly emerging factor, the crowding level of the transportation modes is highly influential among individuals for behavioral changes. “Crowding impedance” on public transportation before and during the COVID-19 was measured by a study in the Seoul metropolitan area in Korea (Cho, 2021). The research focused on the individuals who preferred public transportation as a main mode in the Seoul metropolitan area. According to the research, individuals had tendency to reduce their travel time in a crowded vehicle. Moreover, the research confirmed that the impact of the crowd level of transportation on travel behavior was irrespective of the purpose of the trip. In the research, a comparison between public transport modes revealed that subway passengers paid more attention to crowding levels in the vehicle than the bus passengers. This difference may be due to the fact that buses are more likely to be ventilated. Therefore, crowding in closed conditions without air circulation became the sudden weakness of public transportation with the spread of the COVID-19 (Cho, 2021). Of much relevance to this research, 85% of respondents in a study in the U.S.A stated that the reduction in the usage of public transportation was caused by crowding and the cleanliness level of the vehicle (Parker et al., 2021

p.57). As an example of a developing country, a study in Pakistan analyzed the shift from public transportation to private car and found that the main reason for this shift was the unhealthy condition of public transportation vehicles due to close contact in a closed environment (Abdullah, 2021 p.26). Like in Pakistan, in Istanbul, although the use of private vehicles was costly due to the rising oil prices, all of the private car owners without exception used their car to commute to work instead of using public transportation during COVID-19 (Shakibaei et al., 2021, p.7). It is noteworthy that with the onset of the COVID-19, health-related factors became more dominant than economics in transportation decisions and behavior.

As an interesting case, research in Ghana only concentrated on the factors influencing the public transportation mode choices (Sogbe, 2021, p.1611). According to the research, wearing masks and employing physical distancing during the COVID-19 became more important than ensuring safety in traffic to prevent accidents. It should be highlighted that the cramped seating arrangement in "trotro" which is paratransit in Ghana caused the shift from public to private modes of transportation.

Przybylowski et al. (2021) inquired into individuals' safety criteria perception related to COVID-19 on travel behavior of public transportation users in Gdansk, Poland. Before the COVID-19, the behavior of other passengers was the key factor affecting both safety and comfort. Moreover, before the COVID-19, the number of passengers was not as significant as the behavior. However, during the COVID-19, number of passengers became the dominant factor affecting both safety and comfort. The tidiness of the vehicle for comfort was a more important factor than before the pandemic. Still, the fear of passengers who did not comply with the hygienic regime was a critical factor, as the behavior of the other passengers. As in the Gdansk case, several added factors such as hygiene rules and tidiness became substantial in deciding mode choices.

Similar to public transportation, shared modes of transportation were perceived as risky for COVID-19 infection. Lack of social distancing because of the crowd in

public transportation and hygiene issues in shared travel modes formed the basis for individuals to avoid these modes of transport. For instance, research in China reported that purchasing private cars and bicycles was preferred over the shared and public modes of transportation because of the hygiene issues (Luan et al., 2021, p.277).

The newly emerging factors have also been effective in deciding on the usage of active modes of transportation during the pandemic. In Bangladesh, the impact of perceived risk of transmitting COVID-19 on both cycling and walking was measured (Zafri et al., 2021, p.11). Since the risk of COVID-19 transmission has the greatest impact on travel behavior, it is crucial to understand changing travel behavior to compare the different modes of transportation. Therefore, in the research in Bangladesh, it was seen that individuals who had a bicycle but were regular public transportation users before the pandemic had tendency to start riding bicycles because of the higher risk of transmission in public transportation (Zafri et al., 2021, p.12). Since individuals were fearful about their immune system during the pandemic, the risk of COVID-19 transmission played an important role in shaping their travel behavior (Zafri et al., 2021, p.13).

After explaining the reasons and factors for the changing mobility patterns, it is also important to provide a better understanding regarding the COVID-19 measures for public transportation with a view to detect vulnerabilities and adjust strategies in response to the change. Prevention and control measures for public transportation as a response to COVID-19 are explained in the following section.

2.3 Prevention and Control Measures of COVID-19 for Public Transportation

As COVID-19 pandemic hit the world suddenly, it changed the routine of almost all sectors. However, the hardest hit by COVID-19 was witnessed by public transportation. The sudden decrease in the demand for public transportation was one

of the key issues to tackle during COVID-19. The crowdedness of public transportation, hygiene rules and close contact issues led to the need for intervention in public transportation policy. To ensure the proper use of public transportation and to control COVID-19, new measures for public transportation became inevitable.

According to the literature, the mitigation measures for public transportation as a response to COVID-19 can be categorized in several ways. These categories are listed in the Table 2.3.

Table 2.3: The Categories of the Public Transportation Measures (Author,2022)

Authors	*Measure Categories*
Shahin (2021)	Engineering Controls Administrative Controls Personal Protective Measures
Shen et al., (2020)	Precautionary Measures Control Measures
Zhang et al., (2020)	Single-faceted Measures Multi-faceted Measures
Shortall et. al (2022)	Avoidance of Travel Modal Shift Measures Improvement of Quality Measures

All these measures were implemented to mitigate the effect of the pandemic on public transportation, even though different classifications were proposed in the literature. In the next section; operational, control and personal measures for public transportation will be explained with the examples.

2.3.1 Control Measures for Public Transportation

Public institutions intervened to prevent or to slow the rapid sprawl of COVID-19 transmission. Luchessi et al. (2022) argued that public authorities should take an action to ensure the maintenance of the basic service as public transportation. Common control measures in public transportation mentioned in the literature are categorized in five groups.

Keeping Social Distance for Public Transportation:

The World Health Organization (WHO) recommended maintaining a distance of 1 meter from others in enclosed spaces as a key precaution to prevent the spread of COVID-19. Reducing physical contact in the public transportation vehicle became inevitable to prevent the rapid spread of the COVID-19. In Amsterdam, an online social distance map covering public transportation stops was produced to encourage passengers to maintain a safe distance of either 1 or 1.5 meters in order to prevent the spread of COVID-19. In Figure 2.6, it is clearly shown that it is difficult to maintain the 1-meter social distance around the public transportation stations. The necessity of ensuring social distance in public transportation can be inferred from the social distance map of Amsterdam. Social distance was helping to reduce the crowdedness level of public transportation.

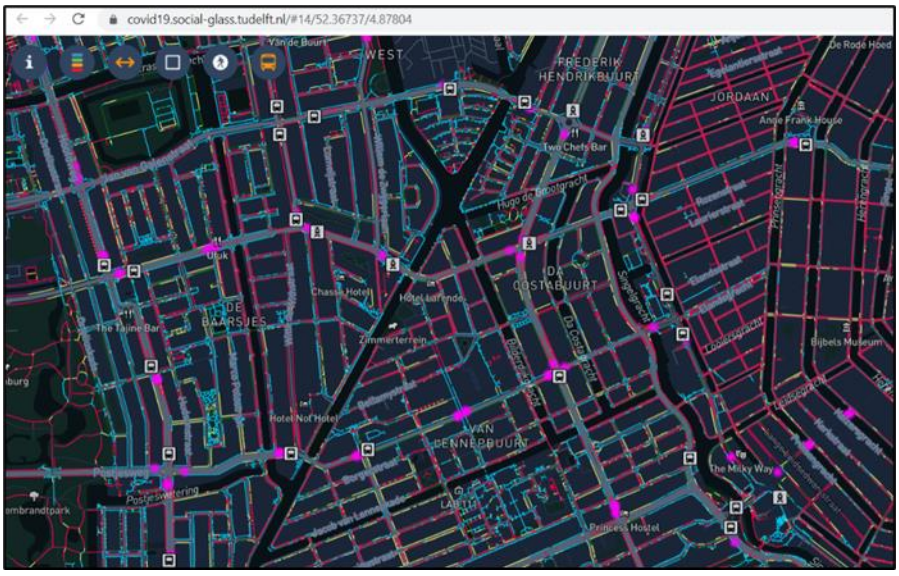


Figure 2.6: Social Distance Map of Amsterdam (The Delft University of Technology, 2021)

Mandatory Mask Wearing for Public Transportation:

Social distancing alone may not be enough to prevent the transmission of COVID-19. A combination of social distancing with mask-wearing in a closed environment can strengthen the efforts to cope with the disease (Dzisi & Dei, 2020). Research in Ghana in 2020 demonstrated that approximately 98% of passengers stuck to the social distancing rule (Dzisi & Dei, 2020, p.6). However, the rate of wearing a mask in a vehicle was relatively low compared to social distancing.

In research conducted in South Korea, the degree of infection exposure was measured with respect to the implementation of social distance and face mask measures (Ku et al., 2021). Figure 2.7 indicates that different scenarios led to changing the level of contagion**.** Using a proper face mask was one of the most effective ways to prevent the contagion of COVID-19 (Tirachini & Cats, 2020).

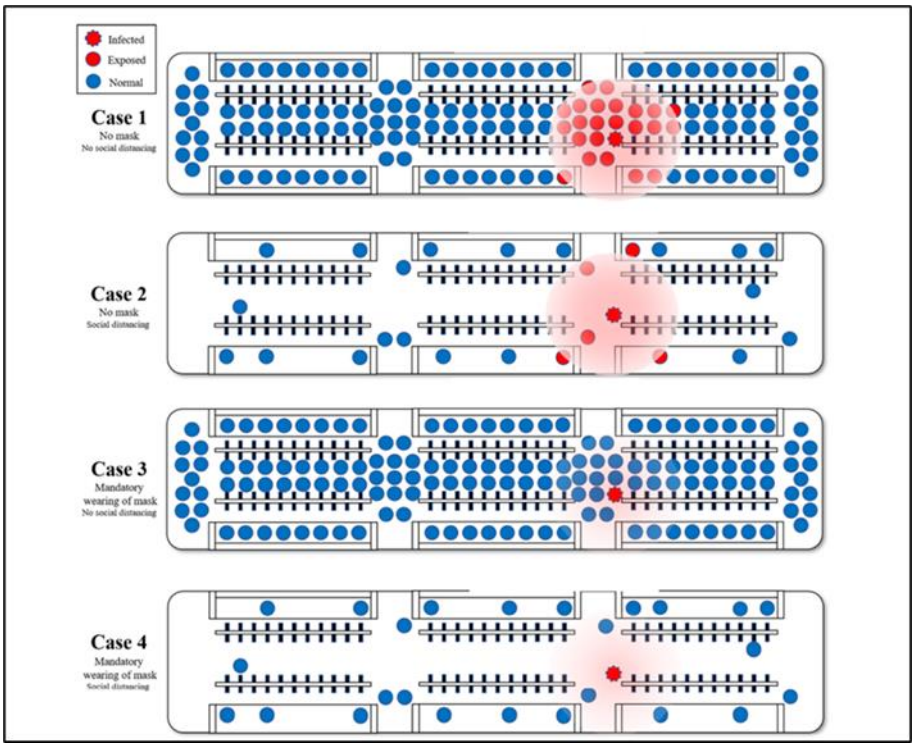


Figure 2.7: Prediction of the transmission risk inside of the public (Ku et al., 2021)

Travel by Reservation for Public Transportation:

The crowd level in public transportation is one of the effective reasons for the decrease in demand. Travel by reservation is one of the ways to limit the number of passengers in a closed environment. In China, passengers had to make a reservation with QR Code before getting on the subway (Zhou et al., 2021). In this way, overcrowd around the station and in the vehicle was prevented and waiting time in the station was reduced.

Health Code for Smart Cards for Public Transportation:

Smart cards for public transportation should match the health code to control the isolation of individuals testing COVID-19 positive. As a central government measure, the health code covers information not only of the individual with a positive COVID-19 test, but also of the individual exposed to COVID-19. To enter public

transportation or any public spaces, valid health code was required. The health code facilitated safe service by tracing the health condition of public transport passengers.

Surface Cleaning and Ventilation for Public Transportation:

COVID-19 virus was considered to endure in a surface or a closed environment from an hour to day (Doremalen, et al., 2020). Therefore, in terms of hygiene and cleaning, the inside of transportation vehicles was seen as high-risk areas. The surfaces in public transport vehicles can be touched by a high number of passengers. Therefore, regular surface cleaning and ventilation were primary precautions to struggle with COVID-19. Besides regular disinfection of the vehicle and regular ventilation during, before and after the trip, it was important to have personal protective measures such as mask and disinfectant in the vehicle. Public transport would be the main vector for the pandemic, unless precautions regarding hygiene and cleanliness were not implemented.

2.3.2 Operational Measures for Public Transportation for Public Transportation

As a response to the rapid spread of COVID-19, public transportation authorities looked for alternative ways to adjust the operation of public transportation (Gkiotsalitis & Cats, 2021). Limiting service times, canceling certain services and closing selected stations were primary ways to adjust the operation of public transportation (Gkiotsalitis & Cats, 2021).

Service Frequency

Limiting service frequencies was a way to prevent the transmission of COVID-19 by reducing the time exposed to public transportation. For instance, Transport for London (TfL) alternated to service schedule to ensure safe travel for key workers such as health workers (UITP, 2020b). Nearly 40 metro lines, which do not have a transfer station with other transportation lines, were closed in 2020 in London (UITP, 2020b). Similar arrangements were implemented all around the world during the

pandemic. To illustrate, in Rome, the service time of metro lines were adjusted for the summer with closure time at 09:00 p.m. (UITP, 2020b). In addition, in Valencia, 35% of reduction in the service was supported on weekdays (UITP, 2020b). Reduction in service frequencies is not only to control the pandemic among public transportation passengers but also to protect public transportation staff. However, Jiao & Azmian (2021) argued that increasing the frequency of public transport services can facilitate physical distancing, reducing crowding and increasing the number of seats available, as opposed to reducing the frequency of services. It is noteworthy that regulating service frequencies without taking into account the physical distance may lead to more crowded vehicles. Additionally, in public transportation vehicles, physical barriers between vehicle drivers and passengers were implemented to protect bus drivers and ensure social distancing (Shahin & Yetişkul, 2021). Similar to physical barriers, backdoor boarding was also a way to minimize the physical connection between driver and passengers (Shahin & Yetişkul, 2021).

Changing Timetables

The staggered working schedule can also be a method to decrease the demand for public transportation at peak hours. Besides remote working strategy previously mentioned, this method was implemented to regulate the overcrowd during peak hours. A staggered working schedule refers to a range of start and end times for working duration. This method is also one of the effective alternatives to prevent congestion in urban transportation literature. The staggered working hours provides a safe public transportation service, especially in workplaces where remote working may not be supported.

Fare Policy

The sharp decline in public transport usage due to the COVID-19 prompted public transport authorities to adopt policies aimed at regaining the demand. While the previously mentioned policies aimed to provide safe and health services, fare policies aimed to regain the lost demand. Although free-fare policies were not very preferable

because of the financial burden to public authorities, the policy was supported during the COVID-19 to prevent the transition from public transportation to automobiles. (Dai & Liu et al., 2021).

The impact of free-fare policy on subway passengers in China was examined in a study, which demonstrated that subway ridership level increased by %24 at peak hours in a month (Dai & Liu et al., 2021). The findings of the research were proof of the need for new policies to attract more passengers. On the other hand, it is crucial to note that providing policies that may increase the demand for public transportation might not be effective in combatting COVID-19.

2.3.3 Personal Measures in Public Transportation

Previously mentioned measures are categorized under non-pharmaceutical interventions (NPIs) supported by the authorities, and they include strategies to mitigate the impact of COVID-19 other than vaccination or medicine treatments. On the other hand, personal measures can cover both non-pharmaceutical interventions and vaccination. Wearing a mask, using hand sanitizer, or materials which protect bodies from infection can be considered as personal measures.

In the literature, personal measures are considered to be not as effective as operational and control measures to combat COVID-19 (Nasir et al., 2016, p.15763). On the other hand, in high-risk areas such as public transport, taking personal precautions in addition to the measures taken by the authorities significantly reduced transmission of the pandemic.

Research in India investigated the effective measures in accordance with perception of passengers (Dasa et al., 2021). In seven measures to cope with COVID-19, the most effective one was alternative seating arrangement with physical distance (Dasa et al., 2021, p.7). However, the provision of personal protective equipment was evaluated as third most effective (Dasa et al., 2021, p.7). Personal measures and

provision of personal protective equipment in public transportation vehicles and stations can help provide health as well as safe travel.

2.3.4 Comparison of Measures for Public Transportation

Effective measures and solutions were crucial to implement during the pandemic because of the serious decrease in the demand for public transportation. The importance of the measures and policies were investigated in Seattle and New York in the U.S and the findings demonstrated a significant interaction between policies and the response of passengers regarding public transportation (Bian et al., 2021, p.282). The delay in policy implementation significantly affected the demand for transportation (Bian et al., 2021, p.281).

Transportation authorities should manage the demand for public transportation and provide a healthy transportation service. The key lessons highlighted in a study conducted in China showed that effective measures comprised wearing mask, regular disinfection and proper ventilation of vehicles (Zhou et al., 2021, p.147).

Gkiotsalitis and Cats (2021) proposed three levels of intervention to manage public transportation systems during COVID-19:

1. Strategic Planning: Identification of the public transportation network plan
2. Tactical Planning: Determination of frequency of services and schedules
3. Operational Planning: Strategies to mitigate COVID-19 impact such as crowding, vehicle capacity, and boarding.

In the light of these three levels, Naveen and Gurtoo (2022) questioned the proper response strategy depending on the passenger with different age, income and education level. Each strategy from green to red was based on the probability of catching COVID-19 (Naveen & Gurtoo, 2022). For instance, red mode operated on high alert with extra care and precautions so that transportation services were not suspended in risky areas (Naveen & Gurtoo, 2022). The color code system aimed to provide uninterrupted public transport services to the public during the pandemic

(Naveen & Gurtoo, 2022). The strategies focused on the same parameters such as safety, cleaning, and personal hygiene; and the study showed that customized transportation services depending on passenger types can be useful to prevent the spread of COVID-19 (Naveen & Gurtoo, 2022).

Immediate measures for public transportation during the COVID-19 should be turned into a long-term solution to have resilient systems. Therefore, in the next chapter, the newly emerging transport policy approaches will be discussed as methods of creating a more sustainable and resilient transport system that can respond to future crises.

2.4 Policy Responses for Adaptation to Post COVID-19: Resilience for Future Crises

A growing concern during the pandemic has been about whether things would return to “normal” after the pandemic, or whether the society would reach “the new normal” with significant changes in areas such as public transport usage (Convay et., 2020, p.2). Therefore, decision makers were encouraged to be prepared for the "New Normal" situation for the long-term planning (Convay et al., 2020, p.2).

In United States, the mode choices of public transportation passengers were analysed in a study, which showed that a significant minority of the respondents expected a change in their choice of modes even if the pandemic passed (Convay et al., 2020, p.9). This research suggested that a complete return to the pre-pandemic way of life was not likely.

Nevertheless, effects of pandemics in the future are still uncertain. A study tried to predict the possible impacts of the pandemic in the future with the help of scenario planning; and four main scenarios were proposed in accordance with the shifting between transportation modes and the extent to which the COVID-19 pandemic would continue (Sameni, Tilennoie & Dini, 2021) (See Figure 2.8)

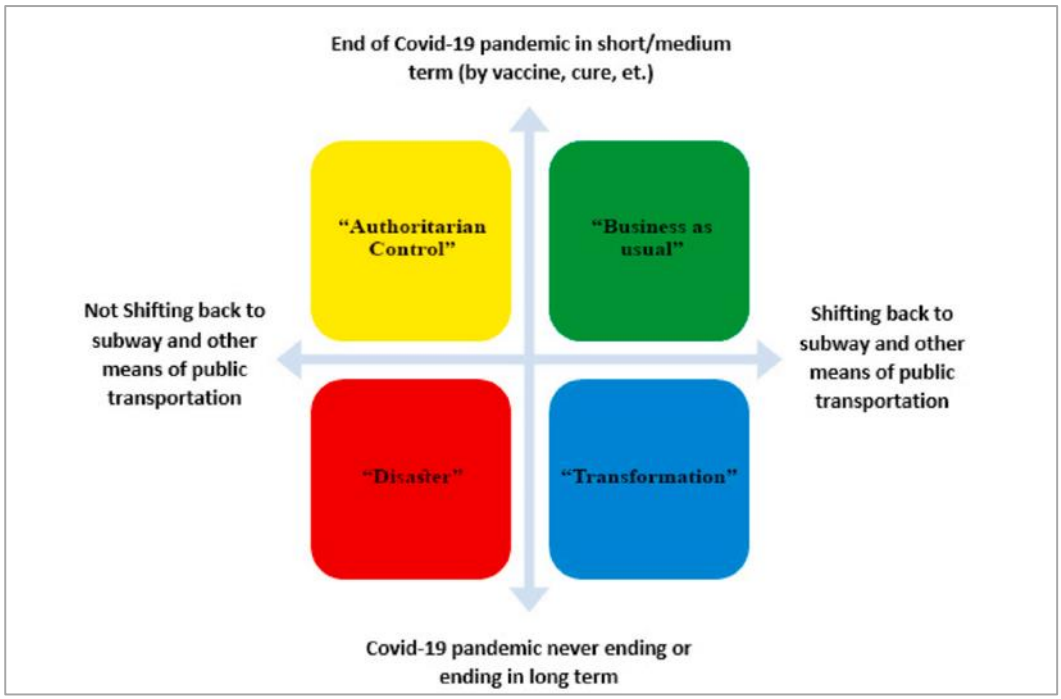


Figure 2.8: The Four Future Scenarios (Sameni, Tilennoie & Dini, 2021)

Scenario 1: "Business as usual" is the most optimistic one compared to others. According to the scenario, the effect of COVID-19 would disappear in a short time. However, the effect of COVID-19 is still seen in the post-COVID-19.

Scenario 2: "Authoritarian Control" alleges that COVID-19 would end up in a short time. On the other hand, tendency of depending on private car would be consistent and permanent. Therefore, the need for strict policies by public authorities could emerge.

Scenario 3: "Transformation" predicts that COVID-19 would have long-lasting impact on public transportation. Moreover, shifting between different modes of transportation may be more visible during the first period of COVID-19. However, because of the financial issues or mitigation of the measures, some individuals may need to return to public modes in the scenario.

Scenario 4: "Disaster" is the most unpromising one between four scenarios. According to the scenario, the long-lasting spread of COVID-19 would lead to attracting the use of private modes because of the fear of infection.

It is clear that in time some of these scenarios became invalid. However, the trends experienced during the pandemic made it clear that in addition to temporary measures to control COVID-19 and possible similar health concerns, it is important to develop new policy approaches to adapt to future crises and to be more prepared and resilient.

2.4.1 Passenger Attraction Policies

Public transportation modes experienced a dramatic decrease in passengers during COVID-19. To prevent unintended consequences of this, the need for policy approaches emerged both to cope with COVID-19 and to manage future crises.

From this point forth, it is crucial to develop passenger attraction policies in light of the COVID-19 measures during the rapid spread. In the first months of the pandemic, public transportation usage was restricted. Due to the declining demand, policies were needed to encourage passengers to use public transport in the Post COVID-19 period. Therefore, the importance of demand management became more visible with the onset of COVID-19.

The measures implemented to control the pandemic could be an alternative for demand management in the future. To control the capacity of public transportation vehicles, Hörcher et al. (2021) proposed social distancing with different demand management methods. In other words, social distancing is regarded not only to combat COVID-19 but also as an effective way to manage the capacity of public transportation. The different social distancing methods are categorized in Figure 2.9.

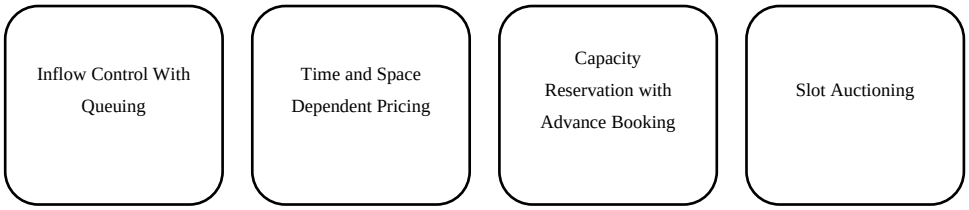


Figure 2.9: Demand Management Methods for Social Distancing (Author, 2022) using the source (Hörcher et al., 2021)

Inflow control with queuing enables public transportation authorities to control the capacity of the vehicles in case of the need for social distance. However, in order to prevent time loss and to use public transport capacity effectively, it may be beneficial for smart cards to provide information in advance.

Time and space-dependent pricing is a way to close the budget gap because of the dramatic decrease in the demand for public transportation, despite being a controversial topic in public transport policy.

Advance booking and slot rationing provide public transportation capacity allocation for passengers. Waste of time and waiting in long ques might be avoided thanks to this method.

Therefore, social distancing methods can be used in the future with the combination of technology to ensure efficient use of public transportation capacity, especially at peak hours.

Moreover, there are studies arguing that in the Post COVID-19 period, passenger attraction policies should be more concentrated on encouraging public transportation rather than limiting the use of private modes. A study in India investigated the relevance of policies on modal shifts from private modes to public modes in Post COVID-19 period (Kamar et al., 2022) and following policies were identified:

- Policy 1: Improving Public Transportation coverage and supply, reducing travel time by 5%.

- Policy 2: Parking prohibition on major streets, reducing congestion and Public Transportation travel time by 10%.
- Policy 3: Early bird pre-peak hour discount of 5%.
- Policy 4: Reducing fare by 10% for return journey for passengers purchasing two-way tickets.
- Policy 5: Combination of Policy 2 and Policy 4.
- Policy 6: Combination of Policy 1 and Policy 3. (p.6)

According to the research, each policy had an impact on the modal shift towards the use of public transportation with a rate ranging between 5% to 6%. The most effective policy was the reduction in travel costs of public transportation. Due to the examination of commuting trips in the research, the most effective policy was related to public transportation costs because of the financial crisis due to COVID-19.

Additionally, in the research observing Metro Manilla in Philippines, COVID-19 was considered as an opportunity to transform into a more sustainable future (Hasselwander et al., 2021). Active mobility and prioritizing public transportation should be promoted as key policies in the short term according to this study. Pop-up bus lanes and corridors were suggested to encourage public transportation. The research emphasized providing efficient infrastructure and technology-based solutions to turn short-term interventions to long-term solutions.

Aligned with the research in Philippines, Thombre and Agarwal (2021) suggested prioritizing public transportation with the help of policy planning. Defining short mid- and long-term policies can be used as a method to attract public transportation passengers. The research put the emphasis on public transportation as the backbone of sustainability. Therefore, according to the research, focusing on challenges caused by COVID-19 should be the focus of short-term policies. It is possible to regain public transportation passengers by providing safer, cleaner and resilient service in the long-run.

Passenger attraction policies should be implemented to ensure the maintenance of public transportation. The short mid- and long-term policy planning should be encouraged to avoid the negative impact of COVID-19 on the ridership level of public transportation. In other words, in the post COVID-19 period, ways to turn the crisis into an opportunity should be sought.

2.4.2 PASS Approach

A systematical approach can be the way to cope with COVID-19 in the long-term. Zhang (2020) proposed a policy framework, named the PASS approach, with four main principles to address the negative impact of COVID-19 on urban transportation. The main principles of the PASS approach can be seen in Figure 2.10.

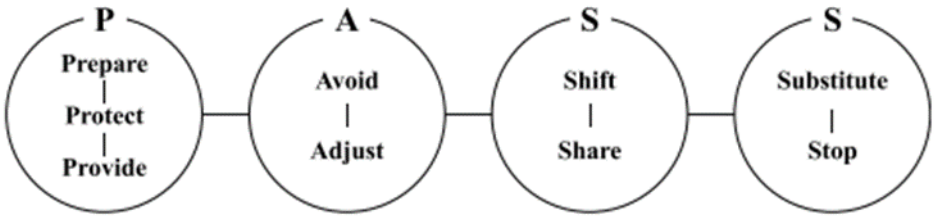


Figure 2.10: The Meaning of PASS (Zhang, 2020)

Zhang (2020) argued that each of the components of "PASS" were integrated with each other. Moreover, each of the components serving a similar purpose together formed a system to manage current COVID-19 and future crises. In the systematic framework, every actor such as public authorities or decision-makers should take on a different responsibility for the issues related to COVID-19. Each of the principles and responsibility of the actors are explained in detail below.

- **Prepare – Protect – Provide**

One of the most important steps is the regulations and legal system, which fall under the responsibility of the government. “Capacity Building” or learning lessons from the history should be encouraged to produce efficient plans. Therefore, transportation operations should prepare contingency plans for the emergency and unexpected events. Moreover, governments should support interdisciplinary research with collaboration with different stakeholders. Providing trustworthy information is crucial with COVID-19. For instance, knowing how the disease is transmitted might be helpful to implement proper measures.

For the components of “Protect”, the main responsibility also falls on the government. Implementing sufficient measures to protect individuals from COVID-19 is the primary responsibility of the government. Especially, control measures should be implemented to minimize the contagion risks. Not only the government but also the passengers should take the responsibility. To minimize the impact of COVID-19, obeying the rules or taking the necessary individual precautions are also of great importance.

Providing guidance, reliable information, protective equipment (hand sanitizer) is also under the responsibility of the government. At the same time, passengers should provide personal health information to enhance the safety of the environment.

- **Avoid - Adjust**

The avoidance of situations that may have a negative impact on the precautions mentioned in the "Protect" and "Provide" principles can be associated with the "Avoid" principle. For instance, the government should avoid inconsistency in policymaking and information.

Policies, behavior of individuals, even the role of the public authorities should be adjusted as a response to COVID-19. Institutional and organizational framework should be reconsidered. Moreover, the operational level of transportation should be rearranged to comply with COVID-19.

- **Shift – Share**

Shift to "pandemic-focused" governance should be supported in all layers of governance to fight against COVID-19.

The components of shift policies are listed by Zhang (2020) as follows:

- Shift to pandemic-focused governance
- Shift to public and active modes of transportation
- Shift to flexible working hours
- Shift to state of emergency situation

In other words, there is a need to harmonize our daily lives with the life of the pandemic to adapt to the new normal.

"Share" puts the emphasis on the importance of collective decision. Most importantly, public transportation modes should be promoted as it offers a collective use of mobility.

- **Substitute - Stop**

COVID-19 should be considered as a transformation opportunity with the tool of "substitute". In adaptation to the new normal, society should substitute market oriented-society with a life-oriented society (Zhang, 2020, p.417).

"Stop" is the last component of the PASS Approach. In order to adapt to the new pandemic life, it is necessary to get rid of some of the old life-style settings. For instance, although the operation of public transportation should be limited, the need for access of essential workers (health workers) should be met. In addition, physical settings of the built environment should be reconsidered to offer different modes of transportation.

2.4.3 Other Post-COVID-19 Policy Approaches

The COVID-19 led to searching for new ways to manage future pandemics or crises. Therefore, several approaches were proposed not only to tackle future pandemics but also to achieve a more resilient and sustainable future.

- ***ARDUOUS Methodical Approach:***

Corozza and Musso (2022) proposed the ARDUOUS acronym to develop a "pandemic free" (p.34) public transportation. Each of the letter or principle represents both potentials and limitations caused by COVID-19. Synthesized key issues in the method are as follows:

- **A**djustment
- **R**edesign
- **D**omesticity
- **U**nsharing
- **O**rganization
- **U**nsustainability
- **S**tandardization

Adjustment is mostly related to the ability to adapt to certain situations. For instance, implementing social distance rules to manage the capacity of public transportation vehicles can be considered as adjustment methods. Increasing the capacity of the public transportation vehicles and proposing new lanes depending on the demand can be the adjustment of public transportation to ensure the efficient use.

Redesign is referring to the rearrangements of layouts of public transportation vehicles. Ventilation, airflow, and hygiene standard in the vehicles should be ensured to adapt to the new requirements.

