Research Article GUJ Sci 36(2): 573-590 (2023) DOI:10.35378/gujs.1022067

Gazi University

Journal of Science

http://dergipark.gov.tr/gujs

The Financial Impact of the COVID-19 Pandemic on Public Transportation and Sustainable Policy Recommendations: A Case Study of Eskişehir

Fatih YILDIZHAN[1,*], Safak BILGIC[2]

[1]*Gaziantep University, Department of Civil Engineering, 27310, Gaziantep, Turkey*
[2]*Eskişehir Osmangazi University, Department of Civil Engineering, 26480, Eskişehir, Turkey*

Highlights

- Total ridership decreased 72,943,157 in 2020 and 2021 compared to pre-COVID-19.
- Municipality financial loss was calculated as $19.69-24.87 million due to the reduction of ridership.
- Sustainable urban transportation policy recommendations were performed within the scope of COVID-19.
- In the cost-benefit analysis of policies, net present value was calculated as 0.28-23.36 million $.

Article Info

Received: 11 Nov 2021
Accepted: 29 Mar 2022

Keywords

COVID-19
Public transport
Financial evaluation
Sustainable transport
Transport policy

Abstract

Financing of public transportation has been a challenge that needs to be concerned because ridership has decreased by up to 90% with the impact of COVID-19. This study presents sustainable policy recommendations and their cost-benefit analyses for the financing problems in public transportation caused by COVID-19. First of all, the public transportation data of Eskişehir-Turkey between the years 2018-2021 were investigated according to different public transportation modes, and financial losses were calculated for municipality. Secondly, within the scope of the study, six policies were recommended as follows: (i) different network and service plans for public transportation, (ii) new or improved low-budget public transportation, (iii) congestion pricing, (iv) bike, bike-sharing and e-scooter, (v) park and ride, (vi) pedestrianization. Crucial points in the implementation of policies and their possible financial impacts were investigated. According to the findings of the study, total ridership decreased 72.94 million in 2020 and 2021 compared to pre-COVID-19. In different modes, it was observed that the decrease buses ridership was higher than in trams. Municipality financial loss was calculated as $19.69-24.87 million. In the cost-benefit analysis results of recommended policies, net present value was calculated as 0.28-23.36 million $ according to different scenarios and sensitivity analyses. It has been foreseen that this is a very suitable period for the implementation of these policies, they could provide sustainable urban transportation and increase the quality of life as well as solving financial problems.

1. INTRODUCTION

Walking and cycling were the modes of transportation with the highest modal share in cities until the middle of the 19th century [1,2]. With the emergence of the automobile era, automobile-oriented city planning and dependence on automobiles have reduced the modal share of these active travel modes [3-5]. As a result of the increase in the number and modal share of automobiles, many economic, social, environmental and health problems have occurred such as traffic congestion, air pollution and noise [6-8]. For instance, the transportation sector is responsible for 30% of total energy consumption [9], 50% of oil consumption [10], 28% of the greenhouse gas emissions [11]. Automobiles are considered the main reason for these problems in cities [12]. Policymakers and planners have developed sustainable urban transportation policies to solve these problems [6]. Public transportation, which produces lower emissions per passenger and transports more passengers than automobiles efficiently, and walking-cycling, which are environmentally friendly and beneficial to human health, are indispensable for these sustainable urban policies [4,5,13]. For instance, the target for London is 80% of all travel by walking, cycling and public transportation by 2041 [13]. However, a detail that could be revised could be COVID-19 pandemic in these sustainable urban policies.

*Corresponding author, e-mail: fyildizhan@gantep.edu.tr

The COVID-19 has paradigm shifted many sectors such as education, trade and health. One of the sectors that have paradigm shifted has been public transportation [14]. In this process, the ridership has decreased up to 90% [15]. In addition to this, because of increasing usage of the automobile by people who can afford it, traffic congestion has increased and the related problems have worsened [16]. Approximately 25% of ridership who have resigned or restricted their usage of public transportation think that public transportation will not ever be safe and do not have any plan to return to public transportation in Gdansk-Poland [17]. These findings show that new regulations should be performed in public transportation [14]. In literature, Dzisi and Dei [18] suggested implementing policies with additional directives and fines for restricting unmasked passengers from using public transportation. Fridrisek and Janos [19] suggested technological solutions such as cashless payments and automatic control of doors. In some studies, the factors affecting the use of public transportation were examined, and stated as overcrowding, hygiene and travel time [20,21]. In order to solve problems related to public transportation, considering all urban mobility could provide a sustainable solution.