Domesticity can be associated with a decrease in mobility, especially for certain professions, because of remote work. However, this situation exacerbates an inequality for the individuals who are dependent on public transportation.

Unsharing draws attention to a tendency towards private modes of transportation because of COVID-19. It is emphasized that immediate action should be taken to attract passengers to public transport modes.

Organization is the backbone of the ARDUOUS methodology. Organization is dwelling on the communication and management with the coordination of public authorities, planners, passengers and so on.

Unsustainability is considered the result of the current system. Lack of management and planning, dependency on private modes, and domesticity can lead to the unsustainability of the current system.

Standardization refers to proposed solutions to prepare for crises and maintain uninterrupted public transportation systems under disruptive events. Standardization offers a common criteria, standards or guidelines as a response to future crises. In this way challenges caused by COVID-19 can be overcome in a fast and effective way. Corazza and Musso (2021) produced the conceptual map to specify the problems and action areas. This conceptual map of the ARDUOUS approach is illustrated in the Figure 2.11.

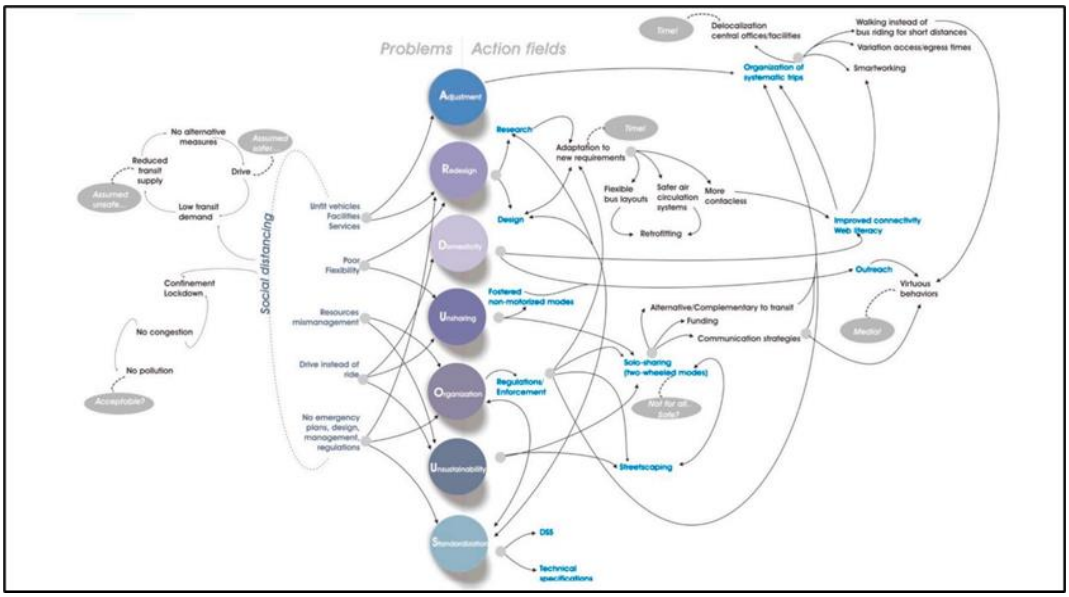


Figure 2.11: Conceptual Map of ARDUOUS Approach (Corozza and Musso, 2022)

As it can be seen in the map, each component of the approach is related to each other. Moreover, as in discussed in the previous section, most of the challenges were caused by the need for social distance and shifting to private modes because of COVID-19. Research, design, incentives for sharing modes, and management in the ARDUOUS approach are the key action fields to tackle COVID-19.

- ***Responsible Transportation***

Budd and Ison (2021) proposed a new post-COVID-19 agenda as a response to the need for reconfiguration of transportation because of the rapid spread. Responsible transportation is defined by Bund and Ison (2021) as follows:

"Responsible Transport delivers safe, secure and equitable mobility that embeds social, economic and environmental wellbeing at the heart of post-COVID transport policy, planning and operations and enables individuals to make considered transport choices." (p.3)

The definition of Responsible Transportation focuses on the importance of choice of the individuals to ensure the sustainability of urban transportation. In other words, besides the importance of individual awareness, Responsible Transport is aware of the role of decision-makers. The behavior of individuals and actions of decision-makers should be in line with environmental, economic, and social concerns.

Responsible Transport might be seen as a top-down approach that is concentrated on individuals. The main idea of the approach is grounded on "taking great responsibility for your actions" (Bund and Ison, 2021. p.4). However, the main aim of the approach is to ensure the bottom-up movement by turning individual action into collective action. At this point, decision makers have a great responsibility to guide individuals with suitable policies and trigger transformation.

Similar to the previous approaches, Responsible Transport suggests combination of transportation policies with technology. According to the agenda, providing information related to newly-emerging factors such as overcrowding, alternative

routes or available seats should be encouraged with appropriate information technology, especially for public transportation.

The fundamental quote of the agenda is “right policy, right place” (Budd & Ison, 2021, p.4) to make public transport responsive.

- ***Avoid-Shift-Improve Framework***

The Avoid-Shift-Improve framework dates back to the 1990s. The framework aims to reduce the negative environmental impact of urban transportation. The main tool of the framework is demand management from a holistic perspective. Although the rapid spread of COVID-19 dragged cities into a transport stalemate, Griffiths et al. (2021) interpreted the pandemic as an opportunity to achieve sustainable urban transportation. Therefore, the policy mix with the help of Avoid-Shift-Improve Framework was proposed to overcome the pandemic (Griffiths et al., 2021). The components of the framework are explained in Figure 2.12.

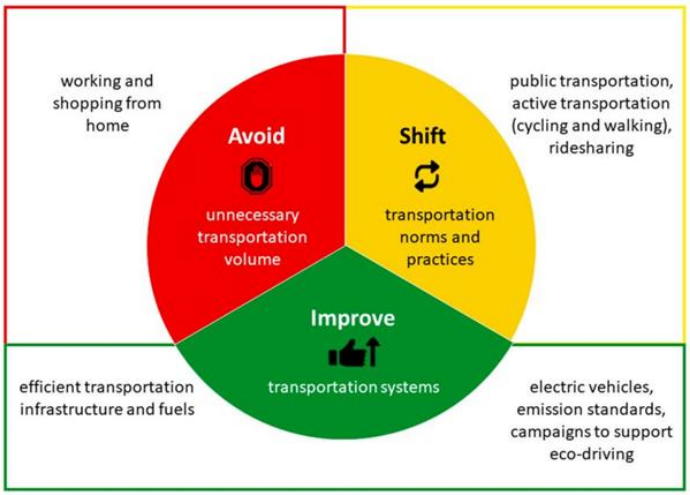


Figure 2.12: Components of Avoid-Shift-Improve (Griffiths et al., 2021)

- **Avoid:** The efficient use of transportation resources is encouraged with the principle of “Avoid”. The principle aims to reduce the excessive volume of transportation. Remote working opportunities and online shopping activities can be seen as a strategy to reduce the crowd and take

the burden on public transportation. The conceptual scheme is on the Figure 2.13. Moreover, physical setting of the built environment should offer different mobility options as a service. In this way, trip distance and dependency on private modes can be reduced. There are several movements, such as 15 Minute City based on the redesign of the built environment, in response to the effects of COVID-19. These movements prioritize the development of walkable and bike-friendly neighborhoods, with amenities in a close proximity, rather than public transportation.

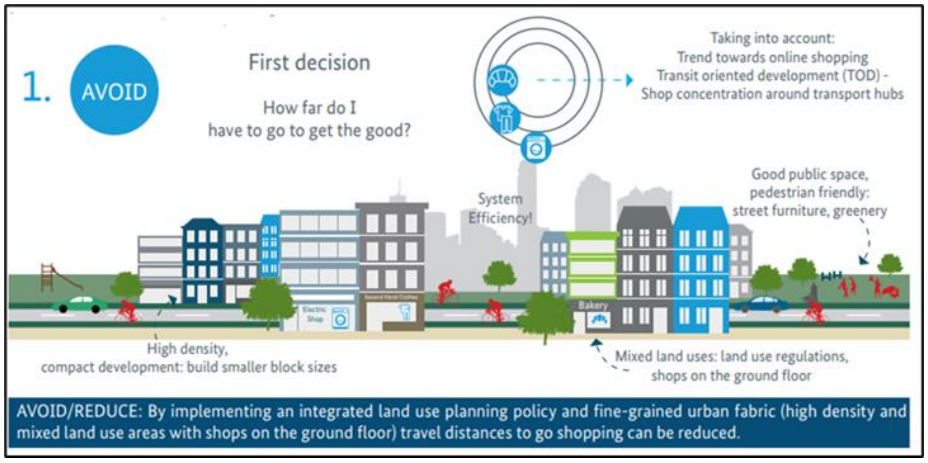


Figure 2.13: Framework of AVOID (Bongardt et al., 2019)

- **Shift:** One of the primary problems caused by COVID-19 is to shift from public transportation to private modes. Therefore, policies and strategies should be implemented to steer individuals towards active or public modes of transportation and illustrated in Figure 2.14. Expansion of bike lanes, ensuring pedestrian friendly environment and providing clean and safe public transportation can be mentioned as key strategies. Public awareness campaign should be conducted to promote active mobility and public modes.

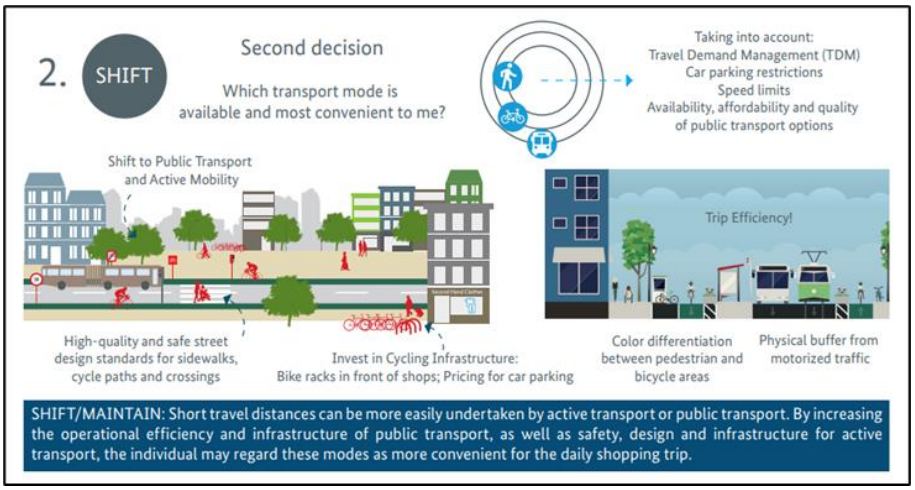


Figure 2.14: Framework of SHIFT (Bondgart et al., 2019)

- **Improve:** The last step of the framework is improving quality and efficiency of transportation system. Social distancing, combination with information technology and time savings should be taken into consideration. The awareness on the mode choice supported with the Improve principle is explained in Figure 2.15.

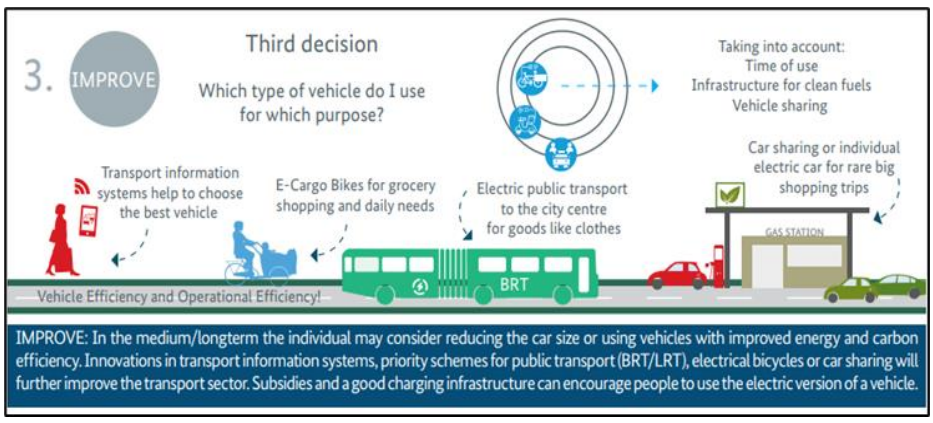


Figure 2.15: Framework of IMPROVE (Bondgart et al., 2019)

2.5 Concluding Remarks

This chapter provided a review of the factors for changing travel behavior during and after COVID-19, of newly emerging mobility patterns, as well as a discussion on measures and policy responses for adaptation to COVID-19. As each of them are highly related to the other, it is crucial to evaluate them by linking and discussing them as a whole. Therefore, as a concluding remark, each section is summarized with a key chart and then at the end of the section, a conceptual schema is produced to evaluate the literature.

In the first section of the chapter, changing mobility behavior and reasons for them were expressed in detail. With the onset of COVID-19, newly emerging factors played a critical role in shaping mobility behavior which was directly related to the changing mobility patterns. In addition to this, health and age were the main concerns in the choice of transportation modes. Income level and availability of private modes also influenced the mode choice and the use of public transportation. In Figure 2.16, the factors affecting mobility patterns are summarized.

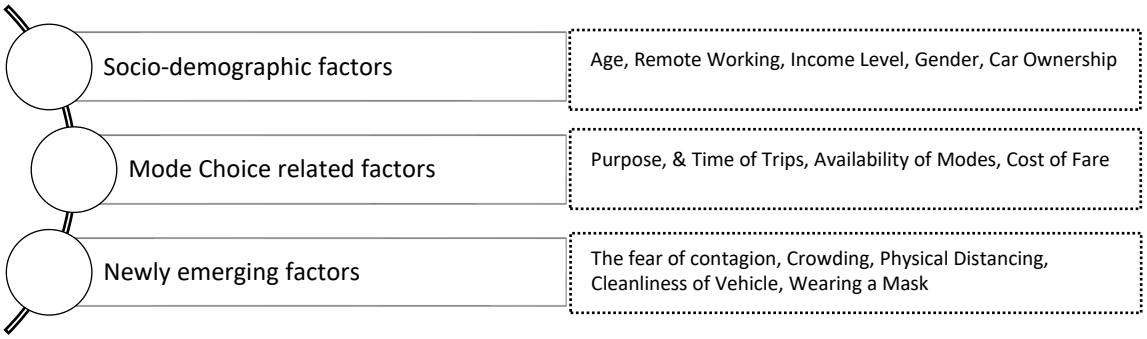


Figure 2.16: Summary of the factors (Author)

Implementation of urgent measures to control the spread of COVID-19 became inevitable. The different types of measures and their levels of effectiveness have been reviewed throughout the chapter. The main types of measures can be seen in Figure 2.17:

Control Measures	Keeping Social Distance Mandatory mask Wearing Travel by Reservation Health Code for Smart Cards Surface Cleaning and Ventilation
Operational Measures	Service Frequency Changing Timetables Fare Policy Additional lines or modes
Personal Measures	Vaccine PPE

Figure 2.17: Summary of The Measures (Author)

COVID-19 led to a decrease in public transportation rates. This changing trend because of COVID-19 caused the passengers who avoided public transportation to turn to private modes and active transportation modes. In developing countries, the use of private vehicles increased more than cycling and walking due to the lack of infrastructure for active transportation modes. However, public transportation is a basic need, and this mode should be planned in such a way that it will be least affected by the future crises. The main concern was that this trend would continue during the post-pandemic period and the demand for public transportation could decrease steadily.

Table 2.4 shows the key findings of the literature. In this research, these key findings were taken into consideration to evaluate the Post Pandemic Period.

Table 2.4: Key Findings of The Literature

Permanent Change	Comparison of Modes	The relation with COVID-19	Demand for active modes

Article	Year	Country	Data Collecting	Key Findings
Ali Enes Dingil & Domokos Esztergár-Kiss	2021	Worldwide	Online Survey (April 10 to May 10 in 2020)	Individual urban transportation modes might dominate the urban transportation in the upcoming years for intercity trips. The riskiest perceived transportation mode is bus.
Hector Monterde-i-Bort, Matus Sucha, Ralf Risser & Tatiana Kochetova	2022	Ten Countries*	Snowball Sampling Survey (the spring of 2020 & the fall of 2020)	Use of public transport loses ground and the level of use might not return the pre-pandemic level for a long time.
Kenneth B. Medlock III, TedTemzelides & Shih Yu (Elsie) Hung	2021	U.S	Spatial Analysis (Janurary in 2019 to July in 2020)	"given evidence that repeated pandemics are becoming more frequent in recent decades, the "shock" might have a permanent component."
Jaeyoung Lee, Farrukh Baig & Amjad Pervez	2021	Pakistan	A Questionnaire Survey	"The pandemic effects in developing countries, especially in Pakistan, may have long-lasting impacts considering the limited resources and facilities" It should be noted that contrary to developed countries, slow recovery from the alarming rate of the use of private modes has been predictable because of poorly equipped public transportation.
Dong-Gyun Ku, Jung-Sik Um, Young-Ji Byon, Joo-Young Kim & Seung-Jae Lee	2021	Korea Seoul	Paired Sample t-test	Since February 2020, when the first COVID-19 trend emerged, the number of domestic car sales in Korea increased every month when compared to that in the previous year.
Anne Halvorsen, Daniel Wood, Darian Jefferson, Timon Stasko, Jack Hui & Alla Reddy	2021	U.S (The New York City)	Descriptive Statistics (The first half of 2020)	A striking decline of up to 95 % of both subway and bus usage has been observed. However, as of late July, subway ridership was still only about 24% of what it was before the crisis, whereas bus ridership was 60%.
Joao T. Aparicio, Elisabete Arsenio & Rui Henriques	2021	Portugal (Lisbon)	(October in 2019 to May in 2020)	The demand on the metro station has been more than the tram and bus station. Demand has slightly changed in peripheral stations and lower-income regions. The number of stops on a public transportation route increase, the impact of COVID-19 on demand decreases
Armando Cartenì Luigi Di Francesco, Ilaria Henke, Teresa Valentina Marino & Antonella Falanga	2021	Italy	A correlation analysis (Februrary to December in 2020)	This is a strong relationship between the number of COVID-19 cases and the usage of public transportation with 0.87 coefficient rate.

Table 2.4 (Continued)

Article	Year	Country	Data Collecting	Key Findings
Angela Stefania Bergantino, Mario Intini & Luca Tangari	2021	Italy	Online Survey (April to May in 2020)	A 50% increase in the number of public bicycles will lead more than 40% of individuals to use bicycles. Moreover, in the post-lockdown period, more people are evidently willing to buy bicycles.
Muhammad Abdullah, Nazam Ali, Syed Arif Hussain, Atif Bilal Aslam & Muhammad Ashraf Javid	2021	Pakistan	Survey (May 9 to 31 in 2020)	67% of the respondents would shift from walking to motorized modes if the walking environments do not improve. Bicycle trips have been declining in Pakistan due to inadequate cycling infrastructure.

To prevent the unintended consequences of COVID-19 and to be ready for future crises, new approaches should be proposed. At this point, implementation of new methods should be prioritized to foster responsible public transport systems that are capable of addressing future crises.

The aim of this chapter was to establish the theoretical framework of the research. The methodology of the research that builds on the findings of the literature review is explained in the upcoming chapter.

CHAPTER 3

METHODOLOGY

3.1 Aims and Research Questions

The aim of the thesis is to analyze the impact of COVID-19 on the use of public transport systems. In particular, the analysis tries to find out whether there is a long-lasting and permanent impact on the demand for public transport. In doing so, the research also aims to investigate the differences of resilience between modes of public transportation in case of crises, particularly health crises. Additionally, it investigates policy responses to identify effective transportation policies for future resilience. Therefore, in the research, first it is questioned whether and how COVID-19 has changed the demand for public transportation. Secondly, it is questioned whether the lessons learned from the crisis led to a new policy approach for resilience for future crisis. In this frame, research questions are formulated as follows:

- Is there a long-lasting impact of COVID-19 on demand for public transportation?
    - Which modes of public transportation recovered fast during the pandemic and in the post-pandemic era?
    - What are the most resilient modes of public transportation? What are the most vulnerable ones?

- Which policy responses and measures have been effective in making public transportation more resilient?
    - To what extent do the measures determine the mitigation of COVID-19 impacts on public transportation?
    - Are there any plans or policies to become resilient for future crises?

3.2 The Method for Data Collection and Analysis

The methodology of the research is planned in two steps as a response to the two research questions. Research methods have been chosen specifically to address these research questions.

Descriptive research is beneficial to answer the first research question. The method is used in order to determine the current situation and to evaluate the effects on public transportation in the post-COVID-19 period. The data were collected for three periods to observe the change in demand for public transportation modes. The monthly public transportation ridership data were compiled before and during the pandemic in the first and second periods. In the third period, to understand the long-lasting impact of COVID-19, data on ridership levels in 2021 and 2022 were collected. For the analysis, the data (public transportation passenger levels and monthly passenger levels per mode between 2018 and 2022) was obtained from Istanbul Metropolitan Municipality - Public Transportation Services Directorate. To investigate the recovery periods of public transportation modes, the monthly number of passengers in 2019 has been compared to the number of passengers between 2020 and 2022.

In the study, the ridership level of public transportation modes has been compared in the periods before, during and after COVID-19.

- Before COVID-19: All months of the year 2019 and January and February of the year 2020 (March 2020 being the declaration of first COVID-19 case)
- During COVID-19: From April 2020 until the end of March 2022 (as March 2022 marks the lifting of the obligation to wear masks in the open air)
- After COVID-19: From April 2022 until the end of December 2022

In doing so, public transportation has been examined under three main categories which are the urban rail system (Metro, Tram, Marmaray), road-based public transportation (Bus, Metrobus (BRT)), and maritime transportation.

In the analysis, the recovery period is the time it takes for demand for public transportation (number of passengers) after the pandemic to return to the pre-pandemic level. Public transportation modes with shorter recovery times (compared to other modes) are characterized as resilient modes, while modes with a relatively slower recovery time are characterized as vulnerable modes.

Moreover, COVID-19 measures of transportation have been compiled with COVID-19 reports published by the Istanbul Metropolitan Municipality by **collecting written documents and reports.**

For the second research question, **semi-structured interviews** have been carried out with policymakers to evaluate the impact of COVID-19 on the resilience of public transportation and policy approaches to be prepared for future crises. The interviews aim to understand the concerns and priorities of policymakers involved in decision-making about the resilience of public transportation. Through interviews, it is expected that policymakers can share their experiences with the challenges and successes in implementing resilience measures in public transport systems, highlighting potential barriers and opportunities for improvement.

Five interviews have been conducted with experts on public transportation sector. The experts interviewed are listed below:

- Deputy Secretary General, Istanbul Metropolitan Municipality
- Head of Transportation Department, Istanbul Metropolitan Municipality
- Pedestrian Accessibility Department Chief, Istanbul Metropolitan Municipality
- General Manager, Istanbul *Şehir Hatları* (Maritime Transportation)
- Head of Transportation Planning Department, IETT

In brief, the steps of the analysis are as follows:

- Explaining the public transportation system in Istanbul
- Examining COVID-19 calendar in Istanbul

- Analyzing the demand for public transport rates and population annually (between 2018 and 2022)
- Comparing the recovery period of different modes of public transportation levels for three main categories (urban rail, road-based and maritime) (between 2018 and 2022)
- Comparing the level of demand for urban-rail lines (between 2018 and 2022)
- Post-COVID-19 responses: resilience for future crisis in Istanbul (in depth interview)

3.3 Selection of The Case

While choosing the study area, the public transportation alternatives of the cities and the level of the impact of COVID-19 have been taken into consideration. In Istanbul, public transportation trips account for approximately 50% of trips (Alpkokin & Ergun, 2012). It is crucial to emphasize that this rate is above the national average. On the other hand, after the declaration of COVID-19 by WHO, about 80% of decline (Aydın et al., 2022) in public transportation usage has been observed in the city. The statistic has underlined the fragility of urban public transportation system in Istanbul, making this case particularly crucial to analyze. Furthermore, the public transport system in Istanbul comprises a diverse set of systems, varying from regular buses, Bus Rapid Transit, urban rail systems and maritime transport systems. This variety allows for a comparison of modes in terms of vulnerability, recovery and resilience. To the knowledge of the author, this is the first research which investigate the change in the ridership of maritime transportation during and after pandemic in the literature, although it should be noted that the research does not focus solely on maritime transport but analyses this mode in comparison with other public transport systems. In short, Istanbul is appropriate to understand the response of public transportation to COVID-19 and the to investigate recovery and resilience in the post-pandemic period.

Using the research methodology described above, the analysis is conducted to explore the changing demand for public transportation during and after COVID-19 in Istanbul. The analysis also explores newly emerging transport policy approaches from the point of decision makers' view. Before the analysis, the next chapter will provide information on public transportation systems and COVID-19 history in Istanbul.

CHAPTER 4

GENERAL INFORMATION ON PUBLIC TRANSPORTATION SYSTEM AND COVID-19 PERIOD IN ISTANBUL

Istanbul is the most populous city of Turkey, connecting the continents of Europe and Asia. The urban transportation system in Istanbul offers a wide range of alternatives compared to other Turkish cities. The public transportation system is mainly provided with the support of bus services under the management of Istanbul Electric Tramway and Tunnel Enterprises (IETT), para-transit modes in the outer districts, and urban rail transportation systems with different lines. By taking advantage of the geographical location of Istanbul, maritime transportation systems also play a role, and they are composed of classical ferries and modern sea buses belonging to the Incorporated Company of Istanbul Fast Ferries (IDO).

In this chapter of the study, each mode of the urban public transportation system is explained in detail. The COVID-19 history and measures for public transportation measures are explained to provide a comprehensive understanding of the background for the impact of COVID-19 on public transportation ridership and the factors that contributed to the observed changes. In the last part, the trends in the ownership of private motorized vehicles are discussed briefly to identify potential reasons for changes in public transportation ridership.

4.1 Urban Rail Systems

Metro Istanbul, established in 1988 under the name of Istanbul Transportation, operates the urban rail systems (Istanbul metro and Istanbul tram systems). Urban rail system in Istanbul covers the regional rail system named Marmaray, metro, tram, light rail, funicular and aerial cable car. The length of the line, number of stations, trip duration, headway and operating hours of these systems are presented in Table

4.1. This information is beneficial in analyzing the change in the ridership level of urban rail systems during and after COVID-19. Adsditionally, the service area of urban rail lines can be seen in Figure 4.1. Each one of them is described in the following sub-headings.

Table 4.1: Information on Urban Rail Systems in Istanbul

	Opening Date	**Length of The Line**	**Number of Stations**	**Trip Duration**	**Headway**	**Operating Hours**
Marmaray	29. 10.2013 / 12.03.2019	76,6 km	43	115 mins	8 mins / 10 mins	06:00 – 24:00
M1A-M1B Metro Lines	03.09.1989 / 14.06.2013	26,8 km	23	32 mins	3 mins	06:00 – 24:00
M2 Metro Line	16.09.2020	23,49 km	16	32 mins	2,5 mins rush hours	06:00 -24:00 / 24 hours weekend
M3 Metro Line	14.06.2013	12,49 km	9	20 mins	5 mins at rush hours	06:00 -24:00
M4 Metro Line	17.08.2012	26,50 km	19	39 mins	4 mins at rush hours	06:00 - 24:00
M5 Metro Line	15.12.2017	20 km	16	32 mins	4 mins 40 sec at rush hours	06:00 - 24:00
M6 Metro Line	19.05.2015	3,3km	4	5 mins	5 mins	06:00 – 24:00
M7 Metro Line	28.10.2020	18 km	15	30 mins	4 mins 40 sec at rush hours	06:00 -24:00
M9 Metro Line	29.05.2021	6 km	5	10 km	8 mins at rush hours	06:00 - 24:00
T1 Tram Lines	13.06.1992	19,3 km	31	65 mins	2 mins at rush hours	06:00 - 24:00
T3 Tram Lines	1.11.2003	2,6 km	11	20 mins	7 mins at rush hours	07:00 - 24:00
T4 Tram lines	17.09.2007	15,3 km	12	22 mins	3 mins at rush hours	06:00 - 24:00
T5 Tram Lines	01.01.2021	8,8 km	12	20 mins	20 mins at rush hours	06:00 – 24:00
Metrobus	15.09.2007	52 km	44	100 mins	2 mins /	24 hours

M1 Aksaray-Airport	**M2** Taksim-4.Levent	**M3** Kirazlı-Olimpiyatkoy	**M4** Kadıkoy-Kartal Metro	**M5** Uskudar-Çekmekoy	**M6** Levent-Hisarustu

Source: Data obtained from the website of Metro Istanbul

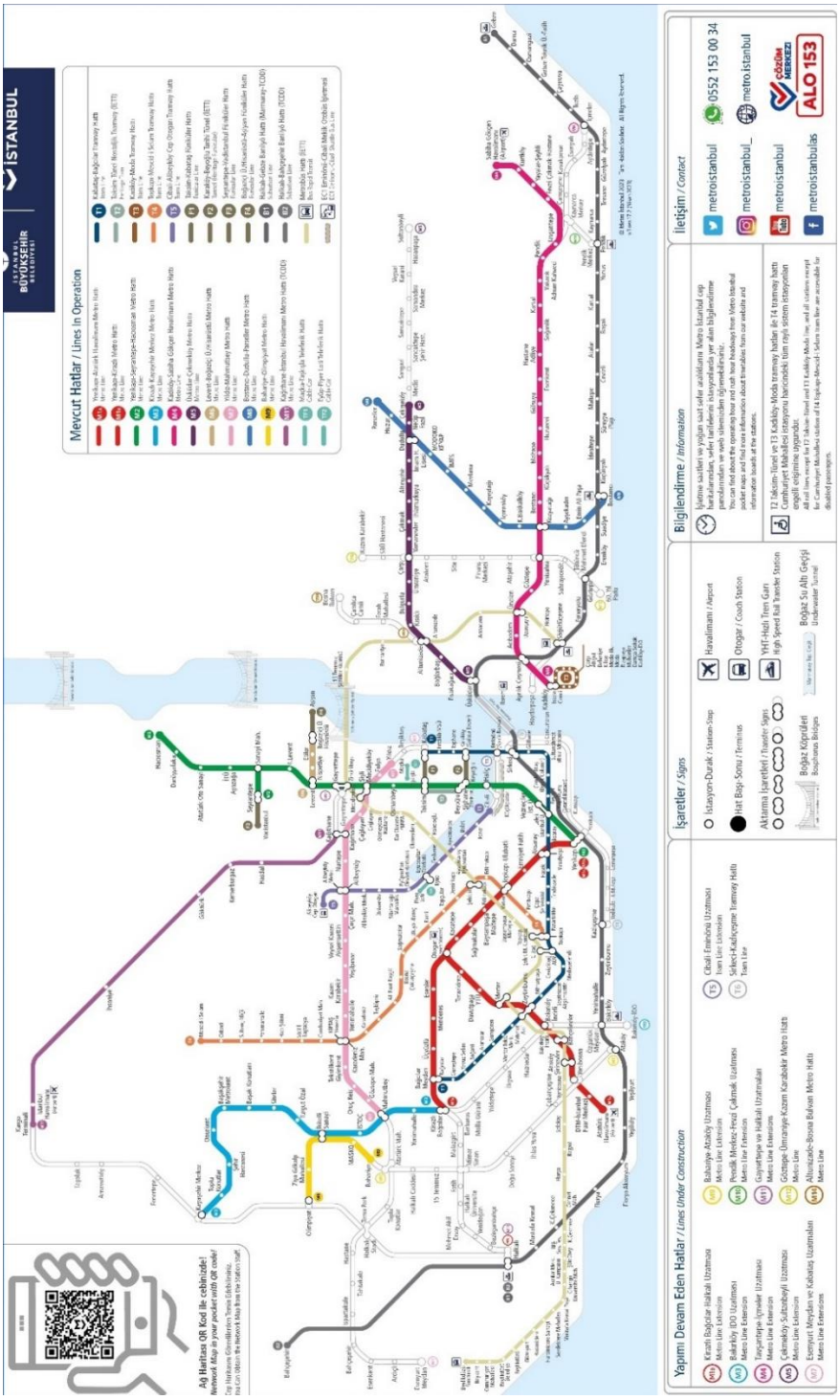


Figure 4.1: Urban Rail Lines Map (IBB,2022)

4.1.1 Marmaray (Halkalı – Gebze)

Marmaray is a system that connects the Anatolian and European sides of the city with a tube passage under the sea. The Republic of Turkey State Railways (TCDD) is responsible for the Marmaray Stations and its infrastructure in Istanbul. An integrated transportation system is provided, with Marmaray and the urban rail systems being integrated with each other in terms of route and fare/ticket integration.

4.1.2 Metro Lines, Funiculars and Aerial Cable Cars

Metro Lines

- **M1A – M1B Metro Lines**

M1A (Yenikapı – Atatürk Airport) line is the first metro in Istanbul, which has been operating since 1989. It is the metro line connecting Atatürk Airport to the old Istanbul (Yenikapı). However, Atatürk Airport is not actively used today.

M1B (Yenikapı – Kirazlı) is a light rail transit which has the same routes as M1A line between Yenikapı and Bus Terminal. The line, which changes the route after the Bus Terminal, ends in Kirazlı and it is integrated with the M3 Kirazlı-Olympic-Basakşehir metro line.

- **M2 (Yenikapı-Hacıosman) Metro Line**

The M2 (Yenikapı-Hacıosman) metro line starts from Yenikapı and provides connections to the historical and cultural center of Beyoğlu with the Golden Horn metro bridge. The line passes through Mecidiyeköy, Levent and Maslak, where important business centers are located.

- **M3 (Kirazlı - Başakşehir) Metro Line**

The M3 (Kirazlı-Olympic-Basakşehir) metro line connects the new urban development areas in the north of the city and the industrial and commercial zones on the route with the help of integration with other lines.

- **M4 (Kadıköy - Sabiha Gökçen Airport) Metro Line**

The first phase of the line was opened in 2012 between Kadıköy and Kartal. The line was extended to Tavşantepe in 2016, and to Sabiha Gökçen Airport on October 2, 2022.

- **M5 (Üsküdar- Çekmekoy) Metro Line**

The M5 line as the second metro line on Anatolian side connects Üsküdar, which is the connection point with the European side and the Anatolian side.

- **M6 (Levent – Boğaziçi University/Hisarüstü) Metro Line**

This short metro line enables passengers of the M2 lines to reach Boğaziçi University and Hisarüstü Area.

- **M7 (Mecidiyeköy - Mahmutbey) Metro Line**

M7 is the metro line that provides the integration of Şişli, Kağıthane, Eyüpsultan, Gaziosmanpaşa, Esenler, and Bağcılarwhich are the residential areas of 3 million of Istanbul's population, with the M2 metro.

- **M9 (Bahariye - Olimpiyat) Metro Line**

It is the line that provides the connection between Bahariye and Atatürk Olympic Stadium, which hosts sports organizations.

Tram Lines

- **T1 (Kabataş – Bağcılar) Tram Line**

T1 Line, as the first and longest tram line in Istanbul, has been operating since 1992. The T1 line is integrated with Kabataş Terminal (Station of Maritime Transportation) and the M2 (Yenikapı - Hacıosman) Metro Line via the F1 (Taksim - Kabataş) Funicular Line.

- **T3 (Kadıköy – Moda) Tram Line**

T3 line is known as a nostalgic tram which operates as a ring between Kadıköy (center of Anaatolian Side) and Moda.

- **T4 (Topkapı – Mescid-I Selam) Tram Line**

The tram line starts from Topkapı, passes through Bayrampaşa, Eyüp Sultan, Gaziosmanpaşa and extends to Sultangazi, extending to the peripheries of Istanbul.

- **T5 (Cibali-Alibeyköy) Tram Line**

The line connects the intercity bus terminal to the historical center of Istanbul, following the coastline of European Side.

Funicular and Aerial Cable Cars

Funiculars and aerial cable cars play an important role in transport considering the topography of Istanbul. By connecting different lines over topographic barriers, they also operate as transfer centers. These are supported at many points in order to ensure integration in public transportation in Istanbul and to shorten transportation times.

- F1 (Taksim – Kabataş) Funicular
- F4 (Aşiyan –Boğaziçi Unıversity) Funicular
- Maçka-Taşkışla Aerial Cable Car Line
- Eyüp-Piyer Loti Aerial Cable Car Line

4.2 Road-based Public Transportation

4.2.1 Metrobuses [Bus Rapid Transit (BRT)]

Istanbul Electric Tramway and Tunnel Enterprises (IETT) is responsible for road based public transportation services in Istanbul under the Istanbul Metropolitan Municipality. The bus rapid transit system in Istanbul is called Metrobus, and it is 52 kilometers long with 44 stations. Metrobus is an alternative way to connect Anatolian and European side but the line is shorter than Marmaray. There are six lines operating 24 hours a day on the east-west axis as Söğütlüçeşme Zincirlikuyu, Cevizlibağ, Avcılar Central - University Campus and Beylikdüzü (Metrobüs Hatları, n.d.).

4.2.2 Buses and Minibuses

There have been both publicly operated buses and privately operated buses in Istanbul. Privately operated buses have been managed by three different operating systems. However, the fact that private buses operate in 76 different narrow areas has been an obstacle for transferring buses to areas in need. Therefore, in 2020, privately operated buses were switched to the control of IETT. 3,041 private buses and 930 public buses started to be operated by IETT. The number of average daily trips is 3 million 785 thousand trips with 6 thousand buses on 814 bus lines operated by IETT in Istanbul.

Minibuses and taxi-minibuses in Istanbul serve as paratransit modes, feeding the public transportation system. Minibuses and taxi-minibuses operate on fixed routes, similar to buses, with more flexible scheduling and can stop to pick up and drop off passengers anywhere along their route. These vehicles are registered and controlled by the Municipality. However, the fare policy is different from the public transportation system. The fare is paid in cash, depending on the distance, and the ticket or fare system is not integrated with public transportation. Due to the lack of

reliable data on their ridership, the paratransit systems are beyond the scope of this thesis.

4.3 Maritime Transportation

In Istanbul, maritime transportation is a unique mode which connects the two continents, Asia and Europe, as well as providing access between the neighborhoods along the Bosphorus. This mode is not only used for access but also used for touristic purposes. Maritime transportation is under the responsibility of *Şehir Hatları*. Services has been operated since 1945 while *Şehir Hatları* was introduced as a subsidiary company of Istanbul Metropolitan Municipality in 2005. The maritime transportation service is provided with 58 piers and 28 ferries. The Maritime lines are shown in Figure 4.2. together with transfer stations.

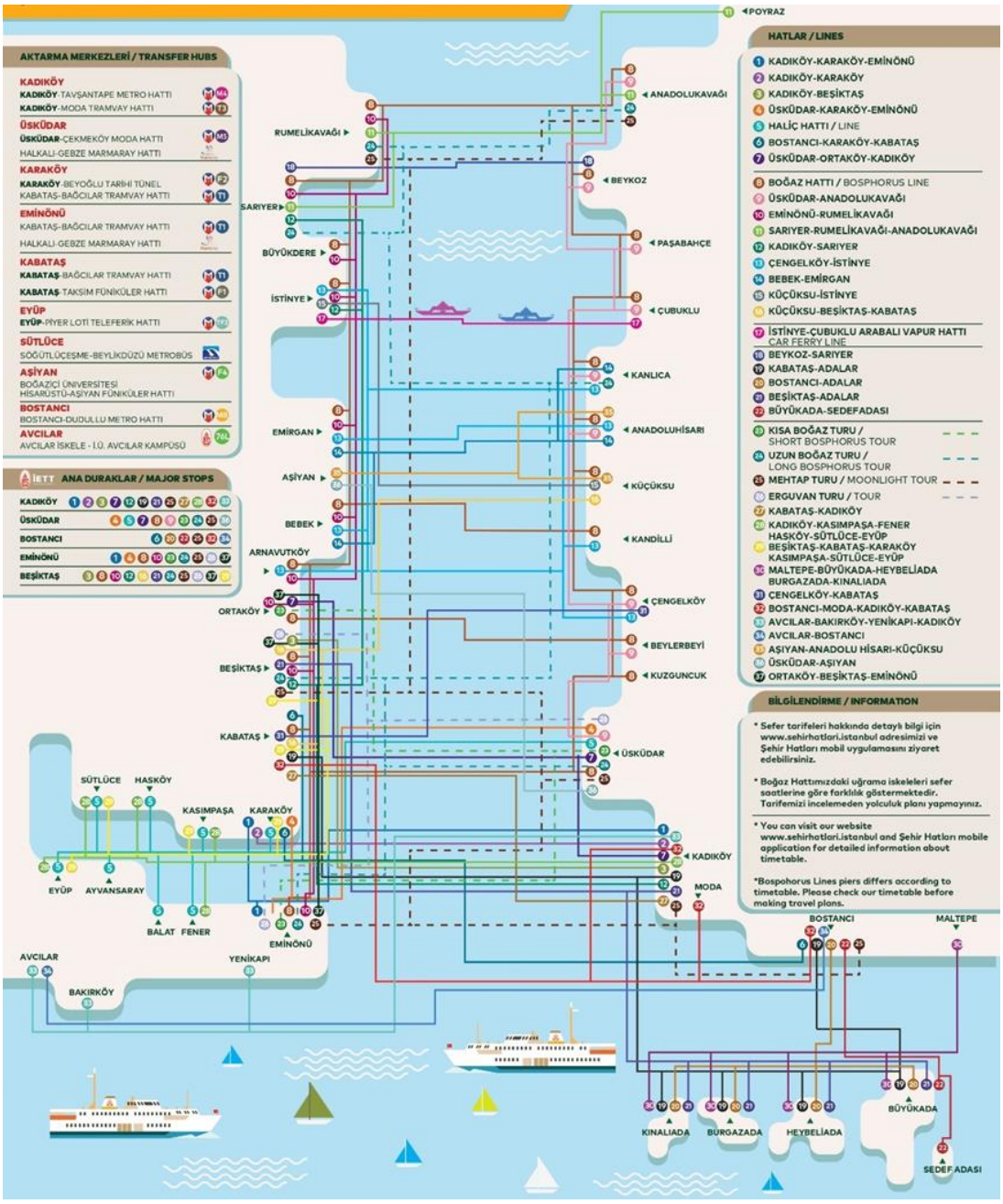


Figure 4.2: Maritime Transportation Lines Map (*Şehir Hatları*, 2022)

4.4 COVID-19 History in Istanbul

In the time line shown in Figure 4.3, key measures and restrictions of COVID-19 influencing urban mobility is demonstrated. The first case with a diagnosis of COVID-19 was seen on March 11, 2020 within the borders of the Republic of Turkey (Gungor, 2020).

The Coronavirus Board and Operations Center of the Ministry of Health had been established before the first COVID-19 case was identified. However, measures for public transportation were implemented to control the spread of the outbreak after the declaration of the first COVID-19 case. Immediately afterwards, measures such as suspending education, switching to distance education, and switching to flexible working hours in public institutions were implemented. The capacity of public transportation was cut in half in the initial period of spread in Turkey, which was an immediate response to control the pandemic.

The number of COVID-19 cases in Turkey reached its peak levels in April 2020 (Gungor, 2020). In order to provide reliable information, "*Hayat Eve Sığar*" mobile application, which includes COVID-19 case density maps, has been launched. In parallel with the increase in cases, more strict measures have been implemented. For this reason, it was a period when curfews were supported intensely.

The list of curfews implemented all day in chronological order is shown in Figure 4.3 and the Table 4.2. In addition, as can be understood from the calendar shown in Figure 4.3, the curfews were implemented according to high-risk groups, with respect to health and age.

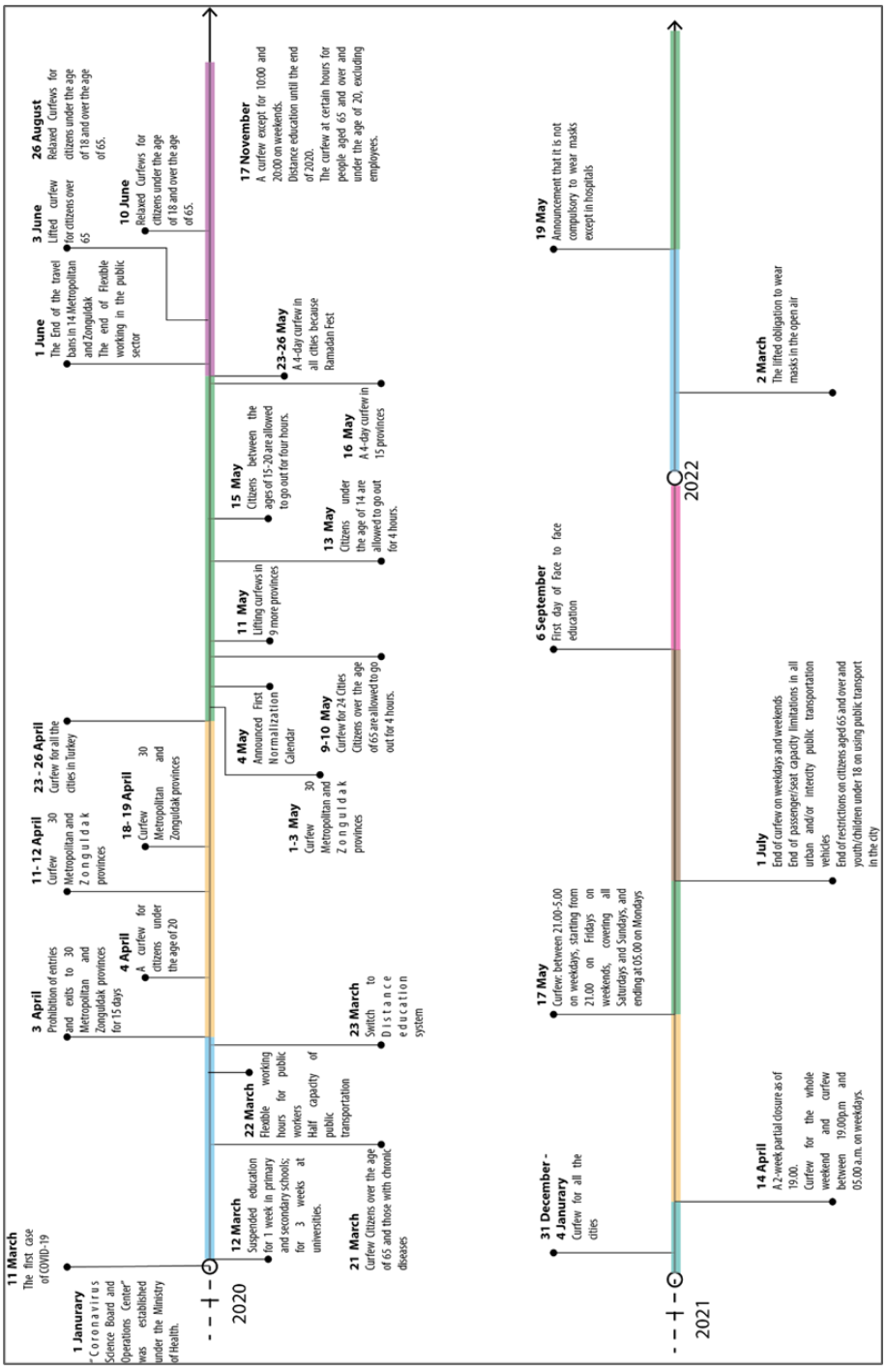
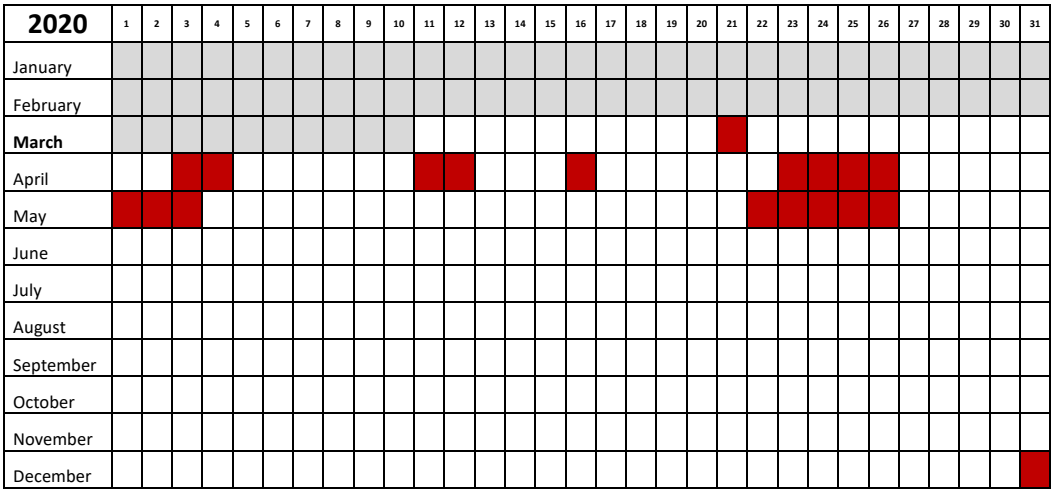


Figure 4.3: The Timeline of COVID-19 in Istanbul

Source: Data obtained from the website of COVID-19 of Istanbul Metropolitan Municipality

Moreover, partial curfews seen in the timeline have been implemented during weekends or after certain time of weekdays (see Table 4.2). Apart from these bans, a curfew has been imposed for citizens over the age of 65 as of March 21, 2020. Additionally, a curfew has been imposed for citizens underthe age of 19 as of April 21, 2020. During the normalization periods, curfews have been alleviated and citizens have been allowed to go out at certain times of the day.

Table 4.2: The Timeline of Curfews in Istanbul



As of May 4, 2020, with the decrease in the number of cases, a gradual normalization period has started and the calendar of the gradual normalization period has been announced.

- **4 to 26 May in 2020**: The first period is called as the preparation of normalization processes.
- **27 May in 2020 to 31 August in 2020:** It is the period in which the measures were determined according to the map in which provinces were grouped as low risk (blue), medium risk (yellow), high risk (orange) and very high risk (red) according to the number of COVID-19 cases.

On January 14, 2021, the steps of the normalization period were accelerated with COVID-19 vaccine. In 2021, the measures have been eased and the obligation to use masks has been abolished as of 19 May. It is possible to say that the second half of 2021 was the beginning of the recovery process.

According to the COVID-19 calendar in Istanbul, local governments implemented measures for public transportation, which will be described in the following section along with their classification.

4.4.1 Prevention and Control Measures adopted in Istanbul for Public Transportation during COVID-19

To control the rapid spread of COVID-19, every city has sought new regulations for public transportation. As discussed in the literature, the categories of the prevention and control measures of the outbreak are demonstrated in Figure 4.4 to interpret their impact on public transport.

Control, operational and personal measures for public transportation in Istanbul were investigated. At first glance, it appears that each type of measure was implemented in Istanbul for public transportation. In addition to the measures, the website of Istanbul Municipality (https://koronavirus.ibb.istanbul/) was established to provide reliable information for citizens. Moreover, in the "Reports to Struggle COVID-19" published regularly, the measures taken regarding the use of public transportation were shared with the public. Different modes of public transportation were taken into consideration separately. The measures were implemented specific to the modes of public transportation. The first measure was the disinfection of vehicles to ensure hygiene in public transportation. The schedule of the public transportation system was regulated to limit mobility except for commuting. To reduce the physical contact, social distance rule was implemented in the public transportation vehicles. Free fare policy was encouraged for key health workers. The change in the measures can be clearly seen in Figure 4.4.

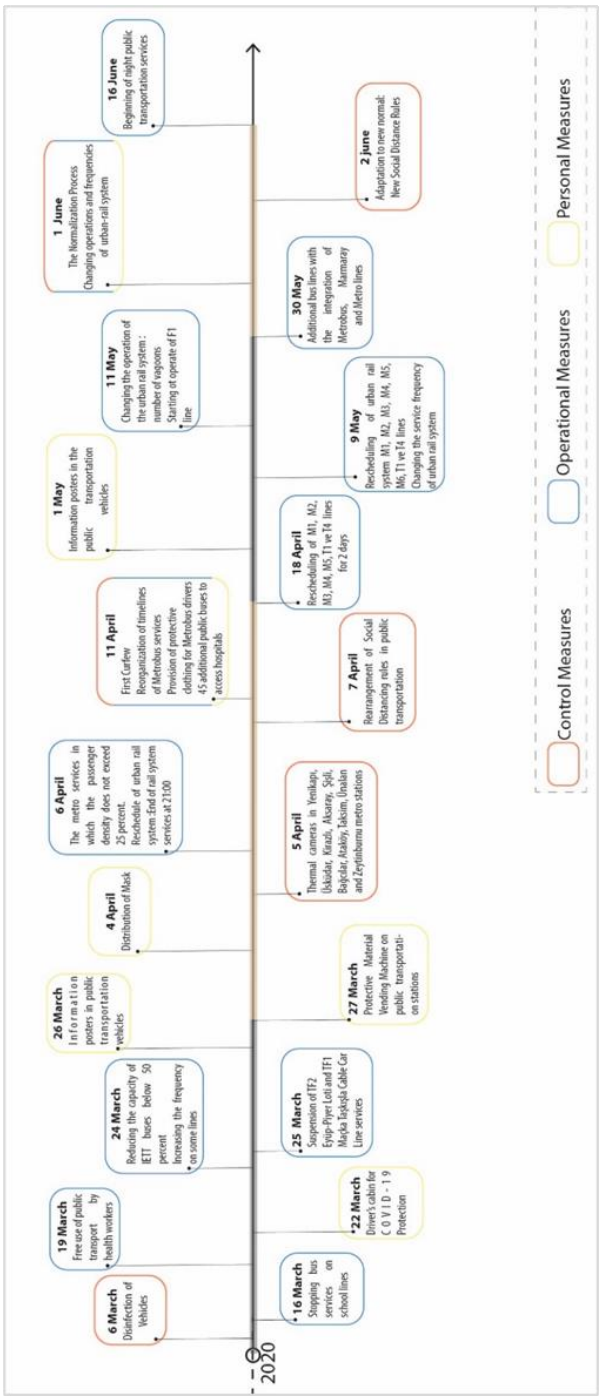


Figure 4.4: The Categories of Measures for Public Transportation During COVID-19 in Istanbul

Source: Data obtained from the website of COVID-19 of Istanbul Metropolitan Municipality

In the early days of the pandemic, the primary purpose was to limit mobility except for non-discretionary travel (going to work, school, and hospital). Subsequently, the regulations concentrated on providing clean and safe public transport. Operational, control and personal measures in Istanbul were implemented in a balanced way to control the spread of the pandemic (see the Figure 4.4.). It is apparent in Figure 4.4 that operational measures were the critical tool for the adaptation to COVID-19.

Implementing flexible working schedule is one of the effective ways to enable individuals to use public transportation capacity. The smart methods (except for Health Code for Smart Cards) mentioned in the literature were not implemented for public transportation in Istanbul.

4.5 The Ownership Level of Private Motorized Vehicles

As one of the key emphases of the literature, the pandemic of COVID-19 resulted in a rise in private motorized modes (Babalık, 2020; Luan et al., 2022; Moody et al., 2021; Ku et al., 2021). Before analyzing public transportation before and after COVID-19, it is important to identify potential reasons for changes in public transportation ridership. The ownership level of private motorized modes has also been discussed with the policymakers to understand the role of public transport in reducing private motorized vehicles ownership levels, and this is described in the section about the interviews made.

The decline in the ridership level of public modes of transportation was accompanied with a shift to private modes. Investigating whether this trend continues is decisive in measuring the resilience of public transport. If this trend continues with a sharp increase, this may mean that a resilient and safe public transport system is not provided with the decrease in public transport use.

First of all, the number of automobiles and motorcycles is examined yearly to compare the periods before and after the pandemic across the country and in Istanbul. Table 4.3 shows the comparison of private vehicles ownership level in Turkey and

Istanbul. The higher rate of increase in Istanbul compared to Turkey might be explained by the suggesting that COVID-19 has affected mobility patterns more adversely in Istanbul.

Table 4.3: Number of Total Private Motorized Vehicles (Automobile & Motorcycle) per Year in Istanbul and Turkey

Years	Istanbul	Turkey	Increase in İstanbul (%)	Increase in Turkey (%)
2011	2.098.687	10.640.301		
2012	2.216.408	11.306.597	5,61	6,26
2013	2.369.564	12.006.749	6,91	6,19
2014	2.514.665	12.686.381	6,12	5,66
2015	2.722.768	13.527.701	8,28	6,63
2016	2.918.470	14.321.731	7,19	5,87
2017	3.104.818	15.138.778	6,39	5,70
2018	3.197.572	15.609.518	2,99	3,11
2019	3.209.565	15.834.375	0,38	1,44
2020	3.379.951	16.611.617	5,31	4,91
2021	3.594.209	17.450.435	6,34	5,05
2022	3.835.146	18.411.266	6,70	5,51

Source: Data obtained from Turkish Statistical Institute (TURKSTAT)

According to the numbers, it is apparent that private motorized vehicle ownership did not fluctuate in Turkey and slightly changed in Istanbul between 2011 and 2017. In 2018, the rate of increase was much lower in Turkey and in Istanbul compared to previous years, probably due to the economic decline in the country. In 2019, the rate of increase in Istanbul was much lower, almost half of the rate of increase in Turkey. However, by 2020, these rates suddenly increased and the rate of private vehicle ownership in Istanbul increased by approximately 5%, exceeding the average increase in Turkey. In other words, because of the pandemic, private vehicle ownership increased throughout the country, and the rate of increase in Istanbul exceeded the Turkish average rate of increase.

It is essential to analyze the level of ownership in 2022 to comprehend if the rate of ownership increased steadily in the post-COVID-19 period. 35 960 private motorized vehicles were added, creating 1% increase in 2022. The data for 2022 clearly showed that after 2019, the increase rate of private motorized vehicle ownership exceeded the rate of Turkey. It should be noted that although fuel prices almost tripled in 2022, private vehicle ownership increased. The continuous increase, especially after 2019, indicates that the pandemic significantly impacted vehicle ownership levels and possibly mobility patterns. In fact, the rise in private motorized vehicles due to the pandemic is expected, as stated in the literature. The fact that the use of private vehicles became more valuable than before the pandemic (Moody et al., 2021) may be one of the reasons for this increase. However, it should be noted that the data is only about the ownership level of private motorized vehicles; unfortunately, the data on the usage of private motorized modes is limited in Istanbul.

4.5.1 Automobile Ownership

Private motorized modes are examined separately as automobile and motorcycle ownership to grasp the change in the ownership in a more detailed way. The change in number of automobiles per month is compared to the change in 2019 which is the year right before the pandemic. The monthly change in the number of automobiles is highlighted in Table 4.4.

While the monthly change in the number of automobiles showed a negative trend in 2019, it started to demonstrate a positive change especially after 2020. Especially in July in 2020, the number of automobiles increased by 24 281 and reached 2 927 974, representing an increase of 0.84%. It can be inferred that concerns over using public transportation created an increase in automobile sales. It can also be interpreted that due to curfews, urban mobility decreased between March and July; and when the population returned to normal life in July, they preferred private vehicles. In fact, Thomas et. al (2021) explained that contagious diseases led to changes in previous transportation decisions.

Table 4.4: The Change in The Number of Automobile per month between 2019 and 2022 in Istanbul

Automobile	2019	2020	2021	2022	Change in % in 2019	Change in % in 2020	Change in % in 2021	Change in % in 2022
January	2 895 629	2 889 968	3 035 727	3 178 321				
February	2 890 918	2 889 938	3 047 221	3 189 717	-0,16	0,00	0,38	0,36
March	2 889 537	2 899 732	3 071 494	3 206 859	-0,05	0,34	0,80	0,54
April	2 889 288	2 904 130	3 087 970	3 225 890	-0,01	0,15	0,54	0,59
May	2 886 943	2 905 769	3 100 848	3 239 828	-0,08	0,06	0,42	0,43
June	2 886 575	2 903 693	3 113 303	3 252 957	-0,01	-0,07	0,40	0,41
July	2 887 997	2 927 974	3 131 936	3 272 563	0,05	0,84	0,60	0,60
August	2 884 905	2 939 395	3 139 669	3 286 820	-0,11	0,39	0,25	0,44
September	2 881 188	2 948 435	3 146 946	3 297 586	-0,13	0,31	0,23	0,33
October	2 881 137	2 969 404	3 152 076	3 307 777	0,00	0,71	0,16	0,31
November	2 879 657	2 990 229	3 154 804	3 320 738	-0,05	0,70	0,09	0,39
December	2 876 156	3 009 710	3 162 884	3 328 008	-0,12	0,65	0,26	0,22
TOTAL	**34 629 930**	**35 178 377**	**37 344 878**	**39 107 064**				

Source: Data obtained from Turkish Statistical Institute (TURKSTAT)

The change in transportation choice became more visible with the increasing number of automobiles in 2020. After July of 2021, the increase rate of number of automobiles gradually decreased. Despite declining automobile ownership in 2019, the increase continued until the end of 2022. The difference in automobile ownership between 2019 and 2022 can be seen very clearly in the Figure 4.5. The necessity of automobile ownership (Luan et al., 2022) might be perceived as the first option for access because of the restriction of public transport during COVID-19. The perception of the necessity of having a vehicle could force individuals to own automobiles. However, although this perception was common throughout the pandemic, after the pandemic, it might lose its prevalence. In other words, the reasons for using automobile can differ before and after the pandemic.

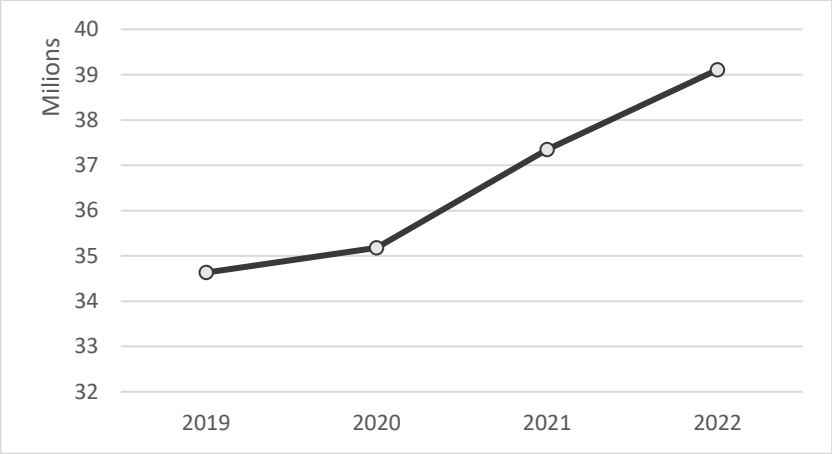


Figure 4.5: The Comparison of Automobile Ownership per year in Istanbul

Source: Data obtained from Turkish Statistical Institute (TURKSTAT)

During the pandemic, one of the main reasons for using automobiles was the fear of contagion. However, this reason might be replaced with comfort, convenience and time-saving after the pandemic. Because of the increase in the demand for public transportation after the pandemic, as discussed in detailed in the next chapter, it can be argued that the effect of factors such as fear of contamination on public transportation might have decreased.