Despite these negative effects of the COVID-19 on public transportation, there have been positive changes in walking and cycling, which are active travel modes for sustainable urban transportation [22]. In the COVID-19 process, the usage of bicycles has increased and infrastructure arrangements for cycling and walking have been encouraged by the policymakers [13,23]. All these positive (increasing active travel modes) and negative (decreasing public transportation and increasing automobile) modal shifts show that sustainable urban transportation policies and plans should be reorganized. The COVID-19 has increased the importance of sustainable urban transportation plans and it has become easier to implement sustainable urban transportation policies in the current situation [13]. While determining these policies, one of the crucial points to be considered is the financial losses of municipalities or operating institutions or local governments due to the decrease in ridership.

The decrease in ridership and related revenues due to the COVID-19 impact should be handled with attention because transportation investments require serious budgets [24]. In order to compensate for the financial losses of the municipality due to the decrease in ridership revenues, policies should be developed to create additional own resources with urban transportation policies such as parking prices and congestion charges [25]. Also, the preparation of sustainable urban transportation plans and/or policies by evaluating not only the problems in the decreasing ridership but also the positive developments in walking and cycling could solve both the financial problems and provide sustainable urban transportation. In literature, the financing of public transportation was reported as a challenge that needs to be concerned [19]. Calculating these financial losses and investigating solutions are crucial for sustainable urban transportation. The main purpose of this study is to investigate the financial losses in public transportation due to decreasing ridership related to COVID-19, and evaluate the compensation of financial loss by recommending sustainable urban transportation policies. In this study, the financial impacts of COVID-19 on public transportation were calculated and sustainable policies were recommended for Eskişehir-Turkey. For changing in ridership, the travel data of Eskişehir were used and changing ridership in different modes of public transportation (bus and tram) pre- and during COVID-19 was calculated. In addition, financial losses were calculated due to the decrease in ridership. In order to solve the problems related to public transportation, some sustainable policies were prepared. The research objectives of this study are as follows: (i) different network and service plans for public transportation, (ii) new or improved low-budget public transportation, (iii) congestion pricing (iv) bike, bike-sharing and e-scooter (v) park and ride, (vi) pedestrianization, investigation of crucial points in the implementation of these policies, investigation of their possible financial impacts for compensating financial losses of public transportation and providing sustainable urban transportation.

2. THE TRANSIT RIDERSHIP OF ESKİŞEHİR PRE- AND DURING COVID-19

Eskişehir is a city that has a high mobility potential, with a population of 888,828 and three universities. Tram lines were first put into service in 2004 as SSK-Otogar and Osmangazi University-Opera lines. In addition to these two lines, Camlica-Batikent, Çankaya-Yenikent and Emek-71 Evler lines were put into service in 2014. A total line length of 41.7 km was reached. Şehir Hastanesi line was opened in 2019. Now, there are tram networks of 55 km and narrow-line (1000 mm rail gauge) 47 street trams which have average

240 passengers capacity are used on lines. Buses with an average capacity 70 passengers are used as rubber-wheeled public transportation.

The tram ridership between the years 2015-2021 is shown in Figure 1. The ridership for tram has increased in Eskişehir over the years. However, the ridership has decreased remarkably with COVID-19, which started in Turkey in March 2020. The decrease in ridership accelerated with the implementation of a general curfew on weekends in April 2020. Although there was an increase in ridership with the June 2020 normalization measures circular letter, ridership was quite low compared to pre-COVID-19. For first six months of 2021, ridership was very low due to the general curfews. Thereafter, ridership increased with the normalization and the starting face-to-face education, but this number was less than pre-COVID-19. This finding shows a continuation of the loss of level of safety and the need for regulation in public transportation.