4.5.2 Motorcycle Ownership

Similar to the level of automobile ownership, the increase rate of motorcycle ownership has demonstrated a stark increase in 2020. The number of motorcycles reached 325 505, increasing by 1.47% between June and July 2020. Since 2020, the demand for motorcycles has increased gradually. Moreover, the increase rate has almost doubled compared to the increase rate of automobiles. Although the number of automobile ownership is higher than for motorcycles, the increase in demand for motorcycles seems to be higher than for automobiles. This change is shown in Table 4.5.

Table 4.5: The Change in The Number of Motorcycle per month between 2019 and 2022

Motorcycle	2019	2020	2021	2022	Change in % in 2019	Change in % in 2020	Change in % in 2021	Change in % in 2022
January	311 325	334 658	373 264	434 142				
February	312 904	336 196	377 097	437 945	0,51	0,46	1,03	0,88
March	315 405	338 340	382 503	442 233	0,80	0,64	1,43	0,98
April	317 561	340 227	387 664	452 795	0,68	0,56	1,35	2,39
May	320 449	342 676	392 207	463 280	0,91	0,72	1,17	2,32
June	322 947	347 067	398 420	469 794	0,78	1,28	1,58	1,41
July	325 505	352 164	404 747	474 823	0,79	1,47	1,59	1,07
August	327 027	356 135	411 067	481 036	0,47	1,13	1,56	1,31
September	329 190	360 345	417 037	486 917	0,66	1,18	1,45	1,22
October	330 798	364 289	421 750	492 576	0,49	1,09	1,13	1,16
November	332 344	367 209	427 435	499 081	0,47	0,80	1,35	1,32
December	333 409	370 241	431 325	507 138	0,32	0,83	0,91	1,61
TOTAL	**3 878 864**	**4 209 547**	**4 824 516**	**5 641 760**				

Source: Data obtained from Turkish Statistical Institute (TURKSTAT)

To compare the two private motorized modes, the change in November and December of 2022 and 2020 can be interpreted. In November and December of 2022, automobile ownership increased by 7 270, while motorcycle ownership increased by 8 057. On the other hand, automobile ownership increased by 19 481, while motorcycle ownership increased by 3032 in November and December of 2020. It should be noted that when access to private motorized modes is considered, owning a motorcycle might be more affordable compared to an automobile. The difference in the rate of increase between automobiles and motorcycles may be due to the relative ease of affordability of the motorcycle. In addition to affordability, the weakening of purchasing power in Turkey also brought the motorcycle, a cheaper private mode, into the forefront. During the pandemic, the number of businesses using moto-courier was steadily increasing, and the number of employees in the

moto-courier sector was growing in direct proportion. 80% of moto-couriers has consisted of those who lost their jobs in the pandemic (Istanbul Planning Agency, 2022). Thus, the increase in the number of motorcycles was more visible compared to the period before the pandemic. The yearly change in the number of motorcycles is shown in the Figure 4.6.

Increase in the number of motorcycles or automobiles might have a negative impact on public transport, as will be assessed in the next chapter.

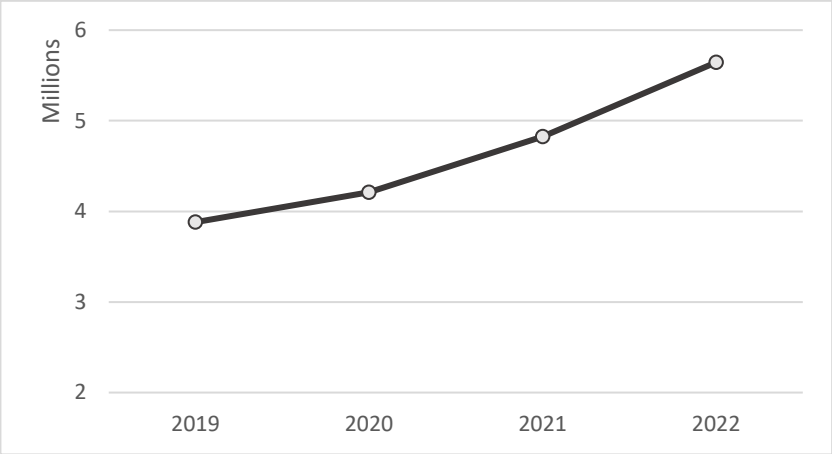


Figure 4.6: The Comparison of Motorcycle Ownership per year in Istanbul

Source: Data obtained from Turkish Statistical Institute (TURKSTAT)

4.6 Summary

In this chapter, the public transportation systems in Istanbul has been described. Istanbul has a well-developed public transportation system that includes various modes of transportation such as buses, metrobus, metro, Marmaray, tram, funicular, and ferries. Each mode of public transportation has different service areas and they are mostly integrated with each other.

The COVID-19 history and measures for public transportation to provide a safe service have also been explained throughout this chapter. In Istanbul, control, operational, and personal measures for public transportation were implemented during different phases of COVID-19. The Istanbul Municipality website was established to provide reliable information, and regular reports on the COVID-19 prevention measures were published. Mode specific measures were implemented to control the spread of COVID-19. These measures were composed of disinfection of vehicles, regulated schedules to limit mobility, social distancing in vehicles, and free fare policies for key health workers. Flexible working schedules were effective in managing public transportation capacity during COVID-19. However, technological methods like online travel reservations were not implemented in Istanbul during COVID-19.

As expected, and as the literature suggests, an increase was observed in the private motorized vehicles during the Pandemic. The more increase in demand for motorcycles compared to automobiles can be caused by the relative ease of affordability of the motorcycle.

Building on this background, the next chapter analyses the impact of COVID-19 on the modes of public transportation. The analysis also includes comparison of modes with a view to evaluate the comparative vulnerability of the modes and to assess the overall resilience of the system. Additionally, effectiveness of measures implemented for public transportation and new policy approaches will be investigated with the help of the interviews with policymakers.

CHAPTER 5

ANALYSIS OF PUBLIC TRANSPORTATION DURING AND AFTER COVID-19

5.1 Introduction

After providing an overview of the history of COVID-19 and the measures taken to ensure safe public transportation in Istanbul, this section presents a detailed analysis of the impact of COVID-19 on public transportation.

The first part of the analysis is based on data collected from the Istanbul Metropolitan Municipality - Public Transportation Services Directorate, and provides an assessment of the demand for each mode of public transportation before, during and after COVID-19. The primary focus of this analysis is to explore the recovery and resilience of the public transportation system, using descriptive statistics to highlight key trends. To achieve this, the change in the ridership level of three main modes of public transportation (urban rail systems, road-based public transportation and maritime public transportation) is compared. To gain a deeper understanding, the differences of the demand for each mode and different metro lines are discussed. The author provides comments on the reasons behind the observed changes in demand for each mode of public transportation, exploring factors such as the location of the metro line, the number of stops, and the availability of alternative transportation options.

In the second part of the analysis, the result of the semi-structured interview with policymakers is presented to interpret the findings of the descriptive analysis. The interview includes both the views of the experts and the comments of the author on the results of the analysis, which were also verified by the interviewees.

Additionally, the recommendations of policymakers are presented and discussed as new policy approaches to make public transportation more resilient.

5.2 The Comparison of Public Transportation Ridership Before, During and After the Pandemic

5.2.1 Trends in Population and Public Transportation

For a better understanding of the fluctuations of the ridership level of public transportation, urban population and the ridership levels are analyzed. The relationship between trends in population and annual ridership level of public transportation is shown in Figure 5.1. The population of Istanbul showed a steady increase between 2017 and 2022. However, the urban population decreased for the first time in 2020. According to Figure 5.1, the population of Istanbul decreased by 56 thousand 815 people and fell to 15 million 462 thousand 452 people in 2020. This was possibly due to online education and online working opportunities during the pandemic, which made it possible for many people to relocate.

In parallel with the decline in the population and the restrictions imposed on urban trips (accompanied with online working and education) ridership levels decreased sharply in 2020. Accordingly, the number of public transport passengers decreased by about 42 percent and almost halved. Compared to the decline in the population of Istanbul in 2020, there was a sharper decline in the number of public transport passengers. Therefore, it is clear that the decrease in the demand for public transportation passengers is not solely associated with the change in the population rate, but can be explained with the online mode of working and education, as well as travel restrictions and curfews.

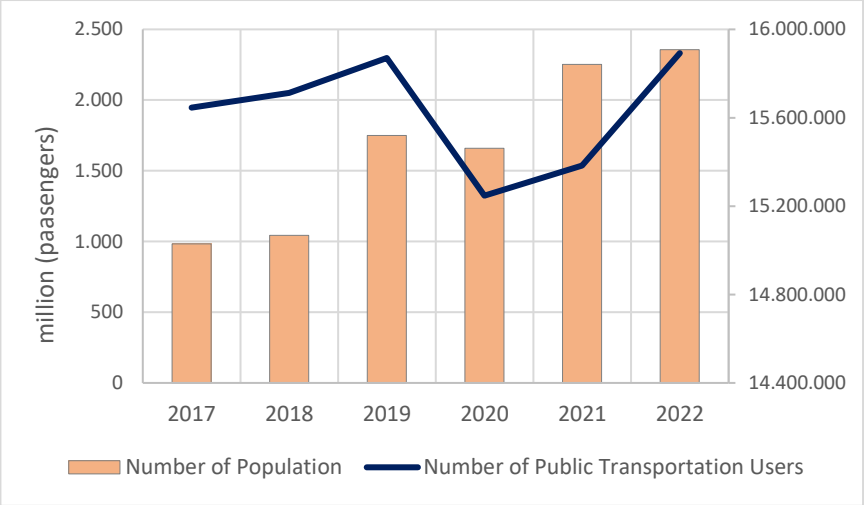


Figure 5.1:The Number of Passengers and Population in the Past 5 Years

Source: Data obtained from Istanbul Metropolitan Municipality - Public Transportation Services Directorate

After the decline in 2020, the population of Istanbul reached almost 16 million in 2021, surpassing the population in 2019. On the other hand, a stark increase in ridership level in 2021 was not observed. In other words, ridership levels of public transportation in 2021 did not reach the level of 2019. Compared to the ridership level in 2020, public transport usage slightly increased by 16%. The curfews and restrictions that continued to be imposed in 2021 could be the reasons for this limited increase in public transportation ridership levels. Since the curfews and restrictions greatly influenced individuals' mobility decisions, the number of passengers was directly affected.

The restrictions because of the pandemic were eased in 2022. Therefore, the public transportation ridership level in the post-pandemic period can help investigate the long-lasting impact of COVID-19.

The population of Istanbul increased by 67 thousand 51 people and rose to 15 million 907 thousand 951 people in 2022. The urban population in 2022 was 0,42% higher than the population in 2021, representing a very slight increase compared to the previous year. On the contrary, the total number of public transportation passengers

peaked in 2022. The number of passengers increased by 51% compared to 2021. (795 794 812 new passengers were added to the system). Additionally, approximately 1,5% of the increase is observed in 2022 when compared to 2019. Individuals who refrained from using public transportation during the pandemic seems to have returned back to using public transportation again after the pandemic. However, to understand the impact of the pandemic on the different public transportation modes, each of them should be analyzed separately.

5.2.2 Public Transportation Ridership Levels of Three Main Categories: Urban Rail Systems; Road-Based Systems and Maritime Systems

Public transportation in Istanbul is categorized under three main modes which are the urban rail system (Metro, Tram, Marmaray), road-based public transportation (Bus, Metrobus (BRT)), and maritime transportation.

The ridership levels of three main public transport categories before, during and after the pandemic is demonstrated in Figure 5.2. The number of public transportation passengers was steadily increasing before the pandemic. The decrease in public transportation usage in all modes during the pandemic (2020) is apparent in the figure.

While maritime transportation usage suffered from an approximately 50% drop in 2020, urban rail systems and road-based public transportation were confronted with an approximately 40% loss in ridership. One of the reasons why the decrease in maritime transportation is higher than other modes may be the removal of services during the pandemic. In spite of the suspension of some of the services of urban rail and road-based public transportation, these modes may be less affected by maritime transportation in 2020 due to adding new lines and changing the timetable, etc.

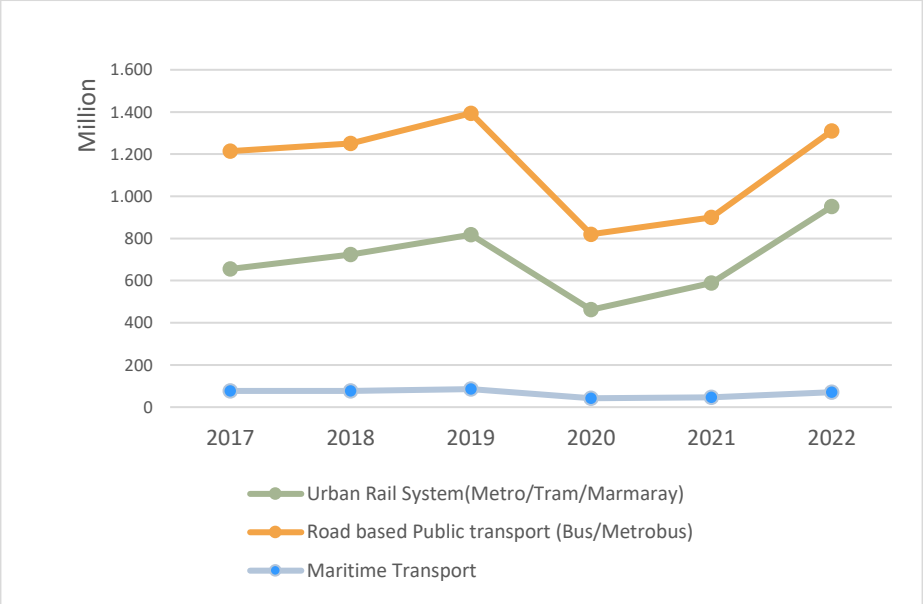


Figure 5.2: Number of Passengers of Three Main Modes

Source: Data obtained from Istanbul Metropolitan Municipality - Public Transportation Services Directorate

In 2021, the urban rail system indicated an increase of approximately 28% in the number of passengers compared to 2020. Since curfews and restrictions were still imposed in the first quarter of 2021, the period should not be considered as the post-COVID-19 period. Furthermore, the continuation of the effects of the newly emerging factors (fear of contagion, lack of hygiene, crowd) may lead individuals to abstain from using public transportation. Due to these reasons, it may be expected that the number of passengers remained lower than in the pre-pandemic period. However, the annual number of passengers of urban rail system increased significantly in 2022, and even exceeded the 2019 ridership levels by 16%, which corresponded to 132 567 115 more passengers compared to 2019.

The change in mobility patterns of road-based public transportation is different than the urban rail system. The number of passengers of road-based public transportation reached 899 952 724 in 2021, which represents an increase of 10% compared to 2020

ridership levels. On the one hand, the recovery of ridership was promising. On the other hand, in 2022, passenger numbers were still 6% below the pre-pandemic ridership level of road-based public transportation.

The hardest hit of the pandemic appears to be in maritime transportation. This public transportation mode could not regain the demand in post-COVID period. Its ridership in 2022 was 17% lower than the ridership in 2019.

In the following sections, each mode of public transportation will be analyzed during and after COVID-19 separately.

5.2.3 Public Transportation Ridership Levels of Each Mode

The three main public transportation modes are investigated in more detail in pre-pandemic, during pandemic and post-pandemic period with a view to compare recovery and resilience for each different mode. Even though as mentioned in the previous section, the urban rail systems indicated a quick recovery from the devastating impact of COVID-19, a detailed analysis is needed to find out which urban rail mode has been more resilient. Furthermore, a detailed comparison between public transport modes is critical for understanding how the impact of the pandemic changes depending on the modes.

The overall change in the ridership level of modes is demonstrated in Figure 5.3 that presents ridership trends between 2017 and 2022. The ridership in 2020 was deeply affected compared to the years between 2017 and 2022. Although the decline in the ridership level was observed in all public transportation modes in 2020, the level of change varied between them.

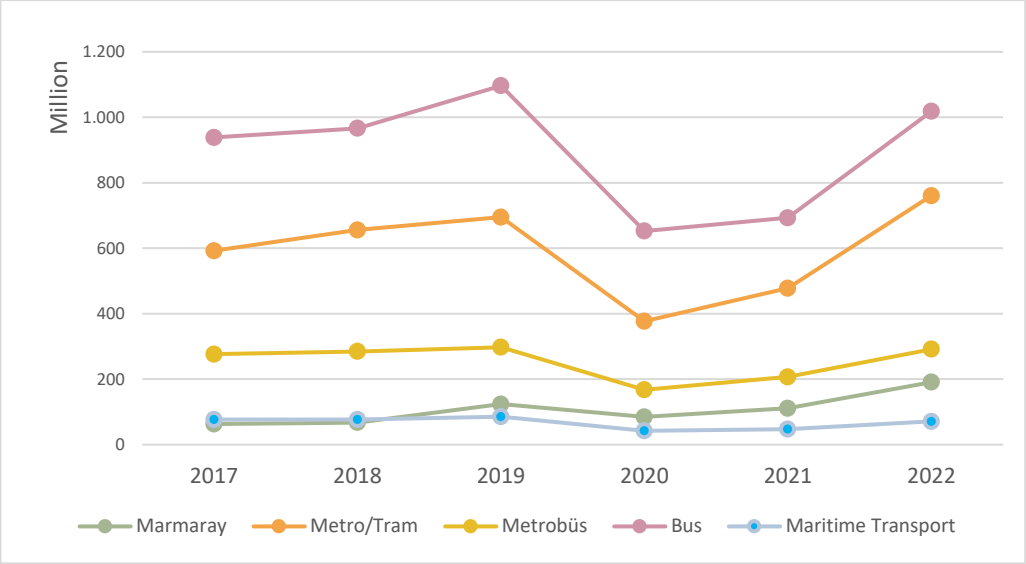


Figure 5.3: Number of Passengers of Each Mode

Source: Data obtained from Istanbul Metropolitan Municipality - Public Transportation Services Directorate

In Figure 5.3, it is apparent that the urban rail systems (Marmaray and Metro/Tram) recovered fast compared to 2019. On the other hand, maritime transportation couldn't recover the reduced number of passengers in 2020. Although maritime transport and Marmaray had similar number of passengers in 2019, Marmaray passengers sharply increased in 2022 unlike maritime transportation. Since the average number of passengers for each public mode is different, the changes and trends in the ridership of each public mode is more clearly shown in Figure 5.4.

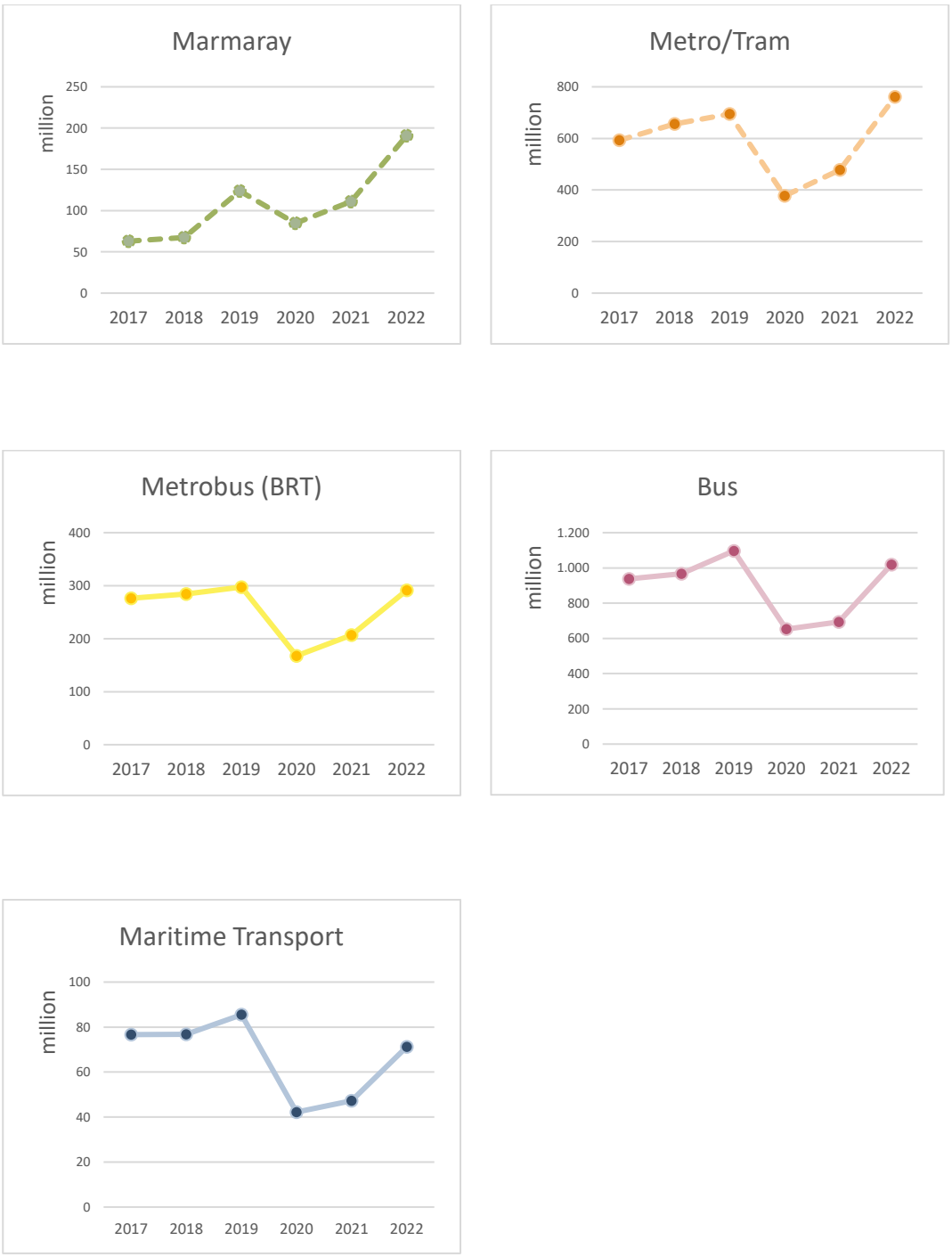


Figure 5.4: Number of Passengers of Each Mode

Source: Data obtained from Istanbul Metropolitan Municipality - Public Transportation Services Directorate

Figure 5.5 illustrates the annual change in the ridership level of different public transportation modes between 2019 and 2022. The ridership level in 2019 is defined as a base level to have a better understanding of the change in the ridership level during and after the pandemic. As clearly seen in Figure 5.5, the sharpest decline was observed in maritime public transportation in 2020 (a 51% decrease in the number of passengers compared to 2019). Furthermore, after the pandemic, the ridership level of maritime public transportation did not reach the level of 2019. On the other hand, Marmaray emerged as the mode which recovered the fastest and significantly exceeded the ridership level of 2019 after the pandemic. Number of passengers in metro and tram systems also exceeded the ridership level of 2019, but not as significantly as in the case of Marmaray. The ridership level of buses and metrobus remained very close to the 2019 level although being still under the level of 2019.

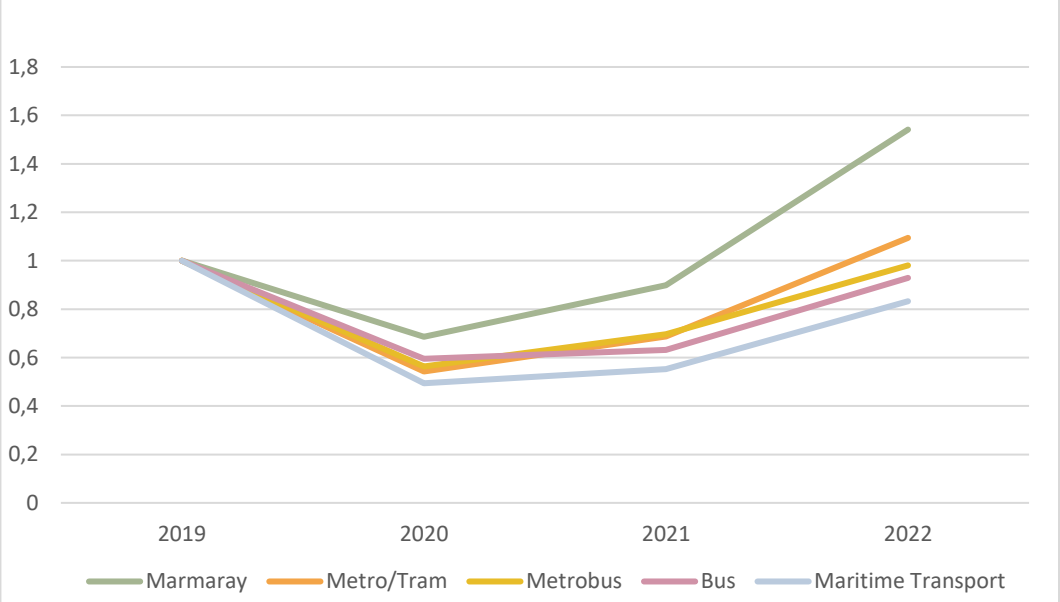


Figure 5.5: The Change in Ridership Level of Different Modes between 2019 and 2022 (Base 2019)

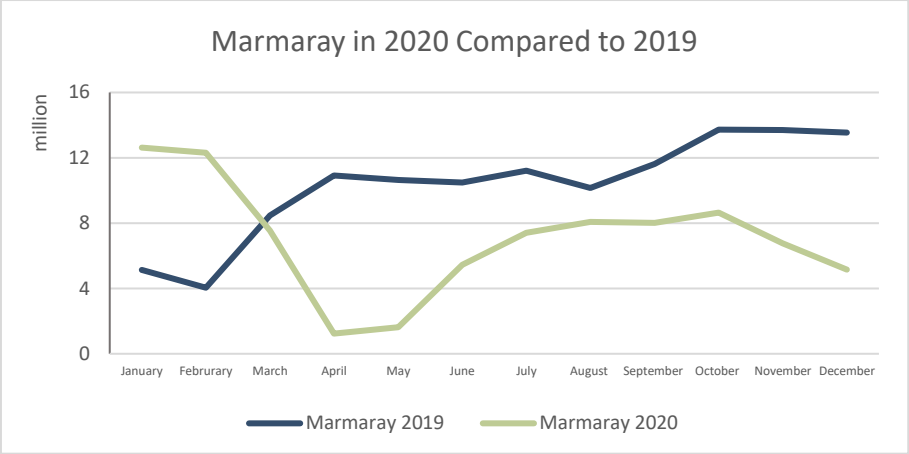
Source: Data obtained from Istanbul Metropolitan Municipality - Public Transportation Services Directorate

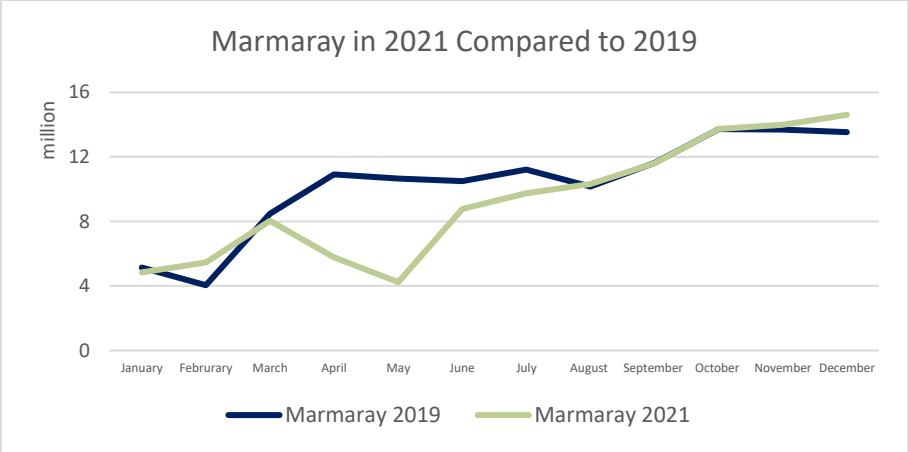
After demonstrating annual change in the demand of different modes in Figure 5.5, the monthly ridership levels of each mode in 2020, 2021 and 2022 is compared to 2019. In Figure 5.6 and Figure 5.7, the monthly ridership level of Marmaray and Metro/tram between 2020 and 2022 are compared to 2019.

Marmaray lost 30% of its passengers in 2020 compared to 2019. In April 2020, a significant decrease of 80% was observed in the number of passengers. This decrease was an expected change considering the intensity of curfews during that period. However, as of May 2021, there was a gradual increase in the number of Marmaray passengers. 1 064 180 more passengers used Marmaray in December 2021 compared to 2019. Most importantly, Marmaray was the only mode to reach pre-pandemic ridership level in 2021. In other words, the fastest recovery was observed in this mode. Parallel to the increase in 2021, an approximately 50% increase in the number of passengers was detected at the end of 2022.

Aparicio et.al. (2021) found that there was an inverse proportion between the number of stops and the rate of being affected by the pandemic (decrease in the number of passengers). Parallel to this, Marmaray has the highest number of stations in all public modes. Additionally, Marmaray was the mode that lost the least passengers in 2020 (30% of decrease), and the mode that recovered the fastest and increased the most (50% increase in the number of passengers) after the pandemic.

Moreover, the rapid recovery of Metro and tram is seen in the Figure 5.7 after Marmaray. Similar to Marmaray, sharpest decline in the number of metro and tram passengers was after March 2019 after the declaration of COVID-19. Unlike Marmaray, the number of passengers in 2019 was reached between February and March 2022. The number of passengers in March 2022 exceeded the number of passengers in 2019 by 1 810 074. The highest number of metro/tram passengers was in October 2022. This may be due to the opening of educational institutions in October. In 2022, which is the year considered as post-pandemic period, a 10% increase was observed in the ridership levels compared to 2019. In the following section each line will be discussed separately.





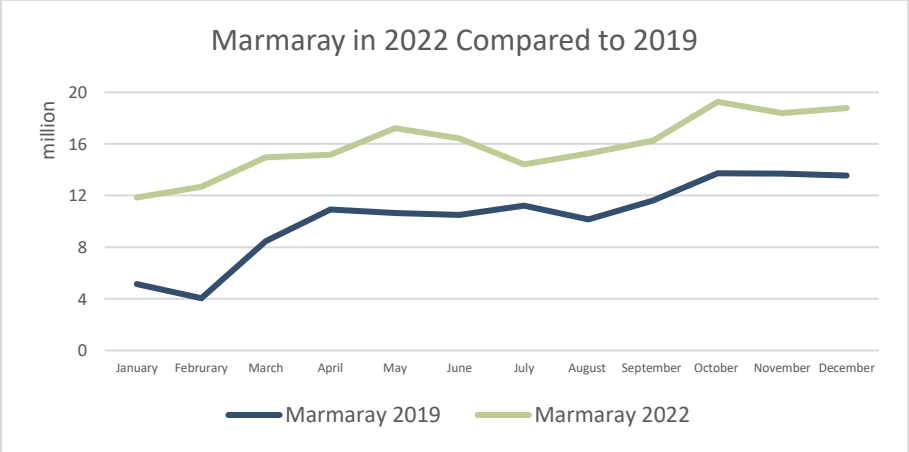


Figure 5.6: The Ridership Level of Marmaray compared to 2019

Source: Data obtained from Istanbul Metropolitan Municipality - Public Transportation Services Directorate

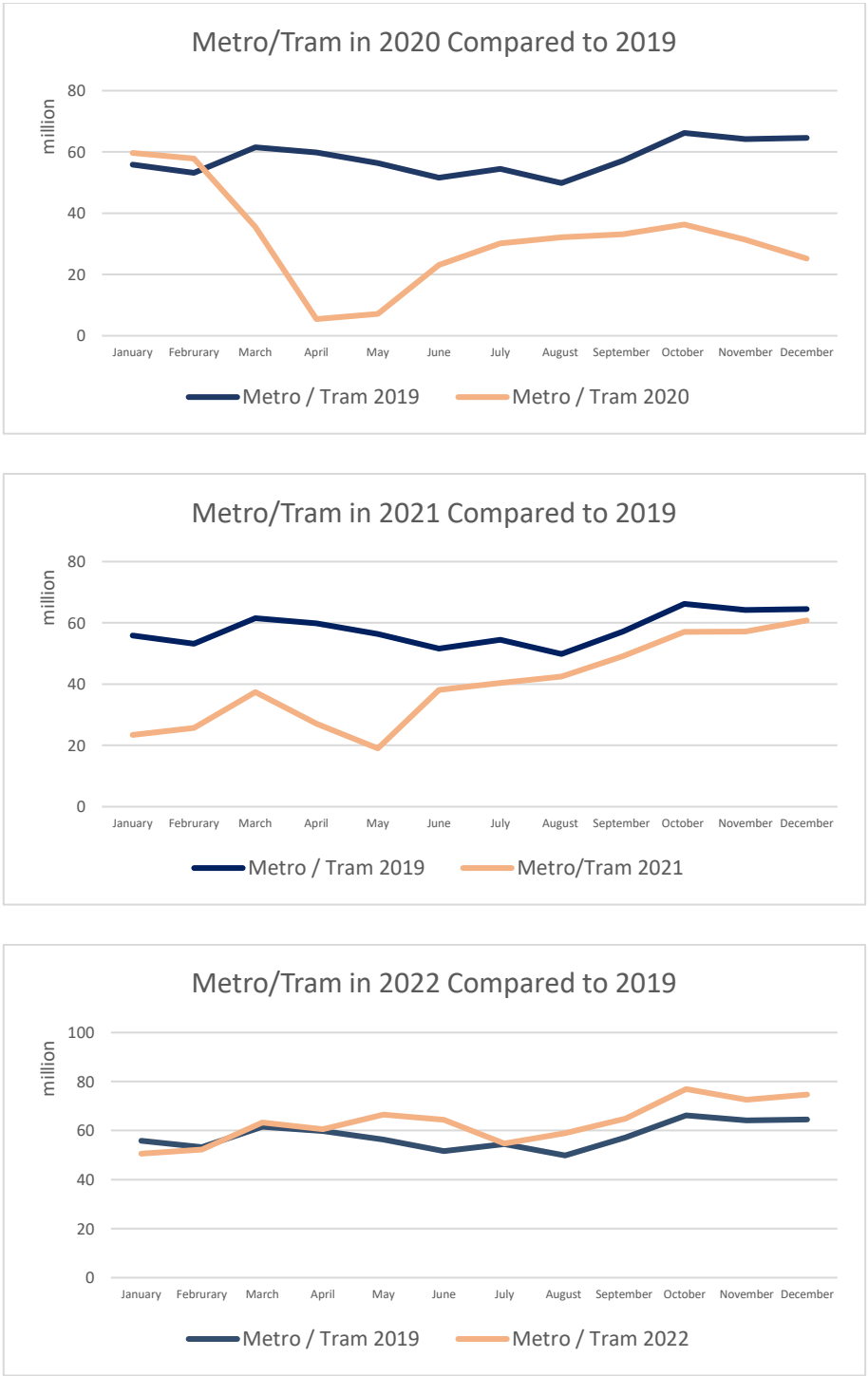


Figure 5.7: The Ridership Level of Metro/Tram compared to 2019

Source: Data obtained from Istanbul Metropolitan Municipality - Public Transportation Services Directorate

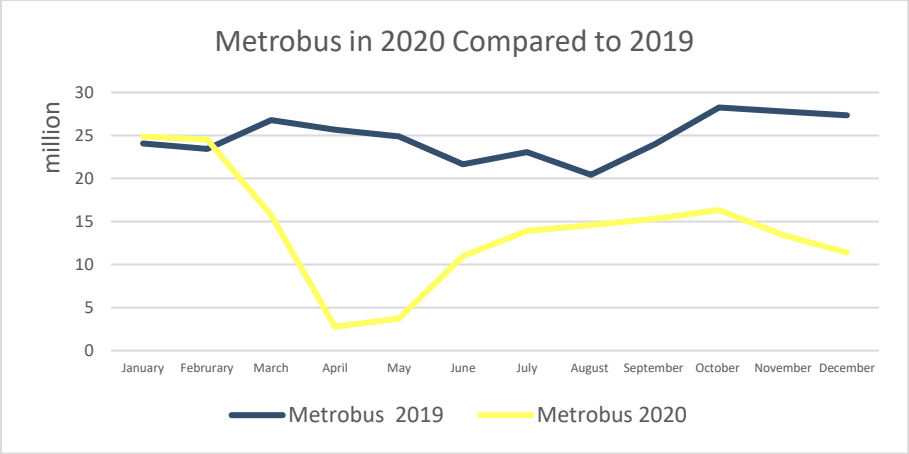
Metrobus and regular busses are examined under road-based public transportation. The monthly ridership levels in 2020, 2021 and 2022 are compared to 2019 in Figure 5.8 and Figure 5.9 Although the buses and metrobuses (BRT) are in the same category, characteristics of the systems are distinct from each other. For instance, Metrobus has a separate road that is not affected by traffic whereas the quality and duration of the journey by bus is significantly affected by traffic levels. While the change in the ridership level is discussed, this difference should be taken into consideration.

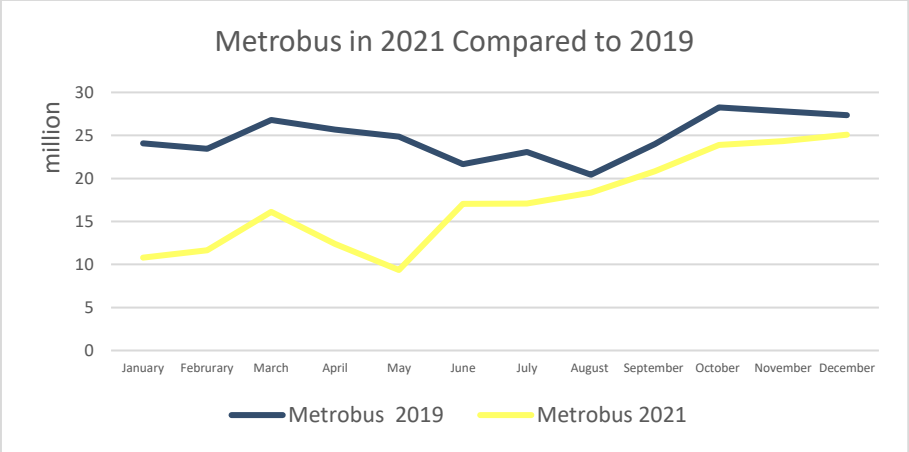
The number of passengers traveling by the Metrobus diminished at the rate of 40% in 2020 compared to 2019. Like Metro and Tram Lines, in 2022 the number of monthly Metrobus passengers almost reached pre-pandemic level. However, the total number of Metrobus passengers in 2022 was 5% below the 2019 level of passengers. Metrobuses could be a substitute for the Marmaray system as both systems provide access across the Bosphorus. In addition, Metrobus lines operate 24 hours a day and at peak hours at a headway of 1-2 minutes. It is seen that considering the annual total number of passengers, Metrobus carries 10 676 691 more passengers than Marmaray. On the other hand, when the recovery period and the ridership trends are taken into account, it turns out that Marmaray recovered faster with a steady increase in the number of passengers. The number of passengers in Metrobus in 2022 did not exceed the numbers carried in 2019. This was because Metrobus had reached its total passenger capacity in 2019. This has also been verified with the interviews. Marmaray, on the other hand, can carry more passengers, and it has not achieved total passenger capacity yet.

Although the rate of decrease was similar to the other modes, the number of passengers who avoided using the bus was relatively high compared to different public transport modes. While metro/tram lines lost approximately 315 million passengers in 2020, bus lines lost 445 million passengers. This means that while metro/tram lines lost 46% of their passengers in 2020 compared to 2019, the number of regular bus passengers decreased by 40%.

The number of monthly bus passengers in June 2022 was 5% higher than in June 2019. However, the annual total number of bus passengers in 2022 was 7% less than the number of passengers in 2019. The slower recovery was observed in the usage of bus compared to the urban rail systems. The slower recovery of bus ridership may be because travel times by bus are prolonged due to the heavy traffic jams.

In a study conducted in the New York City, Halvorsen et al. (2021) found that the recovery period of bus ridership levels was faster than the subway after the pandemic in the New York City. On the contrary, in Istanbul, urban-rail systems had a faster recovery process than road-based public transportation systems.





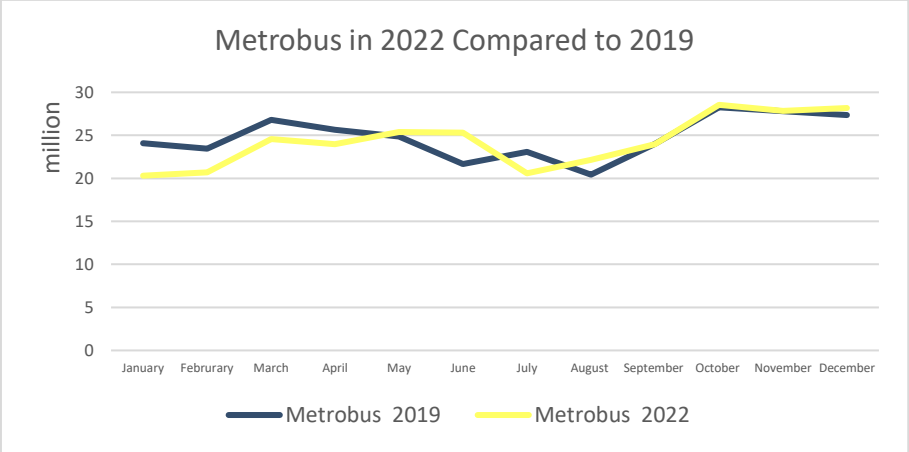


Figure 5.8: The Ridership Level of Metrobus compared to 2019

Source: Data obtained from Istanbul Metropolitan Municipality - Public Transportation Services Directorate

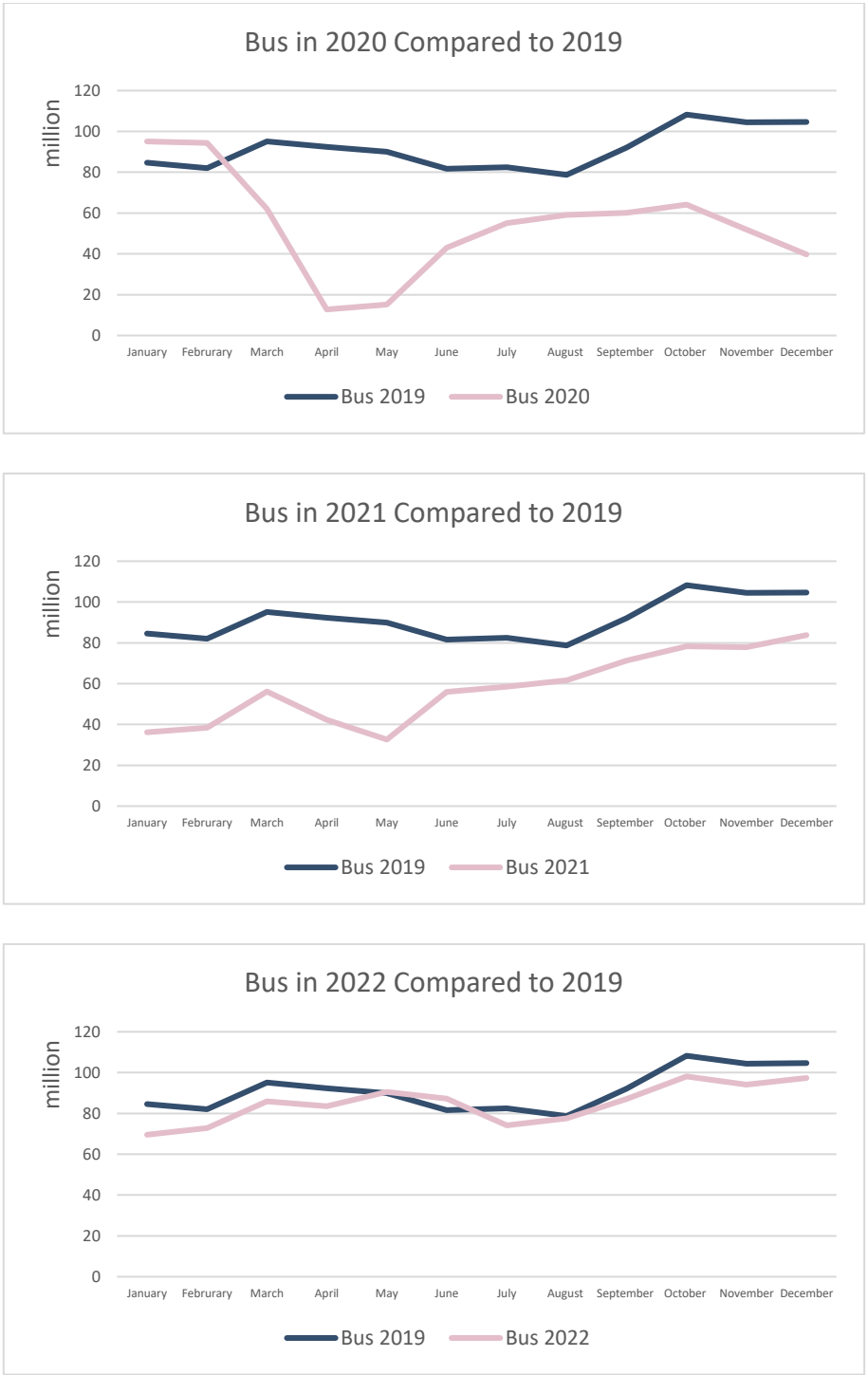
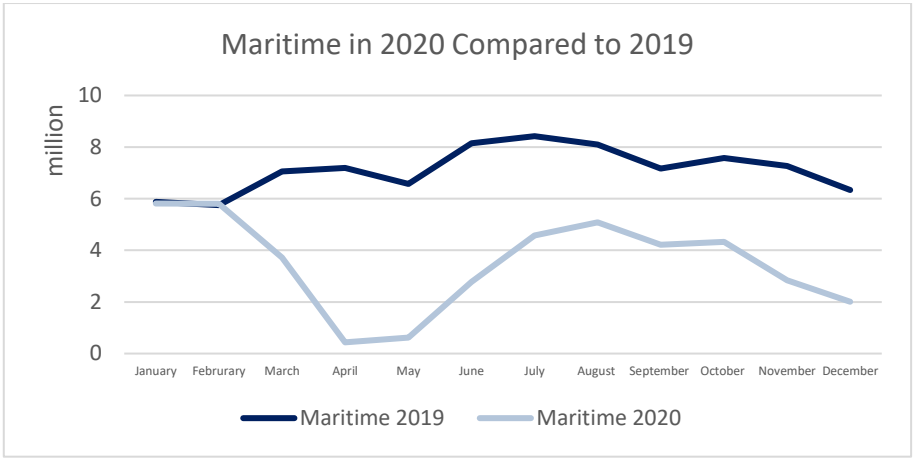


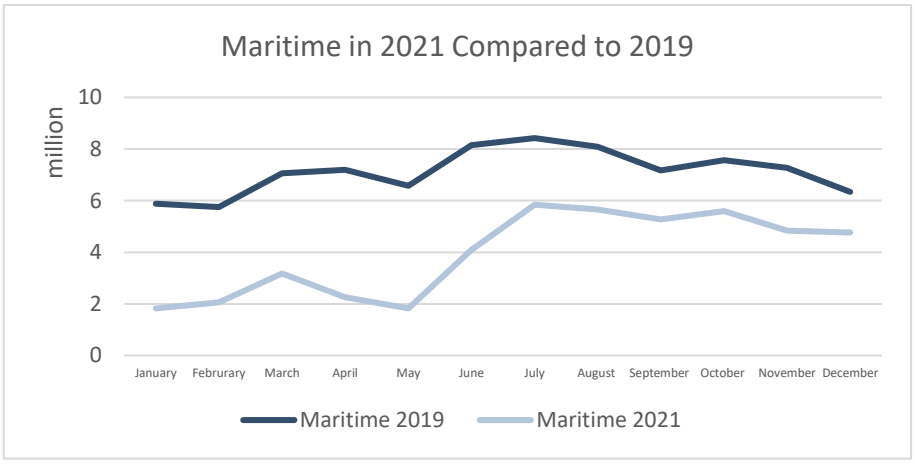
Figure 5.9: The Ridership Level of Bus compared to 2019

Source: Data obtained from Istanbul Metropolitan Municipality - Public Transportation Services Directorate

As described before, maritime public transportation is a unique system that connects two continents in Istanbul as well as providing access between the neighborhoods along the Bosphorus. This system can also be considered as an alternative for Marmaray and Metrobus. In the literature, change in the ridership level of maritime transportation has yet to be examined in public transport. For the Istanbul case, the monthly ridership level 2020, 2021 and 2022 of maritime transportation is compared to 2019 in the Figure 5.10. Although other modes of transportation are widely used in most cities, maritime transport is not widely used depending on the presence of sea transport and the urban form that may make sea transport an effective alternative. Maritime transportation is used not only to connect the two sides but also to provide access between the districts with a coast to the sea.

The lowest number of passengers in 2019 was in maritime transportation. Notably, the number of maritime passengers in 2018 was 9 million more than Marmaray passengers. However, as of 2019, maritime passengers have gradually decreased. It is possible to associate the reason for the decrease in 2020 with the pandemic. The sharpest decline with 50% was in the maritime transportation ridership level. Moreover, the change in the number of passengers is also affected seasonally. Except for 2020, the highest number of maritime transportation passengers was in July each year (2019, 2020, 2021). Unlike other modes of public transport, the number of maritime trips in 2021 remained 50% below 2019. In 2022, the number of passengers using maritime transportation was still 17% below the ridership levels in 2019. According to the statistics, it is more apparent that the most vulnerable mode of public transport is maritime transportation. Although maritime transportation carries fewer passengers than other public modes, it is the mode of transportation that lost the most passengers proportionally in the pandemic. In addition, it could not recover in the post-pandemic period and reach the pre-pandemic level. However, it should also be noted that the reason maritime transportation lost its passengers, as is the case with Metrobus, may be that Marmaray is a faster alternative not affected seasonally.





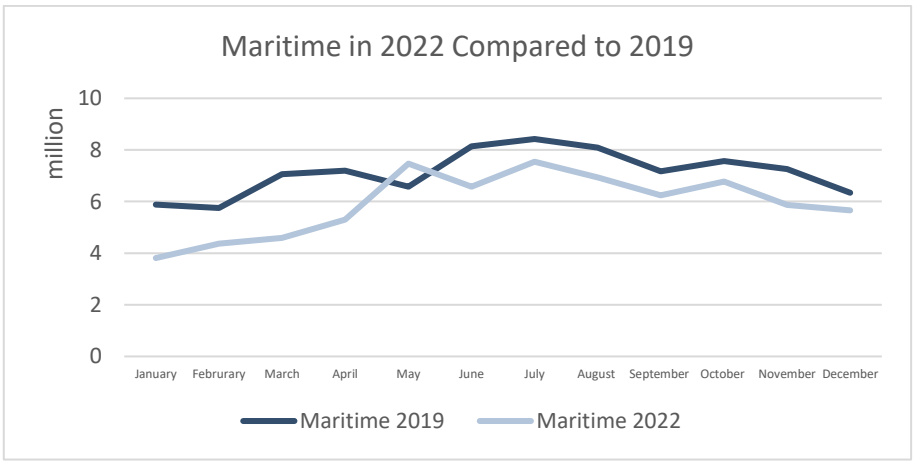
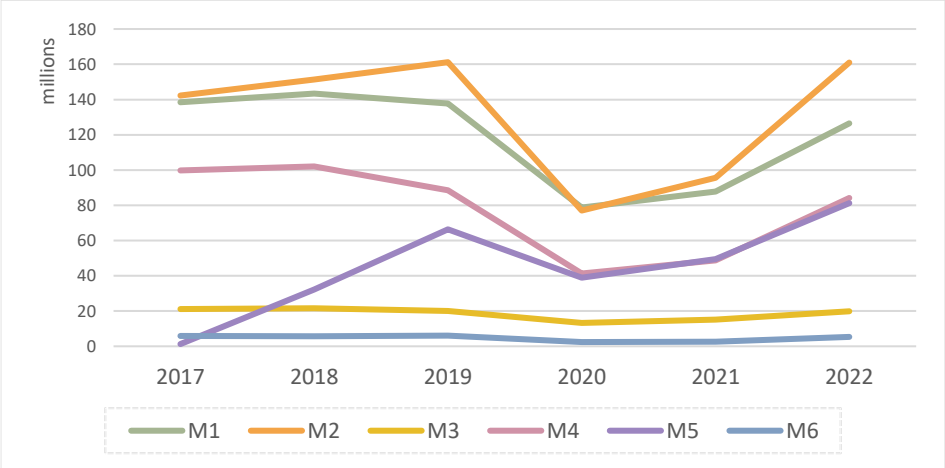


Figure 5.10: The Ridership Level of Maritime Transport compared to 2019

Source: Data obtained from Istanbul Metropolitan Municipality - Public Transportation Services Directorate

5.2.4 Comparison of Ridership Changes in Different Metro Lines

The fastest recovery has been observed in urban rail systems. As mentioned in the Public Transportation System in Istanbul, several metro lines serve as urban rail systems. Therefore, it is vital to identify which lines recovered fast. Six metro lines serving before and after the pandemic have been chosen to be analyzed. The analysis has not included metro lines that started to serve after 2020 and 2021. The reason for this is that it is not possible to measure the effect of the pandemic on these lines. The ridership levels of different metro lines are demonstrated in Figure 5.11.



M1 Aksaray-Airport	**M2** Taksim-4.Levent	**M3** Kirazlı-Olimpiyatköy	**M4** Kadıköy-Kartal Metro	**M5** Üsküdar-Çekmekoy	**M6** Levent-Hisarüstü

Figure 5.11: Number of Passengers on Metro Lines between 2017 and 2022

Source: Data obtained from Istanbul Metropolitan Municipality - Public Transportation Services Directorate

The M2 line between Taksim and Hacıosman and the M6 line serving between Levent and Boğaziçi University have been hit hardest by COVID-19. Due to the online education in the university during pandemic, the sharpest decline was observed on the M6 line. The number of passengers of the M6 line is less than the other lines; so, the sharpest decrease in the number of passengers is not clearly visible

in the Figure 5.11. However, in the next section, the change of all lines is examined in detail, with the number of passengers of each metro line being compared to that of 2019. Measuring the change is essential because the recovery period of each line and the drop in passenger numbers are changing by the lines. The differences in the demand are interesting as all the lines are considered under urban rail systems.

In Table 5.1, the number of passengers of different metro lines between 2017 and 2022 is compared. As in the previous section, it is mentioned that the fastest recovery was observed in urban rail systems. However, the recovery period varied per the metro lines. Hence, it is necessary to draw attention to the ridership change between 2019-2020 and 2019-2022. It is striking that the lines most affected by the pandemic were also the lines that recovered the fastest. However, on the lines where the number of passengers decreased relatively less during the pandemic period, the recovery period was slower than the other lines.

Table 5.1: The Comparison of The Ridership Level of Metro Line

Years	M1 Aksaray-Havalimanı Metro	%	M2 Taksim-4.Levent Metro	%	M3 Kirazlı-Olimpiyatköy Metro	%	M4 Kadıköy-Kartal Metro	%	M5 Üsküdar-Çekmeköy Metro	%	M6 Levent-Hisarüstü Metro	%
2017	138.486.629		142.259.612		21.085.654		99.755.930		1.271.118		5.876.027	
2018	143.381.896	4	151.402.803	6	21.585.069	2	102.047.448	2	32.243.096	100+	5.741.312	-2
2019	137.820.240	-4	161.199.801	6	20.107.607	-7	88.534.570	-13	66.341.571	100	6.062.151	6
2020	78.738.302	-43	77.017.957	-52	13.261.291	-34	41.311.200	-53	38.932.979	-41	2.414.779	-60
2021	87.872.263	12	95.683.117	24	15.046.376	13	48.731.438	18	49.533.035	27	2.569.723	6
2022	126.390.345	44	160.939.604	68	19.946.042	33	84.157.764	73	81.210.578	64	5.294.486	100

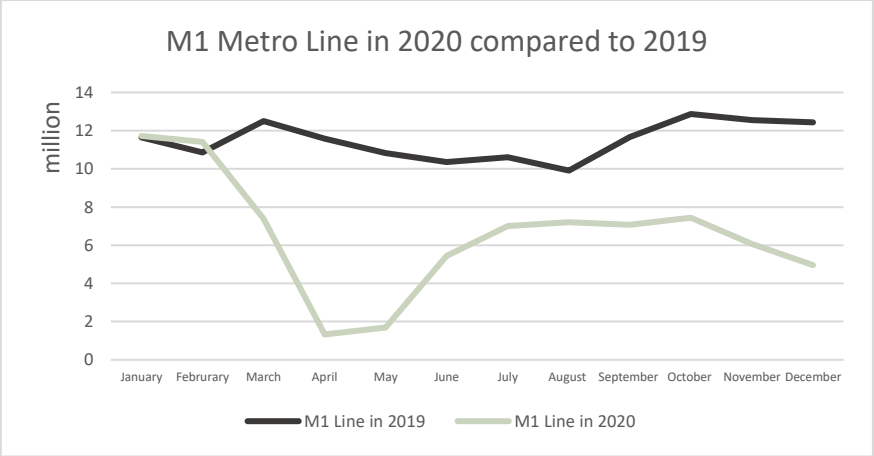
Source: Data obtained from Istanbul Metropolitan Municipality - Public Transportation Services Directorate

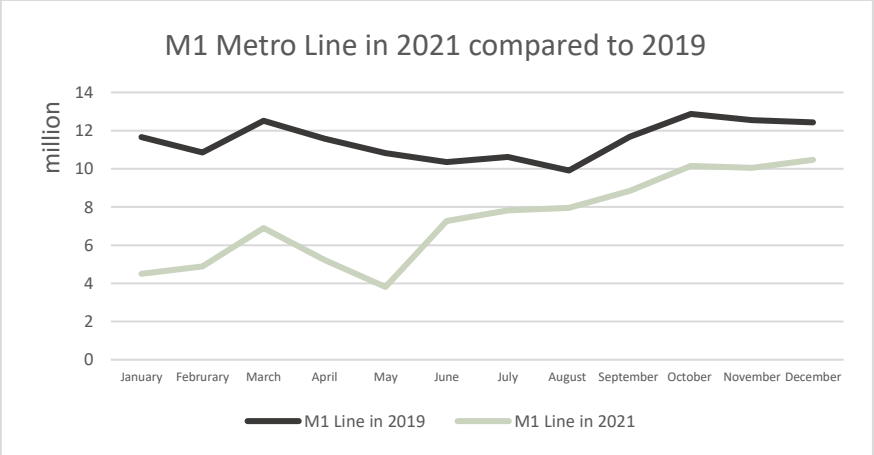
In addition to observing change annually, monthly change between years have also been analyzed to interpret the differences between lines. As the service area of each line is different, the factors that affected ridership levels differ accordingly. Furthermore, the remote working opportunity and online education can have significant influence on travel habits.

The ridership level of M1 and M2 line in 2020-2021-2022 is demonstrated in Figure 5.12 and 5.13. Parallel to the figures, the reason for the change and recovery are discussed.

The number of passengers in M1 line dropped by 43% and lost 4 058 250 passengers in 2020. In April 2020, the number of passengers decreased by about 80%. In all the months until May 2022, the number of passengers continued to fluctuate with a decrease ranging from 80% to 15%. In May 2022, 407 261 more passengers used the M1 line to 2019, reaching and exceeding the pre-pandemic level for the first time. This metro line runs between Atatürk Airport, Kirazlı, and Yenikapı, but the airport does not provide service anymore due to the opening of the new airport. The stations on the line, such as the university, bus station, and exhibition center, were certainly affected during the pandemic and attracted less travels in 2020. However, even in 2022 the ridership levels in 2019 have not been reached and the system does not seem to have fully recovered. Since Marmaray has common stations as a convenient and fast option, it is possible that passengers started to prefer this mode over the M1 line in 2022. It is also possible that the increase in private vehicle ownership during the pandemic affected the ridership level for this line.

The M2 line between Yenikapı and Hacıosman is one of the most intensely used lines. The excessive demand is because the M2 line operates between the central business district and has many transition stations to Metrobus, Marmaray, and other lines. Additionally, tourist attraction points are also located on the M2 line stations. One of the most dramatic declines in number of passengers with 52 % was observed in the M2 line. The total number of passengers in 2022 was 260 197 less than the total number of passengers in 2019. However, the ridership in the last 5 months of year 2022 has been consistently higher than that of 2019. Therefore, despite the decline in passengers, one of the fastest recoveries was also observed on the M2 line. In May of 2022, the number of passengers exceeded the pre-pandemic level (341 507 more passengers), and after August of 2022, the number of passengers continued to fluctuate with an increase ranging from 1% to 13%.