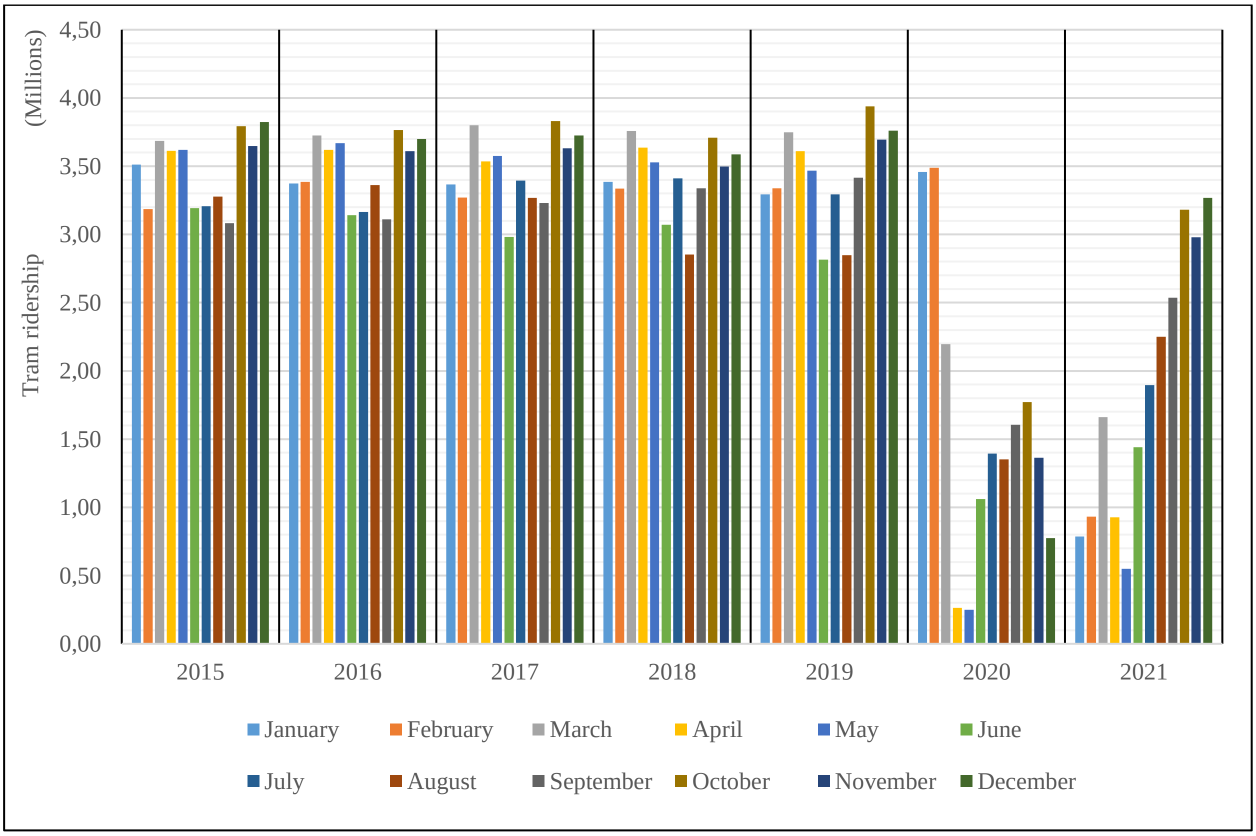

Figure 1. *Tram ridership between the years 2015-2021 in Eskişehir*

Tram and bus ridership for between the years 2018-2021 is given in Figure 2. In 2019 compared to the previous year, there was an increase of 0.27% in trams and 0.54% in buses, respectively. In 2020 compared to the previous year, there was a decrease of 53.97% in trams and 53.49% in buses, respectively. The decrease in ridership in different transportation modes (bus and tram) was at a similar rate for Eskişehir. However, in the study performed for Istanbul-Turkey, the ridership decreased 82% for the bus and 91% for the metro in April 2020 compared to April 2019, respectively [26]. This finding shows that the rate of decreasing ridership could vary in different modes of public transportation and cities of different scales. In addition, there could be reasons for a further decrease in ridership due to the risk of contamination in places such as the closed area and escalators for metro. In 2021 compared to the previous year, there was an increase of 18.09% in trams and a decrease of 3.24% in buses, respectively. This finding shows that the bus has been more negatively affected by COVID-19 than the tram.

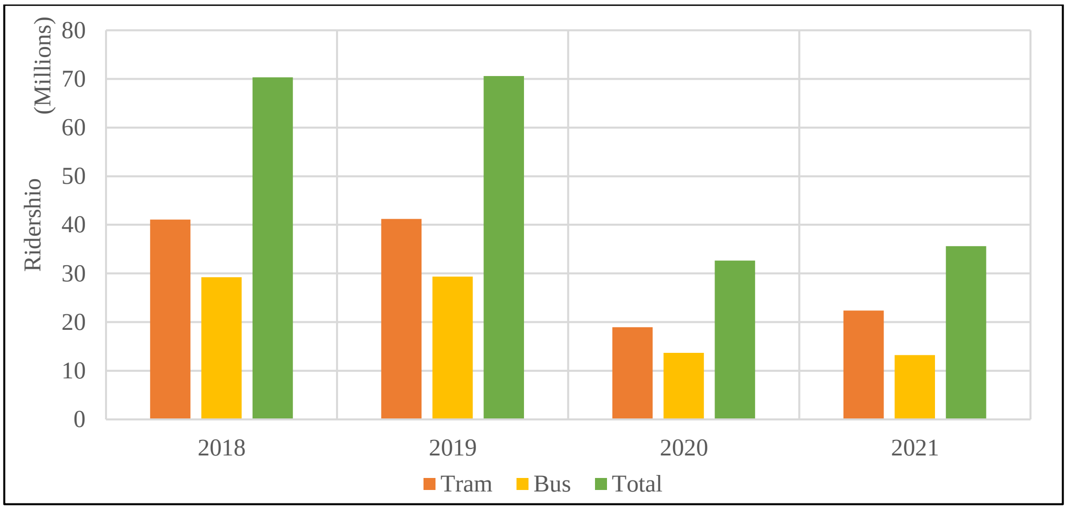

Figure 2. *Tram and bus ridership for pre- and during COVID-19*

In addition to ridership, the number of trips also should be calculated, especially for municipality. The average number of daily trips between the years 2018-2021 is shown in Figure 3. Due to the increasing travel demand and the length of the tram line, the average number of daily trips for tram increased by 6.65% for 2019. This increase mostly depends on the newly opened tram lines (Şehir Hastanesi line). For 2020, when the impacts of COVID-19 were seen, there was a decrease in the number of trip 15.63% for tram, 0.70% for the bus, respectively. These decreases were especially related to partial and full curfew. While the decrease in ridership of tram and bus was similar rate in 2020 (shown in Figure 2), the average number of daily trip of tram decreased more than bus. The reason could be that the bus has to provide a certain number of trips due to its low capacity and minimum headway. For 2021, there was an increase of 0.48% on the tram and a decrease of 5.09% on the bus.

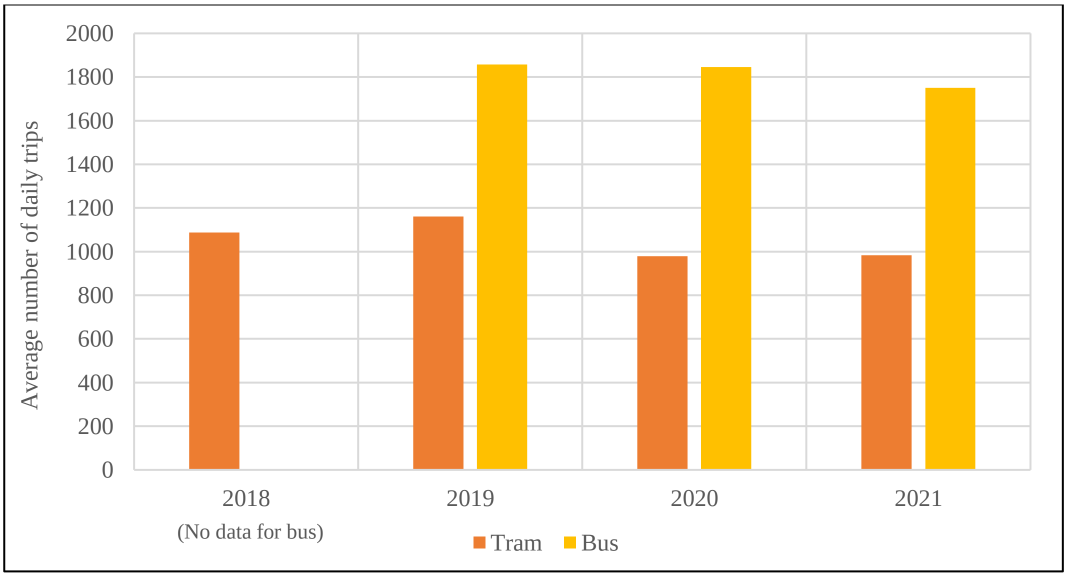

Figure 3. *Average number of daily trips between the years 2018-2021*

The average ridership per trip between the years 2018-2021 is given in Figure 4. The ridership per trip data should be evaluated to figure out the impact of COVID-19 and examine the efficiency of public transportation. In 2019 compared to the previous year, there was a decrease of 6.03% in average ridership per trip for tram, the increase in the number of trips due to the newly opened tram lines is the highly likely reason for this decrease. Also, the vehicle occupancy rate should be considered. Because the tram capacity is 240 passengers and the bus was 70 passengers, the average occupancy rate was 40.42% on the tram and 61.43% on the bus for 2019, respectively. In 2020 compared to the previous year, the average ridership per trip decreased by 45.41% for tram and 53.16% for bus, respectively. The average occupancy rate was