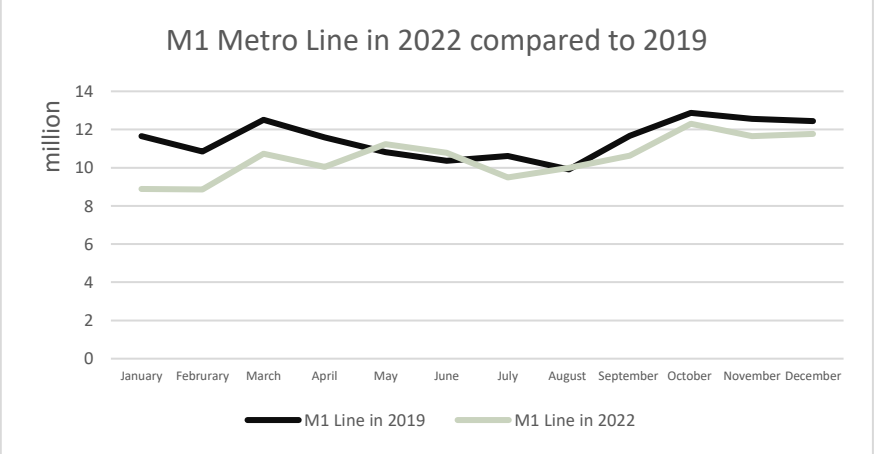
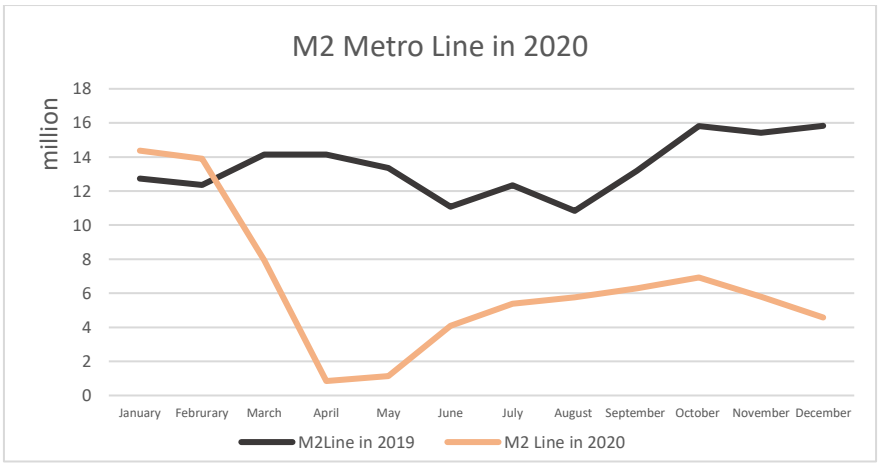
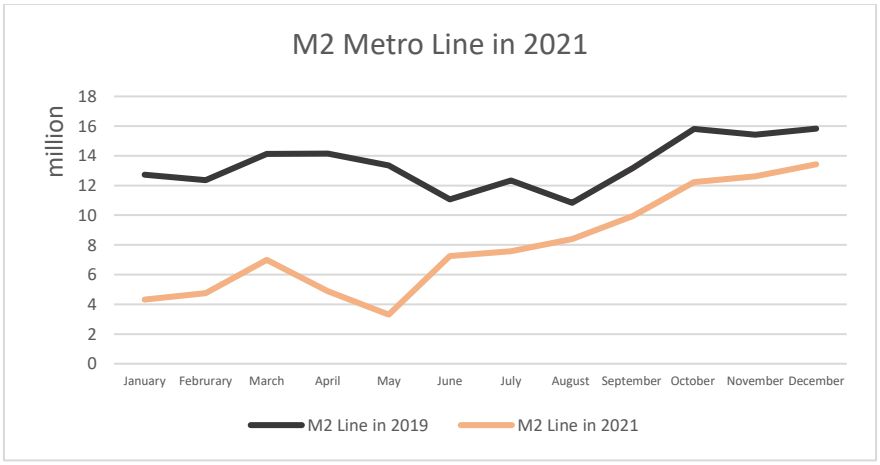


Figure 5.12: The Ridership Level of M1 Line compared to 2019

Source: Data obtained from Istanbul Metropolitan Municipality – Public Transportation Services Directorate





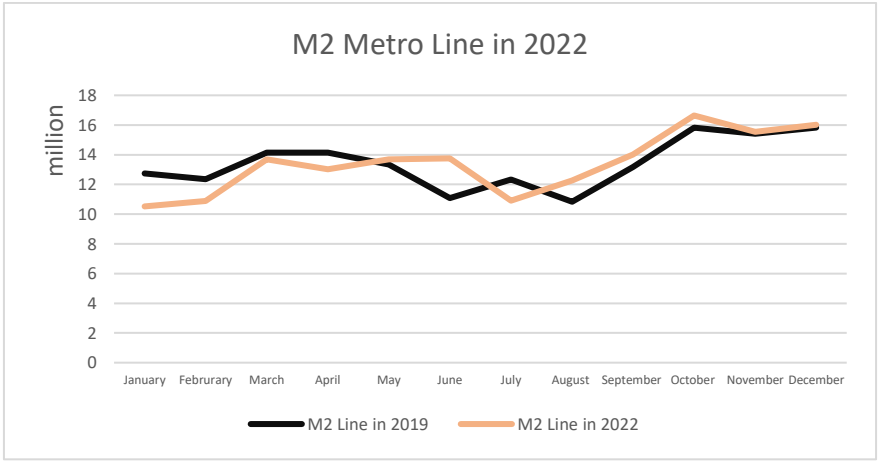


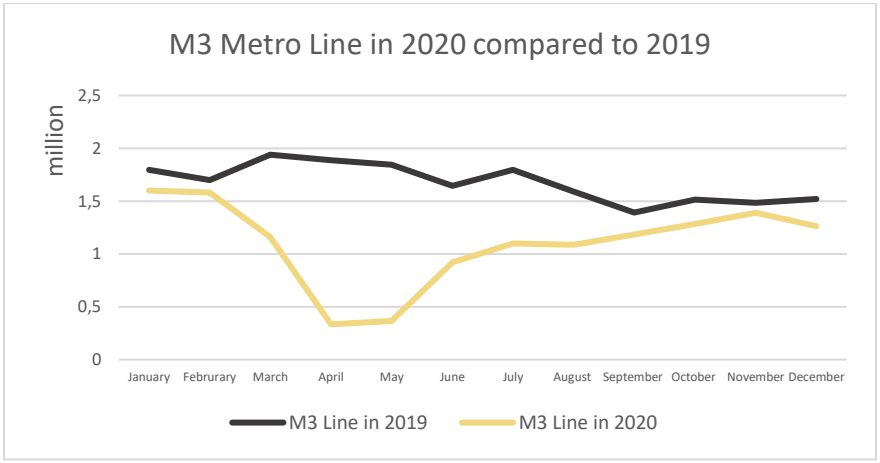
Figure 5.13: The Ridership Level of M2 Line compared to 2019

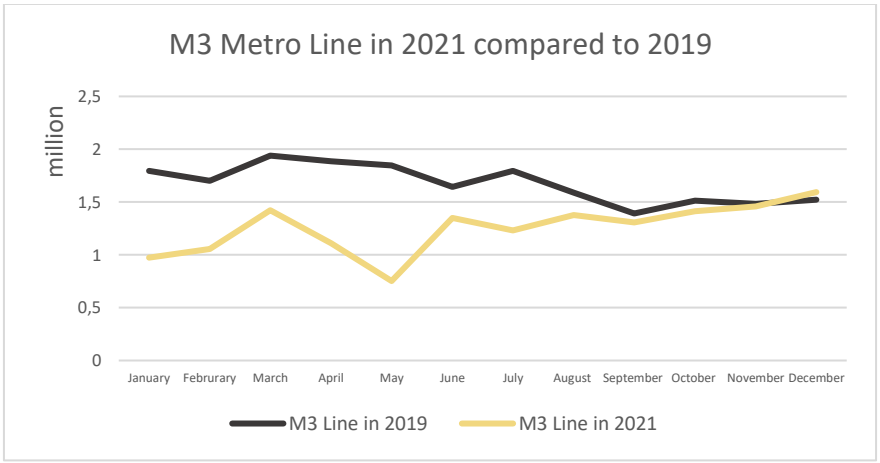
Source: Data obtained from Istanbul Metropolitan Municipality - Public Transportation Services Directorate

The M3 line is operating between Kirazlı (transfer station to M1) and Başakşehir (new urban development area) by passing through the industrial district. The demand for the M3 line was decreasing in 2019. At the end of 2019, 15% fewer passengers chose to use the M3 line than in January 2019. During the pandemic, in April 2020, the number of passengers dropped by 80%. However, a new metro line, which has a transfer station with an industrial district, started to be operated in May 2021. As a result of the newly added metro line, in December 2021, the demand for the M3 line reached the pre-pandemic level with an increase rate of 5% and additional 72 538 passengers. After August 2022, the M3 line continued operating with a steadily rising demand of approximately 25%. However, the total number of passengers in 2022 remained at 161 565 passengers fewer than in 2019.

The M4 line is operating between Kadıköy (center of the Anatolian Side) and Tavşantepe. The line was extended from Tavşantepe to Sabiha Gökçen Airport on 2nd October 2022. In April 2019, 93% of passengers abstained from using the M4 line compared to 2020. From April 2020 to May 2022, the ridership decline rate fluctuated between 90% and 10%. The M4 line has suffered ridership loss until June of 2022. However, ridership level of the M4 line surpassed pre-pandemic levels by 15% as of October 2022. The reason for the increasing rate as of October 2022 was the extension to Sabiha Gökçen Airport. More passengers could prefer to use the M4 line as an alternative option to access the airport. On the other hand, the total ridership level in 2022 was lower than that of 2019. In total, the M4 line lost its 4 376 806 passengers in 2022 compared to 2019. On the one hand, the increase rate of the ridership continues steadily, the total number of passengers can exceed the pre-pandemic level in 2022. It is not enough for the number of passengers to exceed 2019 in just three months to call the system resilient and to claim that it fully recovered. To understand that the public transport system works effectively, the increase in the number of passengers should be continuous or steady. The system is recovered if the rise in the ridership level is constant.

The change in the ridership level of compared to 2019 is more visible in the Figure 5.14 and the Figure 5.15





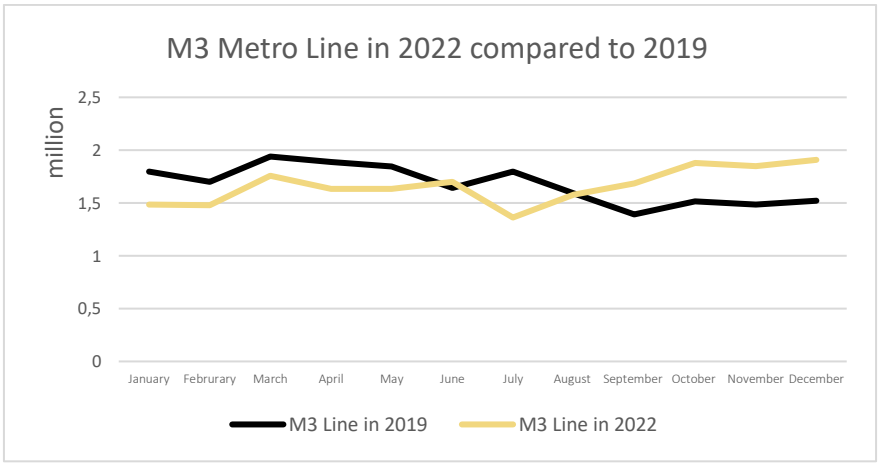
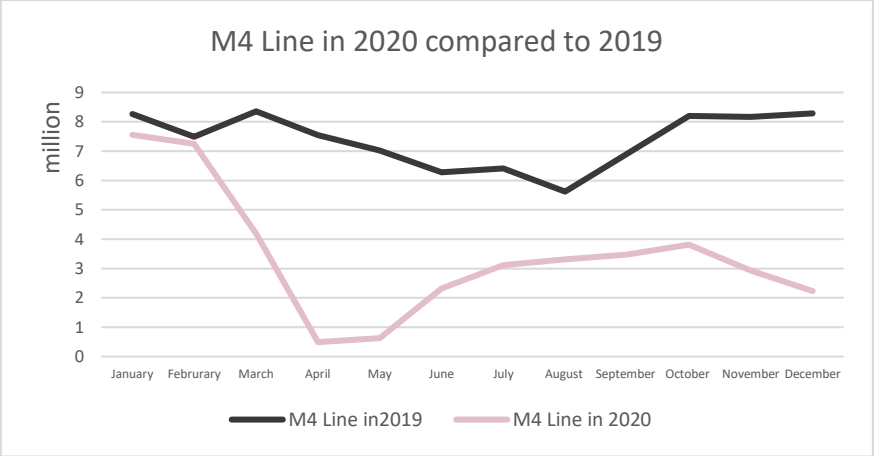
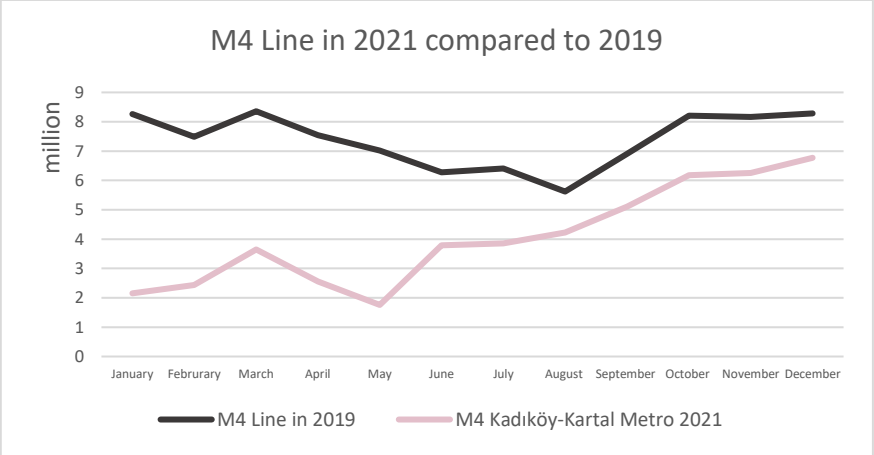


Figure 5.14:The Ridership Level of M3 Line compared to 2019

Source: Data obtained from Istanbul Metropolitan Municipality - Public Transportation Services Directorate





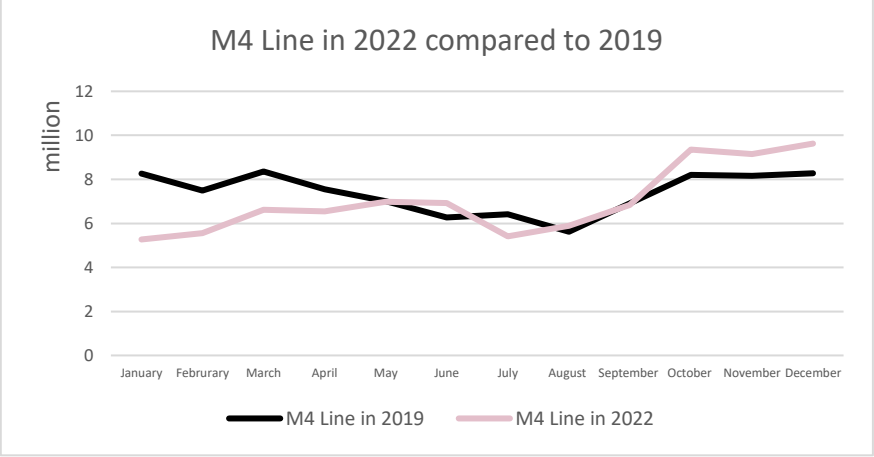
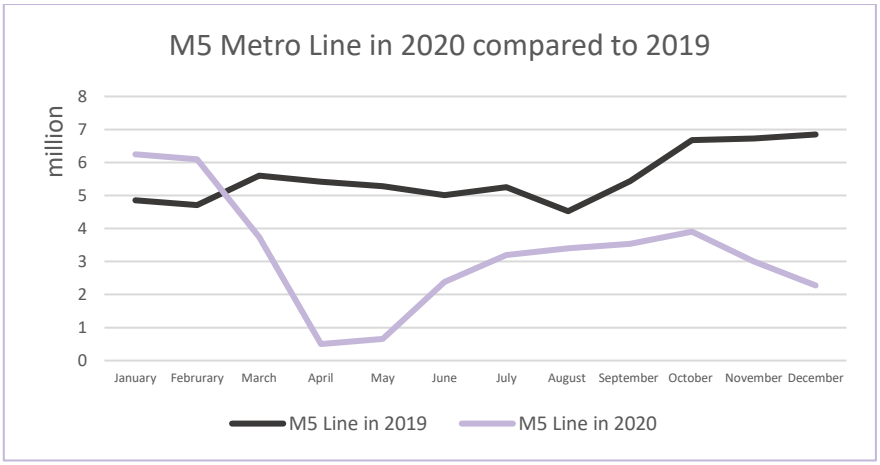


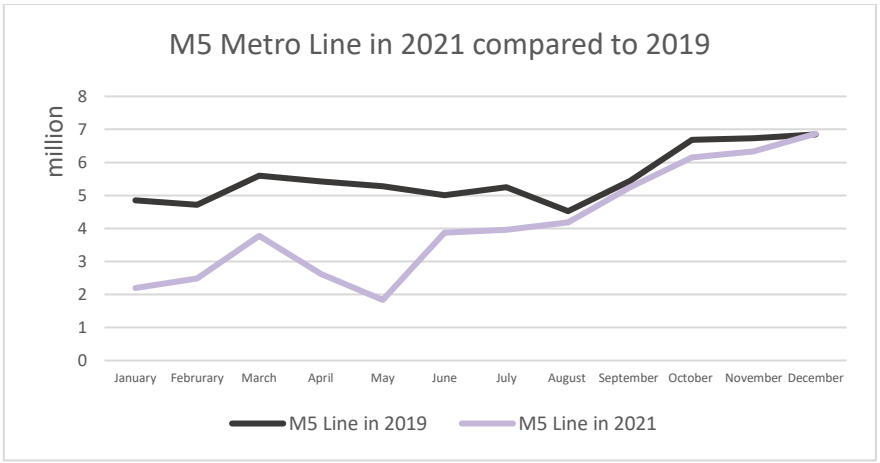
Figure 5.15: The Ridership Level of M4 Line compared to 2019

Source: Data obtained from Istanbul Metropolitan Municipality - Public Transportation Services Directorate

The M5 line is operating between Çekmeköy and Üsküdar. Çekmeköy is one of the farthest districts from the business centers in Istanbul. Similar to the other lines, a 90% of ridership lost was experienced in April 2020. The monthly change in the ridership level of M5 line is illustrated in Figure 5.16. The annual number of passengers decreased by 40% to 38 932 979 in 2020 compared to 2019, while the decrease rate was 25 % in 2021 compared to the 2019 levels, and hence the ridership was 49 533 035 passengers in 2021. At the end of the 2021, the ridership level of the M5 line started to rise with an increasing rate. In May and June of 2022, the most significant increase rate (37-38%) was observed for the M5 line compared to the other lines. The annual number of passengers increased by 22% in 2022 and reached 81 210 578.

The last metro line analyzed is M6 which operates between Levent (transfer station to M2) and the University. Due to the online education introduced in the university with the beginning of the pandemic, the disruptive impact of the pandemic hit the ridership level of the line. The 60% decline in the ridership in 2020 is visible in Figure 5.17. Students continued their education mostly in their hometowns. In light of this information, the ridership curve of the M2 line was almost flattened and dropped by 96% from 537 281 in April 2019 to 21 766 in April 2020. Even though the online education ended in September 2021, the decrease in the number of passengers could not be reversed. In June 2022, the number of passengers abruptly bounced to 410 122 with a 10% increase rate. Nevertheless, in spite of that, this increase has yet to be a lasting impact. In the last three months of 2022, the rate of decrease was around 4%. Additionally, the annual number of passengers in 2022 was 767 665 fewer than in 2019 (12% less).





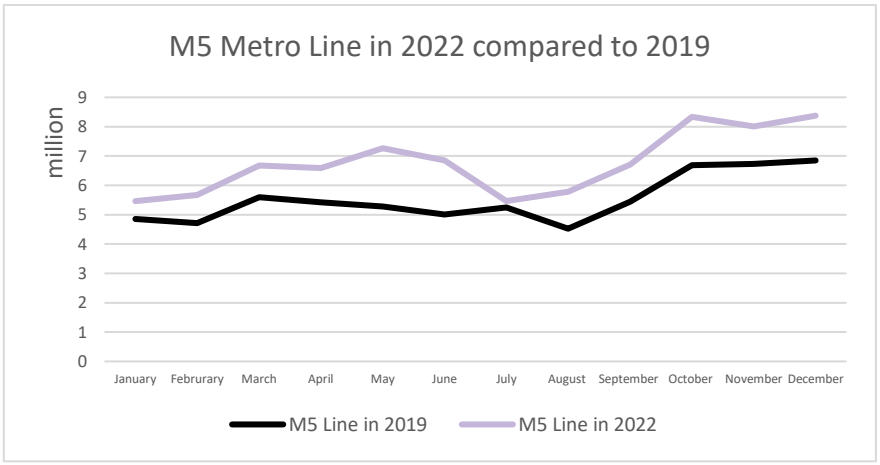
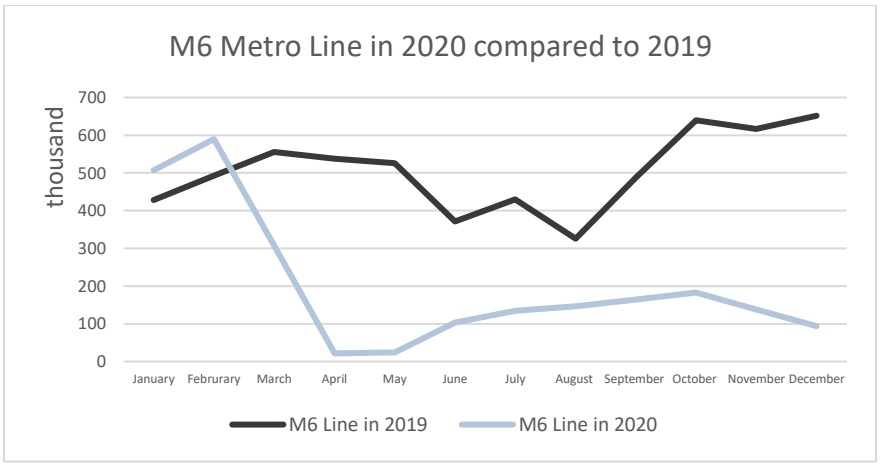
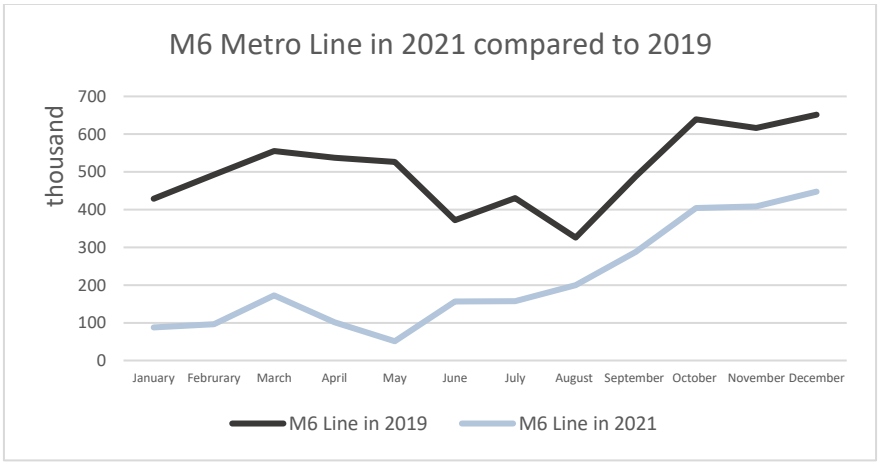


Figure 5.16: The Ridership Level of M5 Line compared to 2019

Source: Data obtained from Istanbul Metropolitan Municipality - Public Transportation Services Directorate





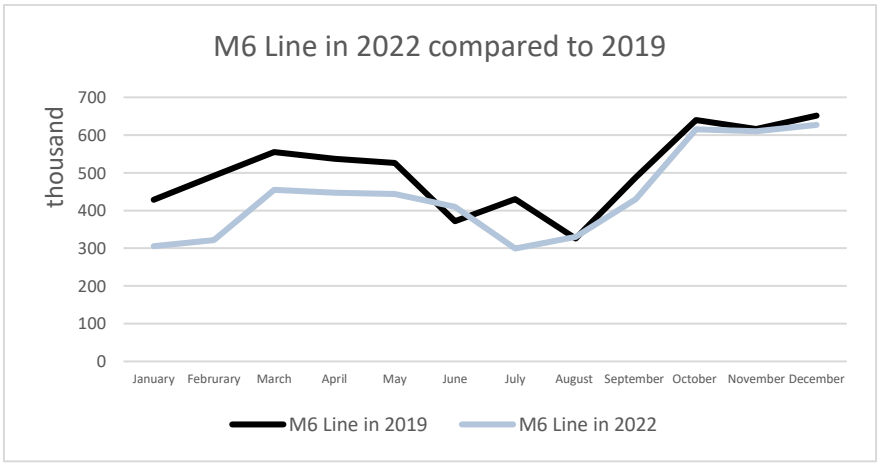


Figure 5.17: The Ridership Level of M6 Line compared to 2019

Source: Data obtained from Istanbul Metropolitan Municipality - Public Transportation Services Directorate

5.2.5 Comparison of Ridership Changes in Different Tram Lines

After analyzing the metro lines, it is important to analyze tram lines to understand the impact of COVID-19. T1 Line (Kabataş-Bağcılar) and T4 Line (Topkapı – Mescid-i Selam) has been chosen to be analyzed. As mentioned in the previous section, the T5 tram line has not been included analysis because the line started to serve after 2020. Additionally, the analysis does not include T3 (Kadıköy – Moda) line. The T3 line operates in a ring system, serving a specific area rather than connecting major urban destinations. Therefore, the annual number of passengers on T3 line is significantly lower compared to the T1 and T5 lines, serving as major transportation arteries in Istanbul. The change in the number of passengers of T1 and T3 line can be seen in Figure 5.18.

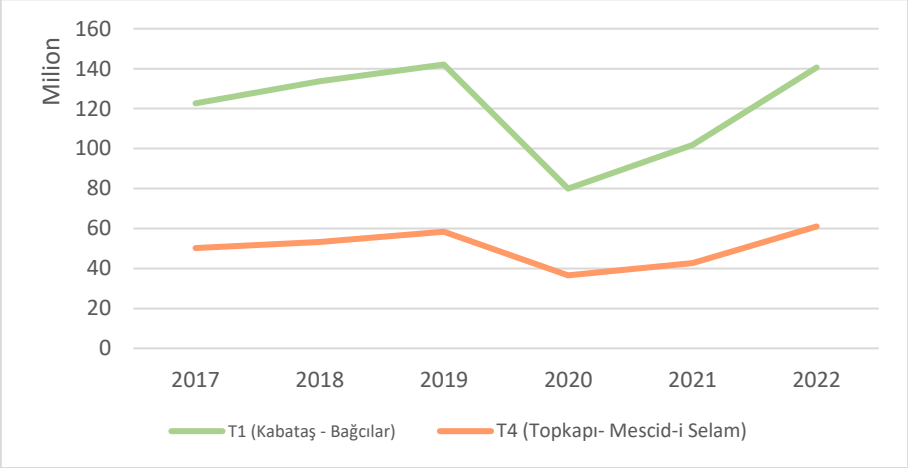


Figure 5.18: Number of Passengers on Metro Lines between 2017 and 2022

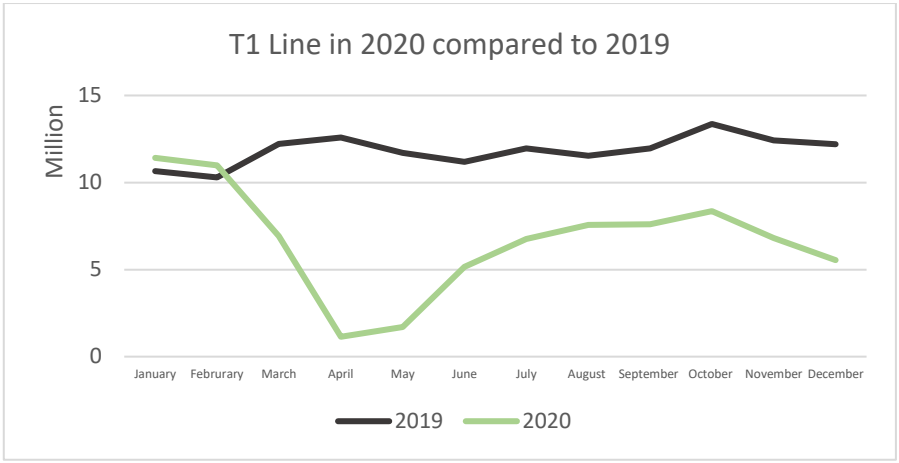
Source: Data obtained from Istanbul Metropolitan Municipality - Public Transportation Services Directorate

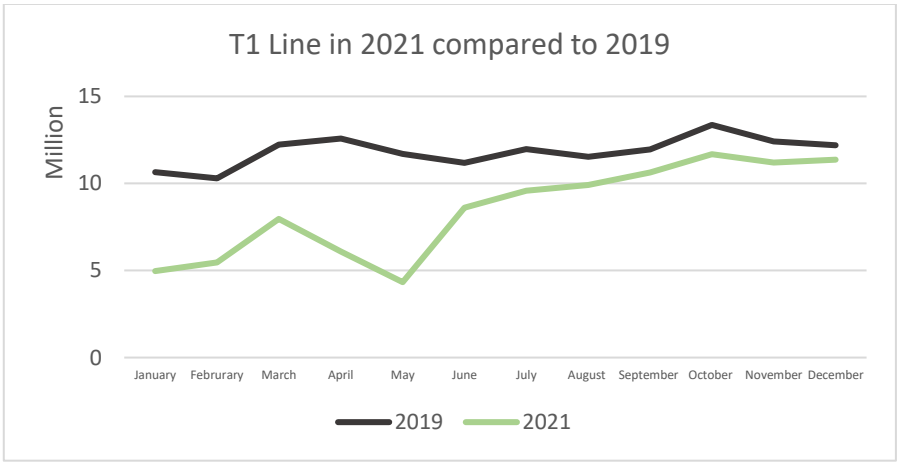
To analyse in a detailed way, the monthly change in the ridership level of T1 and T4 lines is demonstrated in Figure 5.19 and 5.20.

The number of passengers on T1 line dropped by 44%, and lost 62 117 121 passengers in 2020 compared to 2019. The sharpest decline in the ridership level of T1 line was observed after the declaration of COVID-19 on April 2020. It is also important to note that T1 line passes through several major tourist attraction points, making it popular among tourists. The sharpest decline in 2020 might be due to the use of the line for touristic purposes. In 2021, although the number of passengers was close to that of 2019, it could not reach the number of passengers in 2019. However, in May, 2022, 1 047 473 more passengers used the T1 line compared to 2019, exceeding the number of passengers in 2019. May 2022 can be considered as the beginning of the recovery period when the effects of the pandemic were decreasing and the number of tourists increasing. However, annual number of passengers on T1 line in 2022 was 1 502 066 less than in 2019.

T4 line is shorter than T1 line. However, their change in the ridership patterns were similar during COVID-19. Like T1 line, the dramatic decrease in the ridership level of T4 line is in April 2020. In 2020, the number of passengers decreased by 37% compared to 2019. In February 2022, 86 360 more passengers used the T4 line compared to 2019, reaching and exceeding the pre-pandemic level for the first time. Compared to T1 line, T4 line has recovered faster after the pandemic. Furthermore, in 2022, 2 657 952 more passengers used T4 line compared to 2019.

The reasons for slight decrease in the demand for T1 and T4 lines after the pandemic can be related to the capacity of the trams. Before the pandemic, the tram lines were operating at full capacity. After the pandemic, it is not possible to exceed the number of passengers in 2019. Operating at full capacity after pandemic can be considered as a rapid recovery of the tram lines.





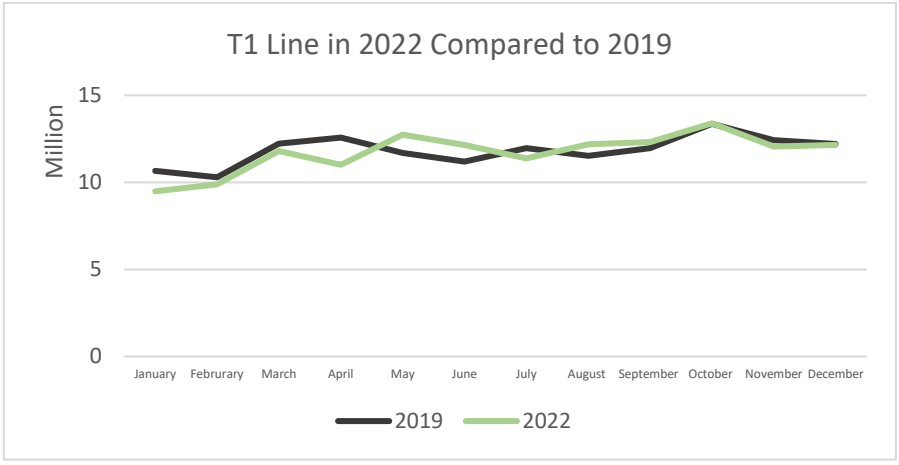
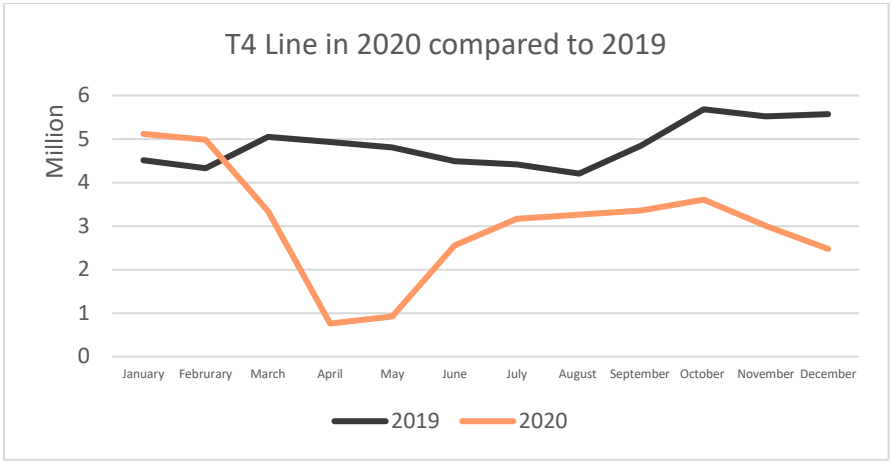
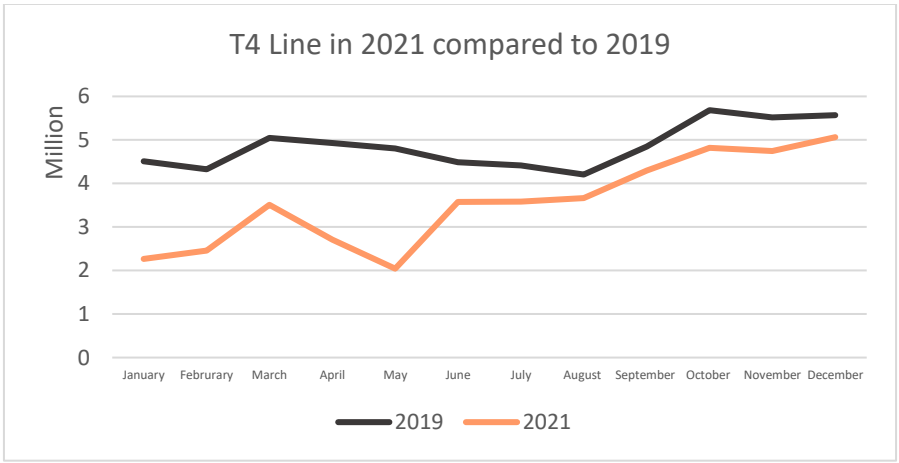


Figure 5.19: The Ridership Level of T1 Line compared to 2019

Source: Data obtained from Istanbul Metropolitan Municipality - Public Transportation Services Directorate





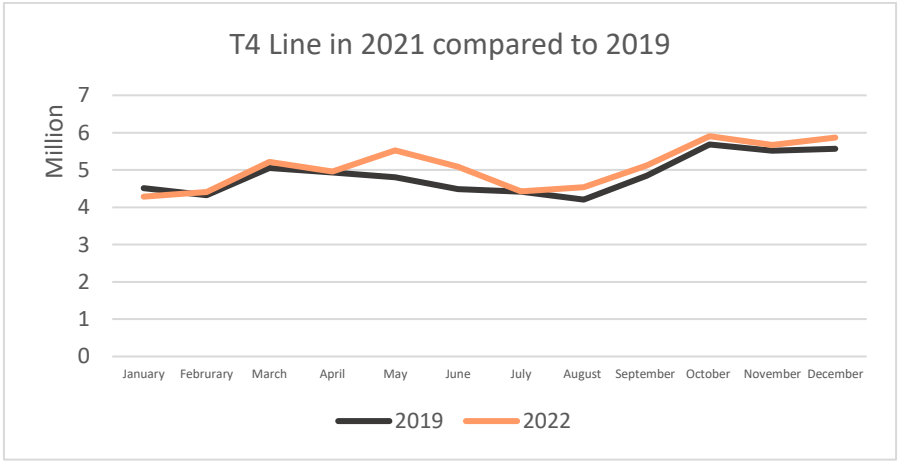


Figure 5.20: The Ridership Level of T4 Line compared to 2019

Source: Data obtained from Istanbul Metropolitan Municipality - Public Transportation Services Directorate

5.3 Policy Responses Resilience for Future Crisis

Semi-structured interviews have been conducted to respond to the second research question which is related to policy responses and measures for making public transportation more resilient to future health crisis. Interviews with policymakers provided a deeper understanding of the factors that influence the development and implementation of resilience in public transportation, especially in the local context. Five interviews were conducted with experts in the public transportation sector. The policymakers interviewed are listed below:

- Deputy Secretary General, *Istanbul Metropolitan Municipality*
- Head of Transportation Department, *Istanbul Metropolitan Municipality*
- Pedestrian Accessibility Department Chief, *Istanbul Metropolitan Municipality*
- General Manager, *Istanbul Şehir Hatları (Maritime Transportation)*
- Head of Transportation Planning Department, *IETT*

The interview questions were formulated through the outcomes of the literature review. Additionally, the interview was built upon the interpretation and discussion of the results of the analysis of public transport systems presented in the previous sections of this chapter. In the following sections, future resilience of public transportation is discussed with the help of the outcomes of the interviews.

5.3.1 Review of the Implemented Policies and Mobility Behavior Factors During and After the Pandemic

In the first part of the interview, the effectiveness of the public transportation measures during and after the pandemic was discussed. In this discussion, the interviewees were also asked questions on the socio-demographic, mobility behavior and pandemic related factors that may have played a role in changing mobility behavior.

During the pandemic, a wide range of policies were implemented to maintain the public transportation service in Istanbul. Regular buses and metrobus vehicles were allowed to carry passengers up to 1/3 of the standing passenger capacity and featured diagonal seating arrangements during the pandemic. The urban rail system reduced the capacity of the vehicles by 50%. Maritime transportation was allowed to carry passengers as much as the vehicle's seating capacity. Furthermore, stickers were applied on the vehicle floor to prevent close contact with standing passengers. In addition to these policies, hygiene rules, changing frequency of the public transportation systems, health codes for smart cards and fare policies were implemented during the pandemic in Istanbul. It was stated that the social distancing or wearing a mask didn't have a long-term impact on public transportation in Istanbul. During the pandemic, the new bus line to provide access to COVID-19 hospital started to operate. According to the interviews, this line is the only one continuing to operate before and after the pandemic. Arrangements regarding timetables and frequencies were implemented only during the pandemic. In other words, in the interviews, the measures for public transportation during pandemic were regarded as immediate measures since they were not implemented after the pandemic.

The common view was that the newly emerging factors had significantly lost their influence in deciding the mode of public transport after the pandemic. The fear of contagion, physical distancing, or wearing a mask was not decisive in using public transportation modes in the post-pandemic period. However, these factors, which were very influential during the pandemic, led to the rise in the idea of individuality in the post-pandemic period. Hence, the interest in private motorized modes accelerated, and ownership of private motorized modes became preferable to public transportation. According to the views of policymakers, second-hand sales of private motorized modes showed a dramatic increase during the pandemic. In fact, it is also possible to interpret this tendency towards private motorized modes as a result of the comfort and convenience factor gaining importance with the pandemic. Comfort and convenience in public transportation are related to travel time and transfers between

different modes in Istanbul. For this reason, private motorized modes may be preferred to provide faster and more comfortable access to avoid traffic congestion after the pandemic. According to policymakers, a private motorized mode was preferred for a comfortable and fast journey compared to public transport to save time, especially on trips requiring transfers between modes. Although the rail system in Istanbul is well integrated for transferring between different lines, integrating other public transportation modes (metro to maritime or metro to the bus) has yet to be fully achieved. Having noted these shortcomings about public transport and the comfort and convenience advantages of private modes, it should also be stated that due to the economic crises, most of the population had to return to public transportation after the pandemic.

Remote working was one of the most effective policies both during and after the pandemic, for addressing health issues overall and for helping operate public transport effectively. Working remotely during the pandemic was a requirement imposed on the population; however, after the pandemic it became a possible option for some people, and hence the intensity of commuting journeys reduced, helping public transport capacity to be used efficiently.

Following this point of view, the most encouraged policy highlighted in the interviews was the implementation of flexible working hours. Flexible working is a way to reduce the commuting burden, especially at peak hours. Flexible working hours can definitely help eliminate traffic congestion which is a major problem in Istanbul. Thanks to flexible working hours, the efficient use of public transportation capacities can encourage public transportation with increased comfort and convenience.

5.3.2 The Underlying Reasons for Changing Mobility Patterns

In the interviews, each mode of public transportation was discussed with experts to provide a better understanding of the underlying reasons for changing demand

before, during and after the pandemic. The changing demand for each mode of public transportation with respect to the recovery period and the resilience was explained in detail.

- ***Private Motorized Modes**:* As explained in the previous chapter, the tendency toward ownership of private motorized modes was gaining popularity during the pandemic. Although the main reason for preferring private modes was fear of contagion or the factors concerning health during the pandemic, these newly emerging factors were replaced with comfort and convenience after the pandemic. After the economic crisis that the country has been going through since the end of 2021, the tendency towards private motorized ownership was interrupted. Additionally, since motorcycles are more affordable than automobiles, it is also possible to observe a shift towards motorcycles in demand for private motorized modes. During the pandemic, the number of businesses using moto-courier was steadily increasing, and the number of employees in the moto-courier sector was growing in direct proportion. Thus, the increase in the number of motorcycles was more visible compared to the period before the pandemic.

- ***Active Modes (Walking and Cycling):*** With the pandemic, awareness of walking short distances increased to avoid the crowd in public transportation. Before the pandemic, walking was perceived as an activity that helped access public transportation stations. During the pandemic, walking was considered as a healthy transportation mode that provides access to daily needs. It is important to note that The Pedestrian Access Department was established in January 2020 under the Istanbul Metropolitan Municipality Transportation Planning Directorate. In other words, the pandemic did not initiate the work on pedestrian access in Istanbul; however, it certainly supported the ongoing studies. The Pedestrian Access Department has been working on "Walking to School Campaigns" and determining pedestrian priority roads to promote walkability. The primary advice of the Chief of the department was to prepare

a strategic plan for pedestrian access to find out the strength and weaknesses to encourage walking. In other words, the plans should be prepared from upper to lower scale to identify the needs and opportunities.

Unlike walking activities, cycling is considered as a recreational activity rather than a transportation mode in Istanbul. Consequently, implementations such as pop-up bike paths during the pandemic were not effective to change the perception of cycling. Cycling culture is not very common in most of the cities in Turkey, although there are increasing examples of bike plans and bike infrastructures. Although the cycling culture could not go beyond being a recreational activity, a Cycling Chiefship was established within the Department of Transportation Planning in Istanbul Metropolitan Municipality in 2019. In order to develop the cycling network in Istanbul, the "Istanbul Bicycle Master Plan" and "Bike Roads Design Guide" were discussed in the Istanbul Bicycle Workshop during the pandemic. According to the results of the interviews, a bike-share network will be promoted in Istanbul, and this will make it possible to collect cycling ridership for Istanbul.

In addition to the cycling and walking, e-scooter gained popularity in Istanbul in the recent years. Especially during the pandemic, e-scooters emerged as an alternative transportation option for passengers who avoided public transportation. However, although the main aim of the e-scooter was to provide an alternative to automobiles or motorcycles for short distances, experts interviewed stated that in Istanbul, walking was being increasingly replaced by e-scooters. As e-scooters are used on roads dominated by automobiles, using e-scooter poses a threat to the health and safety of riders.

- ***Public Transportation:*** In the previous section, it was mentioned that the newly emerging factors almost lost their impact on decisions for using public

transportation. On the other hand, it is apparent that mobility behavior profoundly changed during and after the pandemic. The reasons for mobility changes in urban transportation demand with data could not be analyzed during the pandemic by the local governments. Thus, the underlying reasons for the changing demand for public transportation were supported by the comment of policymakers.

- *Why is the most resilient mode urban rail system?*

The main reason for this was that the urban rail system is the fastest and the most comfortable mode of public transportation. Moreover, climate conditions and traffic congestion do not affect urban rail systems. Furthermore, urban rail systems are well integrated with each line. To illustrate, Marmaray has at least eight transfer stations to other metro or tram lines. Additionally, it has other stations that are integrated into maritime transportation or the Metrobus.

In the previous sections, it was mentioned that the Metrobus was a substitute for Marmaray. However, the number of passengers in Metrobus in 2022 did not exceed the numbers carried in 2019. Experts argued that this was because Metrobus had reached its total passenger capacity in 2019. Marmaray, on the other hand, can carry more passengers, and it has not achieved total passenger capacity yet. Consequently, while Metrobus features crowded vehicles due to operating close to its capacity, Marmaray offers a better level of service in terms of travel comfort. Thus, the capacity of the mode should also be considered when analyzing similar transportation modes. Therefore, the capacity, service level, service area (number of stations), and integration with other public transportation modes can be the reasons why Marmaray has emerged from the pandemic as the most resilient mode.

- *Why is the most vulnerable mode maritime transportation?*

Unlike the urban rail system, maritime transportation is sensitive to climate conditions and not as fast as the urban rail system. Even though voyages were reduced by only 20%, maritime transport lost more than half of the passengers. Maritime transportation is a mode of transportation that can protect social distance rules easily and reduces the risk of transmission with open-air journeys, thanks to its nature. In spite of this, the demand for maritime transportation dramatically decreased during the pandemic. This demonstrated that considering only the newly emerging factors was not enough to explain resilience of public transportation. To encourage the usage of maritime transportation, ticket fees were repriced to be 0.05 Turkish Lirasfree) between 10:00 and 16:00 in 2020. It was observed that the share of maritime systems in public transportation slightly increased thanks to the campaign. Additionally, the transfer between maritime transportation and other public modes is not well integrated. Due to this, when maritime transportation is preferred, the total cost of the journey becomes higher than the rail system. Therefore, after the pandemic, a 50% Discount Campaign for the transfer to or from maritime transportation was supported by *Şehir Hatları*.

Another issue is that maritime transportation is regarded by some as a recreational or touristic activity. According to the interviews, passengers above 65 or tourists preferred maritime transportation more than commuter passengers.

The last factor explaining the vulnerability of this mode was related to socio-economic factors. It has been suggested during the interviews that those with close and easy access to the sea preferred maritime public transportation in general. However, those who live close to the seaside are also those with a

relatively high income. While they may have been choosing maritime transportation under normal conditions, they probably avoided using this mode (together with other public transportation modes) during the pandemic period because they are more likely to have an alternative to public transportation (private vehicle).

On the other hand, rail systems and road-based transport serve a larger part of the city. Therefore, integration with different transport modes is crucial to enlarge the options for access.

In short, the underlying reasons for the vulnerability of maritime transportation is related to its being used for leisure trips, to socio-economic factors and to the need for integration with different public modes.

Almost 34 million more passengers preferred public transportation in 2022 compared to 2019 in Istanbul. Therefore, policymakers stated that a growing population should also be considered as a reason because the unregistered population may have an effect on the number of public transportation passengers.

5.3.3 Policymakers' Views on Adaptation to Future Crisis

The pandemic led to doubts about the need for resilient public transportation. The need for resilient public transportation was revealed after the crisis. However, deficits in the existing public transportation systems must be analyzed to achieve more resilient public transportation. Even if the impact of pandemics on public transportation is disappearing, the need for resilience still exists to adapt to future crises. Also, changing travel behavior because of the spread should be taken into consideration to understand the current needs.

In the interviews, it was revealed that "Emergency Transportation and Action Plan" was prepared for possible disasters by the Transportation Planning Directorate of the Istanbul Metropolitan Municipality. However, the scope of the plan is very limited.

The plan aims to identify alternative bus routes to maritime transportation and rail system.

On the other hand, the pandemic raised the awareness of the meaning of resilience in urban planning. The meaning of resilience in transport practice started to be questioned after the pandemic. Furthermore, Istanbul launched its Sustainable Urban Mobility Plan (SUMP) on March 28, 2022. The principle of durability was taken into account in the SUMP. This principle is built on the ability to maintain the transportation system even in disasters uninterruptedly. Furthermore, due to COVID-19, it was understood that the transportation system needs to recover quickly after unprecedented events.

For the Istanbul case, experts agree that flexible working hours and remote working should be supported to use public transportation capacity efficiently and to be prepared for any crises. Additionally, the recommendations of policymakers to have resilient public transportation systems in light of the lessons learned after the pandemic are summarized below.

- A participatory, inclusive and dynamic planning approach should be adopted. A resilient plan should be responsive to changing conditions. The current needs should be investigated, and the plan should be prepared for the future.

- The transportation plan should have the ability to deal with unpredicted events and recover fast by supporting alternative solutions.

- Human-centered transportation system should be supported, instead of car-oriented systems. For future resilience, as individuals are the critical actors in the urban environment, they should be able to easily adapt to changing conditions in case of unforeseen events. In all circumstances, people have the right to access essential needs. The city should be freed from the domination of private motorized traffic. Less automobiles in the city means more living

and mobile spaces. More mobility options should be provided to have an opportunity to adjust and adapt travel choices in case of crises.

- In order to encourage the use of public transport, first of all, the integration of all public transport modes should be ensured. Then, the urban environment should be redesigned to be suitable for using public transport as well as for walking and cycling. Public transportation station sites might be the pilot area for human-centered environment.

- A holistic approach to transportation planning should be considered, and partial solutions should be avoided. Each mode of transportation should be regarded as part of the whole system.

5.4 Main Findings of The Analysis

In this chapter, the analysis of change in the ridership level of public transportation modes during and after COVID-19 was carried out with the data obtained from Istanbul Metropolitan Municipality. The analysis aimed to find out the resilience and vulnerability of public transportation modes in Istanbul during and after COVID-19. Additionally, five semi-structured interviews with public transportation policymakers were conducted in Istanbul to understand changes in mobility behavior, implemented policies, and the underlying reasons for these changes.

The key findings of the analysis indicated the fastest recovery in the urban rail system (Marmaray, Metro/tram) with a 16% increase in ridership in 2022 compared to the ridership level in 2019. In the urban rail systems, the number of trips in Marmaray which is the longest tube tunnel and commuter rail mass transit system in Turkey increased by 54% in 2022 compared to 2019. The findings also revealed that the level of the ridership on road-based (Metrobus (BRT), Bus) and maritime public transit modes in 2022 remained approximately 17% below the ridership levels of 2019. The most significant drop in the number of passengers was recorded on the

M6 line in 2020 amongst the urban-rail lines. This sharp decline in passenger numbers on the M6 was expected since the operating route between the university and the transfer station runs with line M2. In other words, the number of passengers using line M6 did not reach the pre-pandemic levels and faced a 10% drop in 2022. On the other hand, considering the recovery period, the M5 line exceeded the number of passengers in 2022 at a remarkable rate compared to 2019.

In the interviews, the reasons for the findings of the analysis were discussed with policymakers. The integration with other modes of public transportation, speed, and service area significantly influenced transportation habits before, during and after the pandemic. According to the interviews, the urban rail system emerged as the most resilient mode of public transportation due to its speed, comfort, and resistance to climate conditions or traffic congestion. Furthermore, the urban rail system is well integrated with other public transportation modes, which made it an attractive option for commuters. In contrast, maritime transportation was the most vulnerable mode, primarily due to its sensitivity to climate conditions, slower speed, being considered for leisure trips and its less effective integration with other transportation modes.

Ownership of private motorized modes increased during the pandemic. The reason for the increase in the number of private motorized modes were related to comfort and health concerns such as hygiene and crowd. The health concerns were replaced by comfort and convenience as the primary drivers of this preference in the post COVID-19 period.

Several recommendations for adapting to future crises and enhancing public transportation resilience were discussed in the interviews. Flexible working hours and remote working were emphasized, which proved to be effective in reducing the commuting burden and alleviating traffic congestion during peak hours (Pedestrian Accessibility Department Chief, Istanbul Metropolitan Municipality). This strategy was in line with the AVOID-SHIFT-IMPROVE (ASI) framework's "Avoid" component.

Policymakers also emphasized the need for adopting a participatory, inclusive, and dynamic planning approach that is responsive to changing conditions and centered on human needs rather than car-oriented planning (Deputy Secretary General, Istanbul Metropolitan Municipality). In addition, they highlighted the importance of having a flexible transport system with various alternatives, creating an integrated public transport system, and planning and designing the station areas with a view to make it easy to access public transport as well as to walk and bike.

The pandemic brought about a new awareness for resilience regarding public transportation policies, as evidenced by the interviews with policymakers on urban transportation in Istanbul. Indeed, the pandemic imposed an increase on awareness of the importance of resilient public transportation systems that can adapt to and recover from unforeseeable events. As a result, policymakers began to reevaluate their approach to transportation planning, focusing on the need for human-centered planning and improved integration of all public transportation. In brief, the interviews provided valuable insights into the transformations in public transportation policies and mobility patterns in Istanbul as a result of the pandemic.

CHAPTER 6

CONCLUSION

This chapter provides a comprehensive overview of the research, emphasizing the significance of this study in understanding the impacts of COVID-19 on public transportation and policy responses for adaptation to future crises in Istanbul. In this section, the main research questions are revisited and discussed in the light of the research results. The chapter consists of three main sections. In the first section, the research is summarized. The main findings are described in the second section. Additionally, lessons learned are discussed to better prepare for future pandemics or crises that may impact public transportation systems. In the last section, insights for further research are presented.

6.1 Summary of The Research

Public transportation is one of the essential amenities, providing access to basic needs such as health, work, and education. However, crises such as pandemics and disasters lead to a change in the way people travel in everyday life. During the pandemic crisis, most individuals abstained from using public transportation due to the contagious nature of the pandemic. The impact of COVID-19 has raised concerns that the decrease in the usage of public transportation would become a permanent trend. In response to this concern, providing a resilient public transportation system was discussed to be vital in the literature to ensure continuous access and mobility for all. Different modes of public transportation should be analyzed to offer a picture of the current needs of policy and integrated public transportation system. Therefore, the aim of the thesis has been to analyze the impact of COVID-19 on the use of public transport systems. In particular, the analysis tried to find out whether there is

a long-lasting and permanent impact on the demand for public transport. Additionally, policy responses were investigated to identify effective transportation policies for future resilience.

The first part of the literature review was focused on understanding the impact of pandemic shaping public transportation. The critical reasons for the change in mobility patterns were discussed under three categories: socio-demographic, mode choice related and newly emerging factors. Over the course of COVID-19, newly emerging factors played an important role in changing travel behavior. In addition to these factors, sociodemographic factors were decisive in modes of travel choice. Additionally, changing daily lives because of online education and remote working resulted in a drastic change in mobility patterns.

In light of the literature review, the methodology, which covers descriptive statistics and semi-structured interviews, was introduced with the research questions. Furthermore, Istanbul was selected as a case study to explore the change in the demand in a city which is highly dependent on public transportation.

Before analyzing the public transportation system, a comprehensive background of the public transportation systems in Istanbul was provided, and the timeline of COVID-19 were explained. Public transportation systems in Istanbul are composed of urban rail systems (Metro, Tram, and Marmaray), road-based public transportation (Bus and Metrobus (BRT)) and maritime transportation. The difference between the number of passengers in 2019 and the number of passengers in 2020, 2021 and 2022 was compared to explore the change during and after the pandemic. To do this, each mode of public transport and the demand for the modes were analyzed separately. The demand for the modes before and after the pandemic were compared to determine which public transportation mode recovered fastest and which modes were slowest in recovery.

In the second part of the analysis, five semi-structured interviews were conducted to find out the policy background and the preparedness for resilience to future crises.

Through the discussion of research findings, policy recommendations were made to achieve more resilient and healthy public transportation systems.

6.2 Main Findings and Lessons Learned

The findings of the analysis on whether there is a long-lasting and permanent impact of COVID-19 on the demand for public transport are discussed together with inferences from the literature in this section. The lessons learned from policy responses during the pandemic is discussed to identify effective transportation policies for future resilience. The findings of the research answer the two research questions mentioned in the methodology.

- Is there a long-lasting impact of COVID-19 on demand for public transportation?
    - Which modes of public transportation recovered fast during the Pandemic and in the post-Pandemic era?
    - What are the most resilient modes of public transportation? What are the most vulnerable ones?

- Which policy responses and measures have been effective in making public transportation more resilient?
    - To what extent do the measures determine the mitigation of COVID-19 impacts on public transportation?
    - Are there any plans or policies to become resilient for future crises?

The analysis showed that the impact of COVID-19 on public transport usage was not permanent in the Istanbul case. The total number of public transportation passengers in 2022 exceeded that of 2019 in Istanbul. The main concern in the literature was that the impact of COVID-19 on public transportation would be permanent (Monterde-i-Bort, et al., 2022; Medlock et al. 2021) On the contrary, in Istanbul,

passengers returned to public transportation in the post-COVID period. However, each mode of public transportation experienced this process differently, some featuring a fast recovery while some being more vulnerable. Therefore, each mode was analyzed separately to understand the differences between modes in terms of recovery and resilience.

The key findings of the research indicated the fastest recovery in the urban rail system (Marmaray, Metro/tram) with a 16% increase in ridership in 2022 compared to the ridership level in 2019. In urban rail systems, the number of trips in Marmaray which is the longest tube tunnel and regional rail system in Turkey increased by 54% compared to 2019. The findings are in line with the literature on the inverse proportion between the number of stops and the rate of being affected by the pandemic (decrease in the number of passengers) (Aparicio et al., 2021). Marmaray, with the highest number of stations among all public transport modes in Istanbul, experienced the fastest recovery, recording a significant increase in the number of passengers in 2022 compared to 2019. The speedy recovery of urban rail systems might be caused by their reliable travel time that is not affected by traffic congestion.

The findings also revealed that passenger numbers of road-based public transportation in 2022 were still 6% below the pre-pandemic passenger rates. Contrary to the findings of the literature (Cho, 2021), the advantage of easy ventilation of road-based public transportation did not result in a fast recovery in Istanbul. In a study conducted in the New York City, Halvorsen et al. (2021) found that the recovery period of bus ridership levels was faster than the subway after the pandemic in the New York City. In Istanbul, however; urban-rail systems had a faster recovery process than road-based public transportation systems. Unlike other modes of public transport, the maritime transportation emerged as the most vulnerable mode, recording a 17% decrease in the number of passengers in 2022 when compared to the number of passengers in 2019. To the knowledge of the author, this is the first research which investigate the change in the ridership of maritime transportation during and after pandemic in the literature.

In metro lines, each line was analyzed and discussed to understand the underlying reasons for the change in demand during and after the pandemic. Concerning the analysis, the M6 line encountered the most severe passenger decline in 2020. This severe passenger decline of the M6 line was expected because the operation route is between the university and the transition station with the M2 line. However, after the pandemic, the number of passengers using the M6 line did not reach the pre-pandemic level and faced a 10% decline in 2022. Considering the recovery period, the M5 line surpassed the number of passengers at a striking rate in 2022 compared to 2019. The M5 line is operating between Çekmeköy and Üsküdar (transfer station between Anatolian side and European side). Aparicio et al. (2021) argued that the demand level at the periphery of the city was more affected during pandemic. However, in Istanbul the M5 line (Çekmeköy-Üsküdar) indicated the fastest recovery after the pandemic. It is evident that changes in daily routines, such as remote working had a significant impact on the recovery and resilience of public transportation.

Additionally, the impact of changes in daily life because of COVID-19 was more visible during the post pandemic period. Remote working habits and flexible working hours had continued for some part of the population, affecting the ridership levels.

The rate of private vehicle ownership in Istanbul increased by approximately 5% during the pandemic, exceeding the average increase in Turkey. The decrease in the demand for public transportation in 2020 led to a rise in the ownership of private motorized modes as it was considered a relatively safer mode in the face of the health crisis. On the other hand, the economic conditions in Turkey by the end of 2021, which resulted in increasing oil prices and high inflation rates, influenced the tendency towards using public transportation. In spite of the increase in the ownership of both motorcycle and automobile, a decrease in the demand for public transportation in 2022 was not observed.

On the contrary, after the pandemic, an increase was observed in public transportation ridership levels. This may indicate public transportation is still an option for a certain percentage of individuals with private motorized modes. Other factors affecting the mode choice (private motorized modes or public transportation) should also be analysed in detail in order to determine the factors behind increasing ridership in public transport in Istanbul. These include socio-economic factors; and considering the economic crises that the country has been experiencing since the end of 2021, this factor may play an important role in mode choice. In addition, it is possible that mode choice changes in accordance with the purpose of the trip. Together with various factors, the usage of the private motorized modes (automobile and motorcycle) should be analyzed to see the overall trends.

The five semi-structured interviews that were conducted with the policymakers responsible for different modes of public transportation also revealed possible factors for the change in mobility patterns in the city. The socio-economic factors (i.e., higher-income groups living in close access to sea and hence to maritime transport options), relatively lower speeds and lower levels of integration with other modes of public transportation might result in a decrease in demand for maritime transportation after the pandemic. Additionally, the perception that the maritime transportation is for recreational or touristic activity may have an influence on maritime transport ridership. On the contrary, urban-rail system is well-integrated with other public transportation modes. Moreover, service area of the urban-rail system is larger than the maritime transportation.

The key takeaways of the interview in terms of transport policy were the need for resilient, dynamic, and human-centered transport planning in the face of future crises. The recommendations of policymakers were aligned with the policy responses for adaptation to COVID-19 in the literature. Like in the PASS approach (Zhang, 2020), policymakers emphasized the need for integrated public transportation systems to adapt to changing circumstances. The integrated public

transportation systems reduce the reliance on a single mode of transport, which can be vulnerable to disruptive events. Additionally, as in the Avoid Shift Improve (ASI) framework, policymakers emphasized the "Improve" principle built upon the efficient use of the urban transportation systems (Griffiths et al., 2021). In the interview, the main emphasis was on the need for the efficient use of the public transportation capacity. As a tool for efficient use of public transportation, flexible working hours and remote working were highlighted in the interviews. The key findings and the comparison with the literature are presented in Figure 6.1.

It is important to note that the variation in the usage of different urban transportation modes across countries can significantly influence the changes in mobility patterns. For example, in countries where cycling culture and consequently the usage of bikes are prevalent, the impact of the pandemic on mobility would be expected to be different compared to countries with limited bike usage. A similar argument can be made for car-dependent cities as opposed to cities that rely heavily on public transport. Therefore, policy approaches to be prepared for future crises may differ according to the needs of countries.

When a challenge emerges, daily lives are profoundly changing. COVID-19 posed a great challenge for public transportation due to the change in daily habits such as remote working and online shopping, as well as the fear of contagion. Hence, the constraints and inefficiencies of the existing transportation system were more visible during COVID-19. In such a crisis, maintaining the public transportation system was vital to provide the basic need for mobility. Needless to say, the public transportation system should serve all people under every circumstance, with or without the pandemic.