22.08% for the tram and 28.57% for the bus for 2020, respectively. For 2021 compared to the previous year, whereas the ridership per trip for tram increased by 17.49%, this rate was 1.95% for the bus. Average occupancy rates were 25.83% for tram and 30% for bus, respectively. These rates are below the maximum 50% capacity, which was taken in line with the COVID-19 precautions for public transportation. Also, the decrease in tram ridership has been less than the bus because the tram has a higher capacity and is more reliable than the bus. Because of passengers shifting from public transportation to automobiles, related increase in traffic density and decrease in the reliability of the bus could be the reason for more decreasing ridership on the bus. Buses that have uncontrolled ways (ROW C) are likely to have been affected adversely by operating speed due to increased traffic density. In other words, low capacity, the increase in travel times and the decrease in reliability could be the reasons why buses have been more affected by COVID-19 compared to the tram.

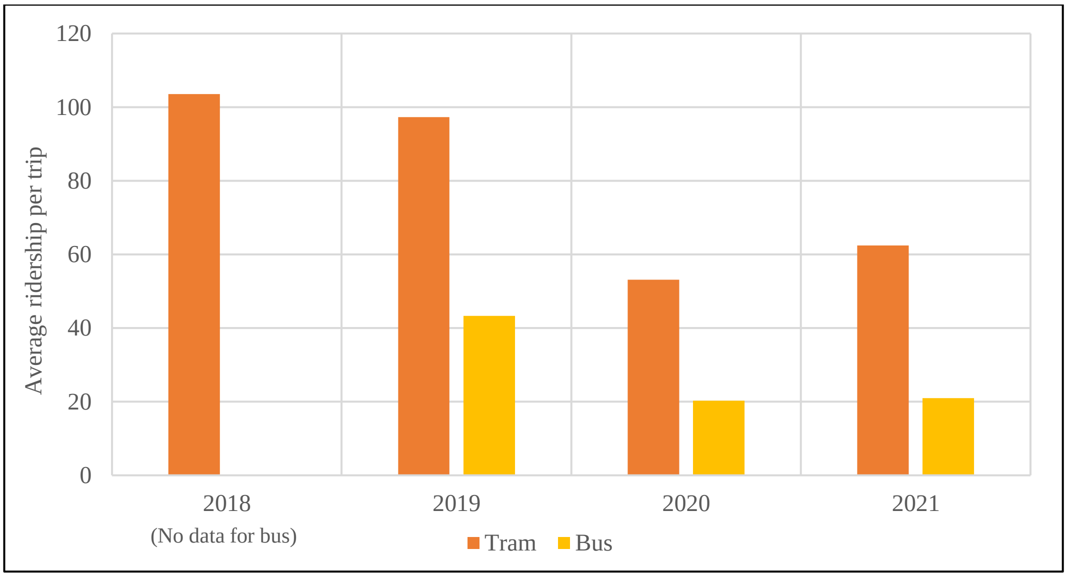

Figure 4. *Average ridership per trip between the years 2018-2021*

2.1. Financial Impact of the COVID-19 Pandemic on Public Transportation in Eskişehir

In the literature, it was stated that public transportation financing is a challenge to be concerned [19]. This study provides a numerical view of financial losses in public transportation due to COVID-19. Firstly, the average ticket price needs to be calculated. Distributions of transportation card and ticket price for each type of transportation card are shown in Table 1. The average ticket price was calculated as 2.19 TL= $ 0.31 because the average dollar rate was 7 TL for 2020. For another Eskişehir feasibility study, the average ticket price for the end of 2019 and the beginning of 2020 was calculated as $ 0.37 (1 $=5.7-5.9 TL) [27], therefore average ticket prices support each other. However, sensitivity analyses (%10 more and less) were made on this price due to the sharply changing dollar rate of exchange within two years.