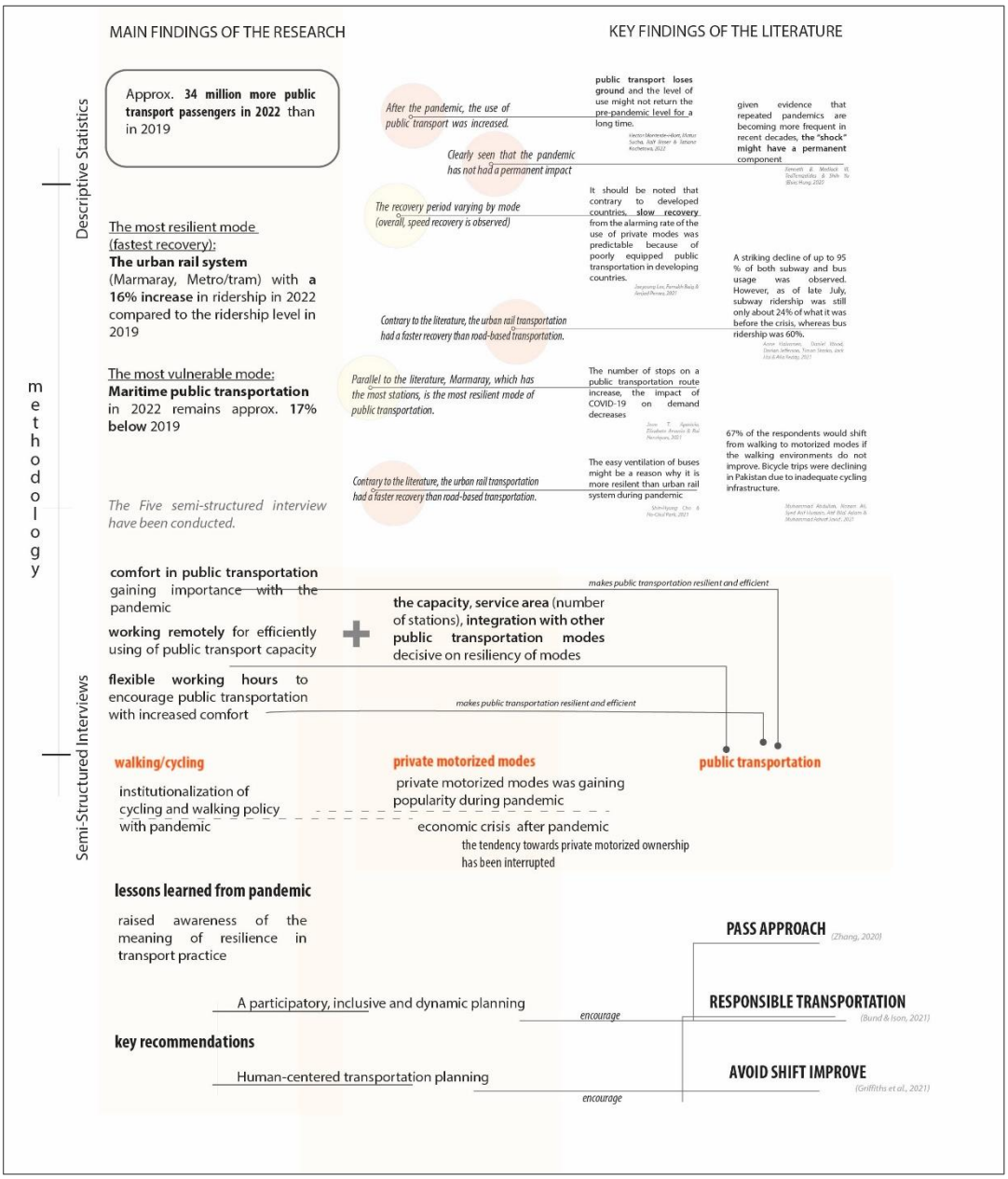


Figure 6.1: The Conceptual Diagram of Main Findings

6.3 Recommendations for a Policy Framework to Ensure Resilience in Public Transportation Systems

One of the most critical parts of the interviews was to evaluate the effectiveness of measures and policies for public transportation to ensure resilience of the system during and after the pandemic. The measures for public transportation in Istanbul mentioned in Chapter 4 was discussed with a view to provide a policy framework for future resilience (See Section 4.4.1).

As discussed in the previous section, the experts put emphasis on remote working and flexible working hours to ensure the effective use of the capacity of public transportation vehicles. However, during the pandemic, a wide range of policies were implemented to maintain the public transportation service in Istanbul. The buses and metrobus vehicles were allowed to carry passengers up to 1/3 of the standing passenger capacity and also featured diagonal seating arrangements during the pandemic. The urban rail system reduced the capacity of the vehicles by 50%. Maritime transportation was allowed to carry passengers as much as the vehicle's seating capacity. Furthermore, stickers were applied on the vehicle floor to prevent close contact with standing passengers. In addition to these policies, hygiene rules, changing frequency of the public transportation systems, health codes for smart cards and fare policies were implemented during the pandemic in Istanbul.

As mentioned in the interviews, these measures were immediate measures and were not considered for long-term planning and operation after the pandemic. The common view was that the newly emerging factors (social distance, hygiene, mask wearing) had significantly lost their influence in deciding the mode of public transport after the pandemic. However, considering the emphasis on the efficient use of the capacity and integration of public transport in the interviews, these policies should be regarded as tools to make public transportation resilient for future crises. Moreover, Hörcher et al. (2021) proposed social distancing, as an effective way to manage the capacity of public transportation. Inflow control with queuing, time and

space-dependent pricing, advance booking has also been described in the literature as effective methods for social distancing.

Considering the outcomes of the literature review, the following set of measures can be recommended for Istanbul and for other cities to run public transport systems in an effective and resilient way in the face of future health crises**:**

- Passenger attraction policies should be encouraged with the help of the methods for social distancing. Ensuring a certain level of personal space can increase the comfort and hence attractiveness of public transport.

- Travel by reservation can be a method for the efficient use of public transportation capacity. This may not be effective for very high demand corridors; but should be studied for possible lines and possible times of the day when demand levels can be manageable by reservation.

- Up-to-date information regarding schedules, occupancy levels, and any service disruptions of public transportation systems through digital platforms should be provided. Providing up-to-date and reliable information to passengers can help to reduce the burden at peak hours or during major events and disruptions. By doing so, individuals can arrange and change their travel. Implementing such a policy effectively helps in mitigating overcrowding around the stations and within the vehicles, leading to a reduction in waiting times at the stations.

- Distance-based pricing is actively encouraged in trips by Marmaray and Metrobus. There are several long metro lines (M1A-M1B, M2, M4, Metrobus) which do not use this system although would be suitable for distance-based pricing. Distance-based pricing can also influence mobility patterns by incentivizing shorter trips and encouraging the use of alternative modes of transportation. By doing so, it can reduce congestion on public

transportation routes and provide operational flexibility during unexpected events.

- The hygiene rules (ventilation and disinfection) should be the main principle for public transportation to be prepared for future crises.

- A flexible public transport network should be encouraged, so that the vulnerability in one component can be compensated by alternatives. Additionally, the built environment should encourage different modes of transportation. Cycling and walking should be integrated with the public transportation systems.

6.4 Further Research

The research was carried out focusing on public transportation usage in Istanbul before, during and after the pandemic. Furthermore, the research dealt with the recovery period of different public transportation modes to explore the policy needs for future resilience against possible crises.

In the research, a descriptive analysis on comparison between different public transportation modes was conducted. The main findings of the literature that public transport system was losing ground after the pandemic was questioned in the Istanbul case. Within the research, the five semi-structured interviews were conducted to evaluate public transportation from the perspectives of policymakers. The study also investigated the resilience of public transportation related to the recovery period with the help of the views of policymakers.

The reasons why maritime transportation is the most vulnerable mode can be studied with a particular focus on fare policy, passenger profiles or purposes of travel on this mode in further studies in the light of the findings of this study. Additionally, in

further research the impact of remote working and flexible working hours on public transportation ridership can be the main focus to analyze the effects of these on resilience of the system.

Further research can be carried out by comparing the impact of COVID-19 on public transportation as well as policy responses in different cities in Turkey to understand how different cities are dealing with similar challenges and learn from their successes and failures. The comparison of different cities in Turkey can provide valuable insights into the effectiveness of different policy approaches and strategies.

Moreover, para-transit modes play a significant role in providing mobility for a large proportion of the population and serve as a public transportation mode. Further research on para-transit modes could help to better understand their role in public transportation systems, their levels of resilience and their vulnerabilities during times of crisis such as COVID-19. The differences between impacts of COVID-19 on para-transit modes and public transportation can be compared because during COVID-19, para-transit modes were particularly vulnerable due to their informal and unregulated nature.

In light of the findings of this study, the parameters impacting travel behavior in Istanbul can be investigated to expand the research. Due to lack of data, this research could not identify factors with certainty regarding the changes in ridership levels, although based on the review of the literature, the interviews with experts and policymakers covered such questions on the factors behind changing travel behavior. Research examining the reasons for changing transportation behaviors in the post-pandemic period will help reach a resilient transportation system by being associated with the thesis findings. Consequently, a travel survey can be designed for Istanbul to develop this research further.

Additionally, in such a survey, active modes of transportation can also be included as one of the main focuses. Due to the limitations of availability of data, in this research, the impact of COVID-19 on cycling and walking could not be analyzed. However, as stressed throughout the study, it would not be possible to ensure the

resilience of the urban transportation system without integration between public and active modes of transportation.

In the literature, most of the research focused on changing travel behavior during COVID-19. However, there is a lack of knowledge on how travel behavior changed after the pandemic. In other words, the parameters discussed in the second chapter should be addressed by analyzing passenger experiences, especially considering vulnerable groups. Therefore, new research is needed to analyze post-pandemic travel behavior.

Particularly in Turkish cities, the research gap still exists on why individuals change their previous mode decisions during and after the pandemic due to the limited data availability mentioned.

REFERENCES

Abdullah, M., Ali, N., Hussain, S. A., Aslam, A. B., & Javid, M. A. (2021). Measuring changes in travel behavior pattern due to COVID-19 in a developing country: A case study of Pakistan. *Transport Policy*, *108*, 21–33. https://doi.org/10.1016/j.tranpol.2021.04.023

Alonso-Almeida, M. D. M. (2022). To Use or Not Use Car Sharing Mobility in the Ongoing COVID-19 Pandemic? Identifying Sharing Mobility Behaviour in Times of Crisis. *International Journal of Environmental Research and Public Health*, *19*(5). https://doi.org/10.3390/ijerph19053127

Alpkokin, P., & Ergun, M. (2012). Istanbul Metrobüs: first intercontinental bus rapid transit. Journal of Transport Geography, 24, 58–66. https://doi.org/10.1016/j.jtrangeo.2012.05.009

Aparicio, J. T., Arsenio, E., & Henriques, R. (2021). Understanding the impacts of the COVID-19 pandemic on public transportation travel patterns in the city of Lisbon. *Sustainability (Switzerland)*, *13*(15). https://doi.org/10.3390/su13158342

Astroza, S., Tirachini, A., Hurtubia, R., Carrasco, J. A., Guevara, A., Munizaga, M., Figueroa, M., & Torres, V. (2020). Mobility Changes, Teleworking, and Remote Communication during the COVID-19 Pandemic in Chile. Transport Findings. https://doi.org/10.32866/001c.13489

Aydin, N., Kuşakcı, A.O., Deveci, M., "The impacts of COVID-19 on travel behavior and initial perception of public transport measures in Istanbul", Decision Analytics Journal, 2: 100029, (2022).

Babalik, E. (2021). Urban mobility after COVID-19: A developing-country perspective. In *Town Planning Review* (Vol. 92, Issue 2, pp. 165–170). Liverpool University Press. https://doi.org/10.3828/tpr.2020.33

Bergantino, A. S., Intini, M., & Tangari, L. (2021). Influencing factors for potential bike-sharing users: an empirical analysis during the COVID-19 pandemic. *Research in Transportation Economics*, *86*. https://doi.org/10.1016/j.retrec.2020.101028

Brough, R., Freedman, M., & Phillips, D. C. (2021). Understanding socioeconomic disparities in travel behavior during the COVID-19 pandemic. *Journal of Regional Science*, *61*(4), 753–774. https://doi.org/10.1111/jors.12527

Büchel, B., Marra, A. D., & Corman, F. (2022). COVID-19 as a window of opportunity for cycling: Evidence from the first wave. *Transport Policy*, *116*, 144–156. https://doi.org/10.1016/j.tranpol.2021.12.003

Buck, M., & Nurse, A. (2021). Cycling in an 'ordinary city': A practice theory approach to supporting a modal shift. *International Journal of Sustainable Transportation*. https://doi.org/10.1080/15568318.2021.1983674

Bucsky, P. (2020). Modal share changes due to COVID-19: The case of Budapest. *Transportation Research Interdisciplinary Perspectives*, *8*. https://doi.org/10.1016/j.trip.2020.100141

Budi, D. R., Widyaningsih, R., Nur, L., Agustan, B., Dwi, D. R. A. S., Qohhar, W., & Asnaldi, A. (2021). Cycling during COVID-19 pandemic: Sports or lifestyle? *International Journal of Human Movement and Sports Sciences*, *9*(4), 765–771. https://doi.org/10.13189/saj.2021.090422

Cartenì, A., Di Francesco, L., Henke, I., Marino, T. V., & Falanga, A. (2021). The role of public transport during the second COVID-19 wave in italy. *Sustainability (Switzerland)*, *13*(21). https://doi.org/10.3390/su132111905

Chang, H. H., Lee, B., Yang, F. A., & Liou, Y. Y. (2021). Does COVID-19 affect metro use in Taipei? *Journal of Transport Geography*, *91*. https://doi.org/10.1016/j.jtrangeo.2021.102954

Cho, S. H., & Park, H. C. (2021). Exploring the Behaviour Change of Crowding Impedance on Public Transit due to COVID-19 Pandemic: Before and After Comparison. *Transportation Letters*, *13*(5–6), 367–374. https://doi.org/10.1080/19427867.2021.1897937

Corazza, M. V., & Musso, A. (2021b). Urban transport policies in the time of pandemic, and after: An ARDUOUS research agenda. Transport Policy, 103, 31–44. https://doi.org/10.1016/j.tranpol.2021.01.010

Conway, M. W., Salon, D., da Silva, D. C., & Mirtich, L. (2020). How Will the COVID-19 Pandemic Affect the Future of Urban Life? Early Evidence from Highly-Educated Respondents in the United States. *Urban Science*, *4*(4), 50. https://doi.org/10.3390/urbansci4040050

Das, S., Boruah, A., Banerjee, A., Raoniar, R., Nama, S., & Maurya, A. K. (2021). Impact of COVID-19: A radical modal shift from public to private transport mode. *Transport Policy*, *109*, 1–11. https://doi.org/10.1016/j.tranpol.2021.05.005

Delft University of Technology. (2021). Amsterdam social distancing map. Retrieved May 13, 2023, from https://amsterdam-social-distancing.social-glass.tudelft.nl/#15.75/52.369629/4.895143

Dingil, A. E., & Esztergár-Kiss, D. (2021). The Influence of the COVID-19 Pandemic on Mobility Patterns: The First Wave's Results. *Transportation Letters*, *13*(5–6), 434–446. https://doi.org/10.1080/19427867.2021.1901011

Earley, R. and Newman, P. (2021) Transport in the Aftermath of COVID-19: Lessons Learned and Future Directions. Journal of Transportation Technologies, 11, 109-127. https://doi.org/10.4236/jtts.2021.112007

Fatmi, M. R. (2020). COVID-19 impact on urban mobility. *Journal of Urban Management*, *9*(3), 270–275. https://doi.org/10.1016/j.jum.2020.08.002

Gkiotsalitis, K., & Cats, O. (2021). Public transport planning adaption under the COVID-19 pandemic crisis: literature review of research needs and directions. *Transport Reviews*, *41*(3), 374–392. https://doi.org/10.1080/01441647.2020.1857886

Güngör, B. (2020). Türkiye'de Covid-19 Pandemisi Süresince Alınan Önlemlerin Kriz Yönetimi Perspektifinden Değerlendirilmesi. *Uluslararası Sosyal Bilimler Akademi Dergisi(USBAD)*. https://doi.org/10.47994/usbad.811463

Habib, K. N., Hawkins, J., Shakib, S., Loa, P., Mashrur, S., Dianat, A., Wang, K., Hossain, S., & Liu, Y. (2021). Assessing the impacts of COVID-19 on urban passenger travel demand in the greater Toronto area: description of a multi-pronged and multi-staged study with initial results. *Transportation Letters*, *13*(5–6), 353–366. https://doi.org/10.1080/19427867.2021.1899579

Halvorsen, A., Wood, D., Jefferson, D., Stasko, T., Hui, J., & Reddy, A. (2021). Examination of New York City Transit's Bus and Subway Ridership Trends During the COVID-19 Pandemic. *Transportation Research Record: Journal of the Transportation Research Board*, 036119812110288. https://doi.org/10.1177/03611981211028860

Hasselwander, M., Tamagusko, T., Bigotte, J. F., Ferreira, A., Mejia, A., & Ferranti, E. J. S. (2021). Building back better: The COVID-19 pandemic and transport policy implications for a developing megacity. *Sustainable Cities and Society*, *69*. https://doi.org/10.1016/j.scs.2021.102864

Hörcher, D., Singh, R., & Graham, D. J. (2022). Social distancing in public transport: mobilising new technologies for demand management under the COVID-19

crisis. *Transportation*, *49*(2), 735–764. https://doi.org/10.1007/s11116-021-10192-6

Hu, S., Xiong, C., Liu, Z., & Zhang, L. (2021). Examining spatiotemporal changing patterns of bike-sharing usage during COVID-19 pandemic. *Journal of Transport Geography*, *91*. https://doi.org/10.1016/j.jtrangeo.2021.102997

Hua, M., Chen, X., Cheng, L., & Chen, J. (2021). Should bike-sharing continue operating during the COVID-19 pandemic? Empirical findings from Nanjing, China. *Journal of Transport and Health*, *23*. https://doi.org/10.1016/j.jth.2021.101264

Istanbul Planning Agency (IPA), (2022). İki Teker Üstündeki Kent İşçileri: Moto Kuryeler. Retrieved May 30, 2023, from https://ipa.istanbul/wp-content/uploads/2022/02/Moto-Kuryeler.pdf

Jenelius, E., & Cebecauer, M. (2020). Impacts of COVID-19 on public transport ridership in Sweden: Analysis of ticket validations, sales and passenger counts. Transportation Research Interdisciplinary Perspectives, 8, 100242. https://doi.org/10.1016/j.trip.2020.100242

Jiao, J., & Azimian, A. (2021). Exploring the factors affecting travel behaviors during the second phase of the COVID-19 pandemic in the United States. *Transportation Letters*, *13*(5–6), 331–343. https://doi.org/10.1080/19427867.2021.1904736

Kamar, S., Shaheem, S., Vinayaka, B., & Mathew, S. (2022). Public Transport Passenger Attraction Using Policy Interventions for a Post-COVID Scenario. *Transportation in Developing Economies*, *8*(1). https://doi.org/10.1007/s40890-022-00151-w

Khadem Sameni, M., Barzegar Tilenoie, A., & Dini, N. (2021). Will modal shift occur from subway to other modes of transportation in the post-corona world in developing countries? *Transport Policy*, *111*, 82–89. https://doi.org/10.1016/j.tranpol.2021.07.014

Ku, D. G., Um, J. S., Byon, Y. J., Kim, J. Y., & Lee, S. J. (2021). Changes in passengers' travel behavior due to COVID-19. *Sustainability (Switzerland)*, *13*(14). https://doi.org/10.3390/su13147974

Lee, J., Baig, F., & Pervez, A. (2021). Impacts of COVID-19 on individuals' mobility behavior in Pakistan based on self-reported responses. *Journal of Transport and Health*, *22*. https://doi.org/10.1016/j.jth.2021.101228

Li, H., Zhang, Y., Zhu, M., & Ren, G. (2021). Impacts of COVID-19 on the usage of public bicycle share in London. *Transportation Research Part A: Policy and Practice*, *150*, 140–155. https://doi.org/10.1016/j.tra.2021.06.010

Luan, S., Yang, Q., Jiang, Z., & Wang, W. (2021). Exploring the impact of COVID-19 on individual's travel mode choice in China. *Transport Policy*, *106*, 271–280. https://doi.org/10.1016/j.tranpol.2021.04.011

Lucchesi, S. T., Tavares, V. B., Rocha, M. K., & Larranaga, A. M. (2022). Public Transport COVID-19-Safe: New Barriers and Policies to Implement Effective Countermeasures under User's Safety Perspective. *Sustainability (Switzerland)*, *14*(5). https://doi.org/10.3390/su14052945

Medlock, K. B., Temzelides, T., & Hung, S. Y. (Elsie). (2021). COVID-19 and the value of safe transport in the United States. *Scientific Reports*, *11*(1). https://doi.org/10.1038/s41598-021-01202-9

Metro Istanbul. (n.d.). All lines. Retrieved May 13, 2023, from https://www.metro.istanbul/Hatlarimiz/TumHatlarimiz

Metrobüs Hatları. (n.d.). https://iett.istanbul/icerik/metrobus-hatlari

Monterde-I-bort, H., Sucha, M., Risser, R., & Kochetova, T. (2022). Mobility Patterns and Mode Choice Preferences during the COVID-19 Situation. *Sustainability (Switzerland)*, *14*(2). https://doi.org/10.3390/su14020768

Moody, J., Farr, E., Papagelis, M., & Keith, D. R. (2021). The value of car ownership and use in the United States. *Nature Sustainability*, *4*(9), 769–774. https://doi.org/10.1038/s41893-021-00731-5

Naveen, B. R., & Gurtoo, A. (2022). Public transport strategy and epidemic prevention framework in the Context of COVID-19. *Transport Policy*, *116*, 165–174. https://doi.org/10.1016/j.tranpol.2021.12.005

Palm, M., Allen, J., Liu, B., Zhang, Y., Widener, M., & Farber, S. (2021). Riders Who Avoided Public Transit During COVID-19: Personal Burdens and Implications for Social Equity. *Journal of the American Planning Association*, *87*(4), 455–469. https://doi.org/10.1080/01944363.2021.1886974

Parker, M. E. G., Li, M., Bouzaghrane, M. A., Obeid, H., Hayes, D., Frick, K. T., Rodríguez, D. A., Sengupta, R., Walker, J., & Chatman, D. G. (2021). Public transit use in the United States in the era of COVID-19: Transit riders' travel behavior in the COVID-19 impact and recovery period. *Transport Policy*, *111*, 53–62. https://doi.org/10.1016/j.tranpol.2021.07.005

Patlins, A. (2021). Adapting the Public Transport System to the COVID-19 Challenge, Ensuring its Sustainability. *Transportation Research Procedia*, *55*, 1398–1406. https://doi.org/10.1016/j.trpro.2021.07.125

Pawar, D. S., Yadav, A. K., Choudhary, P., & Velaga, N. R. (2021). Modelling work- and non-work-based trip patterns during transition to lockdown period of COVID-19 pandemic in India. *Travel Behaviour and Society*, *24*, 46–56. https://doi.org/10.1016/j.tbs.2021.02.002

Ponte, C., Carmona, H. A., Oliveira, E. A., Caminha, C., Lima, A. S., Andrade, J. S., & Furtado, V. (2021). Tracing contacts to evaluate the transmission of COVID-19 from highly exposed individuals in public transportation. *Scientific Reports*, *11*(1). https://doi.org/10.1038/s41598-021-03998-y

Przybylowski, A., Stelmak, S., & Suchanek, M. (2021). Mobility behaviour in view of the impact of the COVID-19 pandemic-public transport users in gdansk case study. *Sustainability (Switzerland)*, *13*(1), 1–12. https://doi.org/10.3390/su13010364

Qi, Y., Liu, J., Tao, T., & Zhao, Q. (2021). Impacts of COVID-19 on public transit ridership. *International Journal of Transportation Science and Technology*. https://doi.org/10.1016/j.ijtst.2021.11.003

Schaefer, K. J., Tuitjer, L., & Levin-Keitel, M. (2021). Transport disrupted – Substituting public transport by bike or car under Covid 19. *Transportation Research Part A: Policy and Practice*, *153*, 202–217. https://doi.org/10.1016/j.tra.2021.09.002

Scorrano, M., & Danielis, R. (2021). Active mobility in an Italian city: Mode choice determinants and attitudes before and during the COVID-19 emergency. *Research in Transportation Economics*, *86*. https://doi.org/10.1016/j.retrec.2021.101031

Shakibaei, S., de Jong, G. C., Alpkökin, P., & Rashidi, T. H. (2021). Impact of the COVID-19 pandemic on travel behavior in Istanbul: A panel data analysis. *Sustainable Cities and Society*, *65*. https://doi.org/10.1016/j.scs.2020.102619

Šinko, S., Prah, K., & Kramberger, T. (2021). Spatial modelling of modal shift due to COVID-19. *Sustainability (Switzerland)*, *13*(13). https://doi.org/10.3390/su13137116

Sogbe, E. (2021). The evolving impact of coronavirus (COVID-19) pandemic on public transportation in Ghana. *Case Studies on Transport Policy*, *9*(4), 1607–1614. https://doi.org/10.1016/j.cstp.2021.08.010

Teixeira, J. F., Silva, C., & Moura e Sá, F. (2021). The motivations for using bike sharing during the COVID-19 pandemic: Insights from Lisbon. *Transportation Research Part F: Traffic Psychology and Behaviour*, *82*, 378–399. https://doi.org/10.1016/j.trf.2021.09.016

Thomas, F. M. F., Charlton, S. G., Lewis, I., & Nandavar, S. (2021). Commuting before and after COVID-19. *Transportation Research Interdisciplinary Perspectives*, *11*. https://doi.org/10.1016/j.trip.2021.100423

Thombre, A., & Agarwal, A. (2021). A paradigm shift in urban mobility: Policy insights from travel before and after COVID-19 to seize the opportunity. *Transport Policy*, *110*, 335–353. https://doi.org/10.1016/j.tranpol.2021.06.010

Tirachini, A. (2020). The Journal of Public Transportation is published by the Center for Urban Transportation Research at the University of South Florida Journal of Public Transportation | scholarcommons. *Journal of Public Transportation*, *22*(1), 1–21. https://doi.org/10.5038/2375-091.22.1.1

Tirachini, A., & Cats, O. (2020). COVID-19 and Public Transportation: Current Assessment, Prospects, and Research Needs. Journal of Public Transportation, 22(1). https://doi.org/10.5038/2375-0901.22.1.1

Zafri, N. M., Khan, A., Jamal, S., & Alam, B. M. (2021). Impacts of the COVID-19 pandemic on active travel mode choice in bangladesh: A study from the perspective of sustainability and new normal situation. *Sustainability (Switzerland)*, *13*(12). https://doi.org/10.3390/su13126975

Zhang, J. (2020b). Transport policymaking that accounts for COVID-19 and future public health threats: A PASS approach. Transport Policy, 99, 405–418. https://doi.org/10.1016/j.tranpol.2020.09.009

Zhang, Y., & Fricker, J. D. (2021). Quantifying the impact of COVID-19 on non-motorized transportation: A Bayesian structural time series model. *Transport* Policy, 103, 11–20. https://doi.org/10.1016/j.tranpol.2021.01.013

Zhou, H., Wang, Y., Huscroft, J. R., & Bai, K. (2021). Impacts of COVID-19 and anti-pandemic policies on urban transport—an empirical study in China. Transport Policy, 110, 135–149. https://doi.org/10.1016/

APPENDICES

A. The Interview Questions

1. Impact of COVID-19 on Travel Behavior

    1.1. During the pandemic, transportation behaviors changed a lot. Which parameters do you think are more effective in this change after the pandemic?

2. Impact of COVID-19 on Mobility Patterns

    2.1. Especially during the pandemic period, a serious decrease in the use of public transportation was observed. A rapid recovery process is observed today. How and why has the demand for different modes of transport changed in this process?

    2.2. Which mode of transport do you think is the most vulnerable and resilient, especially when considering public transport?

3. Prevention and Control Measures for Public Transportation

    3.1. Which of the measures for public transportation, especially during the pandemic period, do you think has an impact on transportation behaviors?

    3.2. Do you think curfews and fear of contagion have a lasting impact on avoiding public transport?

3.3. Do you think that the measures for public transportation have an effect on the fast recovery of urban rail systems?

4. Policy Responses to Post-COVID-19 Adaptation: Resilience to Future Crises

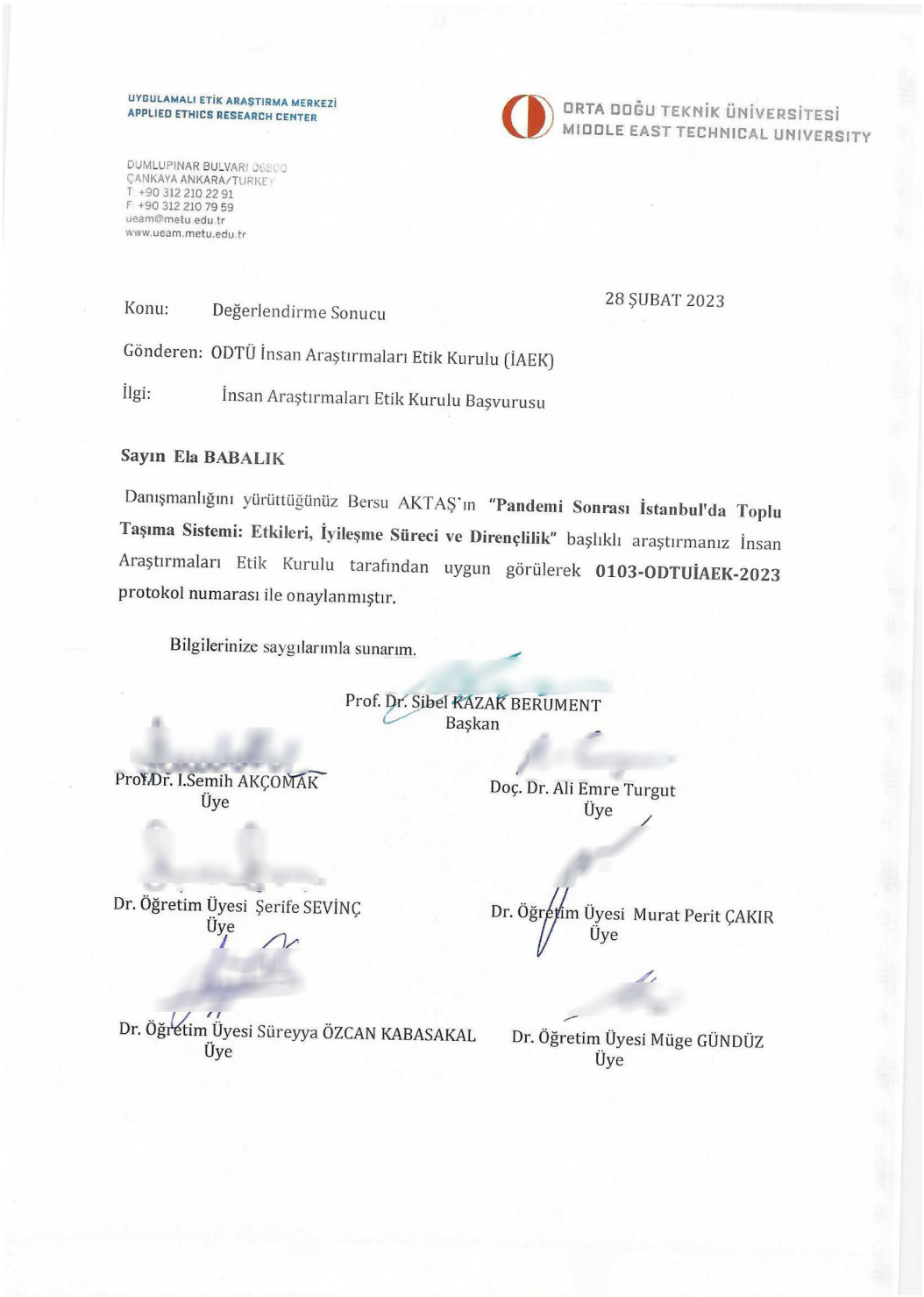
4.1. Does the Istanbul Transportation Directorate have an emergency plan for crisis situations?

4.2. Newly emerging approaches to ensure resiliency in public transportation are discussed around the world. Did such approaches have an impact on the SUMP approved in Istanbul?

4.3. The pandemic highlights the need for cycling and walking in urban transportation systems. What is the impact of the pandemic on the development of policies on this issue?

4.4. Are there any policies that were decided to be implemented permanently from the measures during the pandemic process? What measures should be implemented permanently? Do you have any suggestions for public transportation resilience for future crises?

B. The Approval of Ethics Committee



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28 ŞUBAT 2023

Konu: Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Ela BABALIK

Danışmanlığını yürüttüğünüz Bersu AKTAŞ'ın **"Pandemi Sonrası İstanbul'da Toplu Taşıma Sistemi: Etkileri, İyileşme Süreci ve Dirençlilik"** başlıklı araştırmanız İnsan Araştırmaları Etik Kurulu tarafından uygun görülerek **0103-ODTUİAEK-2023** protokol numarası ile onaylanmıştır.

Bilgilerinize saygılarımla sunarım.

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