***Table 1**. Distributions of transportation card and the average ticket price for 2020*

Type of transportation card	Ratio	Average ticket price
Normal	%56	2.58 TL
Discount	%33	1.63 TL
Single-Use	%5	3.58 TL
Transfer	%6	0.38 TL

The financial losses of municipality due to decreasing ridership are given in Figure 5. As shown in Figure 2, the ridership decreased by about 38 million in 2020 compared to the previous year. For 2021, ridership decreased by about 35 million compared to 2019 (normal period). According to calculations, there was a loss of approximately 10.25-12.95 million dollars for 2020 and 9.44-11.93 million dollars for 2021. Total two-year losses were approximately 19.69-24.87 million dollars.

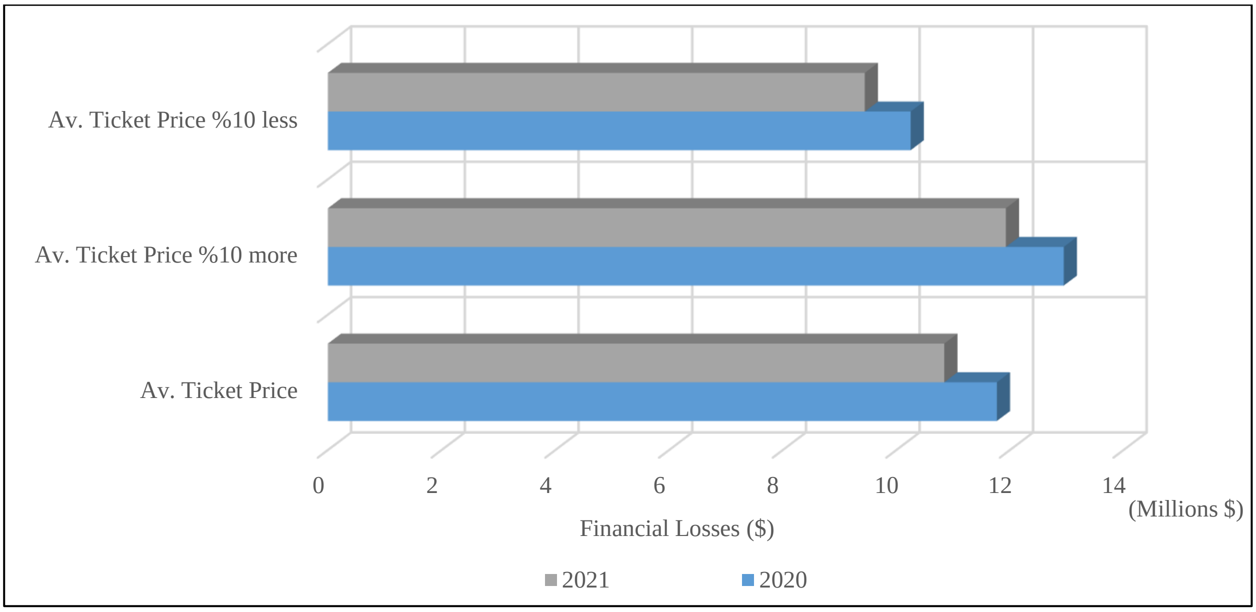

Figure 5. *Financial losses of public transportation during COVID-19*

In addition to these financial losses, there have been financial losses in trams and buses that are idle, and operating costs of buses have increased due to increased traffic density. In terms of the national economy, the losses are much greater and difficult to calculate. Due to the increasing traffic density, there are many losses such as fuel, environmental, accidents and loss of time in personal and public vehicles.

3. RECOMMENDED POLICIES

In the literature, it was stated that governments could minimize the problems caused by COVID-19 and increase their revenues with some policies [25]. Information on recommended policies within the scope of the study and crucial points in the implementation of these policies in the context of COVID-19 for Eskişehir are given in this section.

3.1. Different Network and Service Plans for Public Transportation

When planning public transportation, factors that adversely affect the usage of public transportation such as low frequency, tortuous itinerary, longer travel time, lack of services must be taken into account [28]. For planning the public transportation network, there are two widespread networks: feeder-trunk and direct line. Which network would give the optimum result depends on features such as ridership profile and physical characteristics [29]. Feeder-trunk system provides savings in operating costs, flexibility in the number and size of different vehicles, using different transportation modes together and more frequent services off-peak hours. However, there are extra walking and waiting times, due to the mandatory inter-line transfer [29,30]. The direct line is more advantageous on a long travel. While designing the line structure, the length of the avenue and the number of local streets should be considered [30].

The operation of public transportation is as crucial as the proper planning of public transportation. If the public transportation is not operated properly, the desired results could not be achieved and passengers could not prefer public transportation at the desired level. Limited-stop and express services could improve the level of service of public transportation by increasing operating speed and reducing travel time. Limited-stop services skip low-demand stations and only stop at main stations with higher passenger demand. Express services, on the other hand, travel non-stop for most of the line and drop off passengers in the city center or the other end of the line [31].

Recommended locations of service plans for Eskişehir are given in Figure 6. Feeder-trunk and direct line (different network) should be coordinated according to the vehicle fleet and travel demand. Different network was not recommended for Eskişehir within the scope of this study. Extra limited stops and express service were recommended during peak hours on trams and bus. Negative impact of travel time and overcrowding on the usage of public transportation due to COVID-19 was stated in the literature [20,21]. Thanks to this policy, travel time could be shortened, and crowding could be reduced.

3.2. New or Improved Low-Budget Public Transportation

Public transportation is one of the main modes of sustainable transportation, its neglect is a major problem in many regions [32]. Many criteria should be considered when determining public transportation systems, and the priority order of these criteria should be determined according to the investment [27]. In addition, the criteria should be evaluated according to different factors in which they are related. For instance, when considering environmental criteria in public transportation, not only vehicle emission values, but also the production source of energy should be considered [33]. It should be taken into account that transportation investments require a significant budget [12,24], replacing the chosen system with another system would lead to worse results [34], and each public transportation system has different advantages and disadvantages [27]. With these approaches, the most optimum system should be determined among the alternatives.

Considering the losses of the operating institutions due to the decreasing ridership related to COVID-19 and budget limitation, it is more important than ever to choose the most economical option by considering the implementation and operating costs [13]. Due to the limited budget, a new system was not recommended for Eskişehir. If the budget is not enough for a new system, the existing systems could be improved with exclusive lane or intelligent transportation applications.

Recommended locations of exclusive lane buses for Eskişehir are shown in Figure 6. Thanks to exclusive lane buses, faster and more reliable transportation could be provided in regions with high traffic density. Moreover, it also does not require a high construction cost or new vehicle cost. Exclusive lane buses were recommended in the 2017 Eskişehir Transportation Master plan, but the municipality has not implemented it until now. In addition, some improvement should be performed to conventional bus transportation, which feeds the rail systems or is the trunk line. This approach is crucial for increasing ridership [35]. Recommended intelligent transportation applications are real-time information for bus stations, occupancy level information for bus-tram and lastly, providing this information with a mobile application. Real-time information and occupancy level information were among the policies specified for COVID-19 in the literature [25]. Occupancy information, shortening of travel time and waiting time at the station related gains of this policy can reduce the risk of COVID-19 transmission and increase the level of service of public transportation.

3.3. Traffic Congestion Pricing

Traffic congestion pricing is the price that drivers pay when using certain urban roads, based on traffic density, distance traveled, time and day of the week, season, and vehicle type [36]. Many city planners have put traffic congestion pricing on their agenda in order to solve traffic problems in the world, but the community often does not support this practice [37]. Traffic congestion pricing does not require a budget and can be self-financed [36]. Thus, it can solve the traffic problem, especially in the central business district (CBD), which is the commercial heart of cities [38]. According to cost-benefit analyses, it was taken very profitable results in traffic congestion pricing applications [39]. While there are different types of congestion pricing schemes and congestion pricing technologies, the best technology choice depends on the application. Also, attention should be paid to the gradual implementation of congestion pricing [39]. Public transportation can be financed with congestion pricing revenues.

Recommended locations of traffic congestion pricing for Eskişehir are shown in Figure 6. This policy was also recommended in the 2017 Eskişehir Transportation Master plan, but the municipality has not implemented it until now. Congestion pricing was recommended in some regions of CBD. Congestion pricing can provide financial support for local governments' to compensate financial loss due to COVID-19. Mogaji et al. [25] suggested congestion price in policies related to COVID-19 and also stated that governments can generate revenue. It can also provide extra financial support for different networks, service plans, and improved low-budget public transportation (policies mentioned in sections 3.1 and 3.2). In addition, the usage of automobiles could be significantly reduced in CBD and related to problems could be solved. In the study conducted for Erzurum-Turkey, it was stated that the traffic congestion problem could be reduced by 52.55% thanks to congestion pricing [37].

3.4. Bike, Bike-Sharing and E-Scooter

Cycling plays a crucial role in sustainable urban transportation. It does not only reduce traffic congestion and its harmful effects [40], but also positively affects the health of cyclists [2]. The study estimated that there would be an 11% reduction in CO_2 emissions between 2015 and 2050 because people shift from motorized vehicles to cycling, also resulting in saving $24 trillion [41]. Bicycles are also used as a feeder line for public transportation systems. Around 47% of train users in the Netherlands come to their access stations by bicycle [42]. It can also be used as a trunk line, especially for university access or short distances. Besides cycling, bike sharing, which is a series of bike stations distributed over a certain area and offered to users, is also a new and reputable mode of transportation [23,43]. In particular, the bike-sharing scheme, short trip of 1 to 5 km, is seen as a preferable alternative [23,44]. Bike-sharing has a positive effect on public transportation as a complement to public transportation service [35]. New micro-mobility options, shared or individual e-scooters have become popular worldwide [45]. In Turkey, the e-scooter regulation entered into force on April, 2021. In the regulation, it is stated that the usage of e-scooter on pedestrian paths is prohibited, and usage on the vehicle road is prohibited if there is a separate bicycle path or bicycle lane. These regulations show the necessity of cycling infrastructure for safe, comfortable and rapid usage of e-scooter. The biggest obstacle to cycling is the lack of cycling infrastructure [40].

Recommended locations of cycling infrastructure for Eskişehir are shown in Figure 6. Recommended regions were around the campus because it has a remarkable student population with its three universities. One of the few positive changes from the COVID-19 has been the increase in cycling [23]. Implementation of this cycling infrastructure in addition to the existing cycling infrastructure is crucial in terms of sustainability because of a continuation of cycling by increasing modal share. Also, cycling infrastructures should be performed much faster and cheaper than highway investments. After the implementation of cycling infrastructure, some points should be considered in the operation time. In the study, it was determined that improvements such as a decrease in price, an increase in the number of bicycles available, improving accessibility, and marketing campaigns would increase demand of cycling significantly [23].

3.5. Park and Ride

Park and ride (P&R) is a facility where users park their cars by driving them to the parking station and using public transportation to reach their final destination [46]. Thus, many positive gains are obtained in traffic congestion, travel times, costs for users, the usage of public transportation and quality of life [47,48]. P&R has been widely used in developed countries for many years. For instance, the UK started using it in the early 1970s. Until 2007, there serve more than 130 facilities and the total capacity is approximately 70,000 parking spaces [49]. Two factors that should be considered are; selection of location of P&R and the well-suited public transportation system. Otherwise, users could not give up their choice of automobile [47]. According to the P&R ride component, it can be categorized as bus-based P&R and rail-based P&R. Rail-based P&R is more advantageous than bus-based P&R due to high comfort, speed and safety. However, if the land value is high near the rail system, access to rail-based P&R can be provided by bus-based P&R [28].

Recommended locations of P&R for Eskişehir are shown in Figure 6. The recommended locations were chosen as regions with high traffic density and sufficient public transport networks. The P&R policy was stated as a long-term recommendation for COVID-19 in the literature [25].

3.6. Pedestrianization

Pedestrianization is the most environmentally friendly type of urban transportation and still has a very crucial position in urban transportation for planners and policymakers, despite automobile-oriented cities [5]. The emergence of pedestrian malls to stimulate tourism and commerce due to the dominance of the automobile shows the importance of this mode for social life [1]. Pedestrianization is performed in 3 different ways as a concept. While motorized vehicle access is restricted in full-time pedestrianization, part-time pedestrianization motorized vehicle access is only allowed at certain times [8]. In the traffic calming concept, there are no restrictions on motor vehicle passages, but arrangements are made to allow slow passage of vehicles. In addition, sidewalk widths should be sufficient for pedestrians [8]. The biggest obstacles to the implementation of pedestrianization can be listed as follows:

- Businessmen having shops on those streets: The alleged ‘customer automobile need argument’ is not true [8]. Istanbul, Taksim-İstiklal or Ortaköy street, where the positive gains of pedestrianization are seen, could be given as an example for this in Turkey [50].
- The low service level of public transportation, poor cycling infrastructure and inadequate networks: Two of the obstacles to pedestrianization are public transportation and cycling [1]. Therefore, these modes and networks should be improved with a holistic approach. Before implementation of pedestrianization, the infrastructure and service level of public transportation and bicycles that would support pedestrianization should definitely be improved.
- Political, institutional and social barriers: Political, institutional and social barriers are more dominant than technical and financial barriers [1].

Recommended locations of pedestrianization for Eskişehir are shown in Figure 6. There is full-time pedestrianization in some region of CBD. In addition to existing full-time pedestrianization, part-time pedestrianization and the calming concept were recommended in commerce and tourism regions.

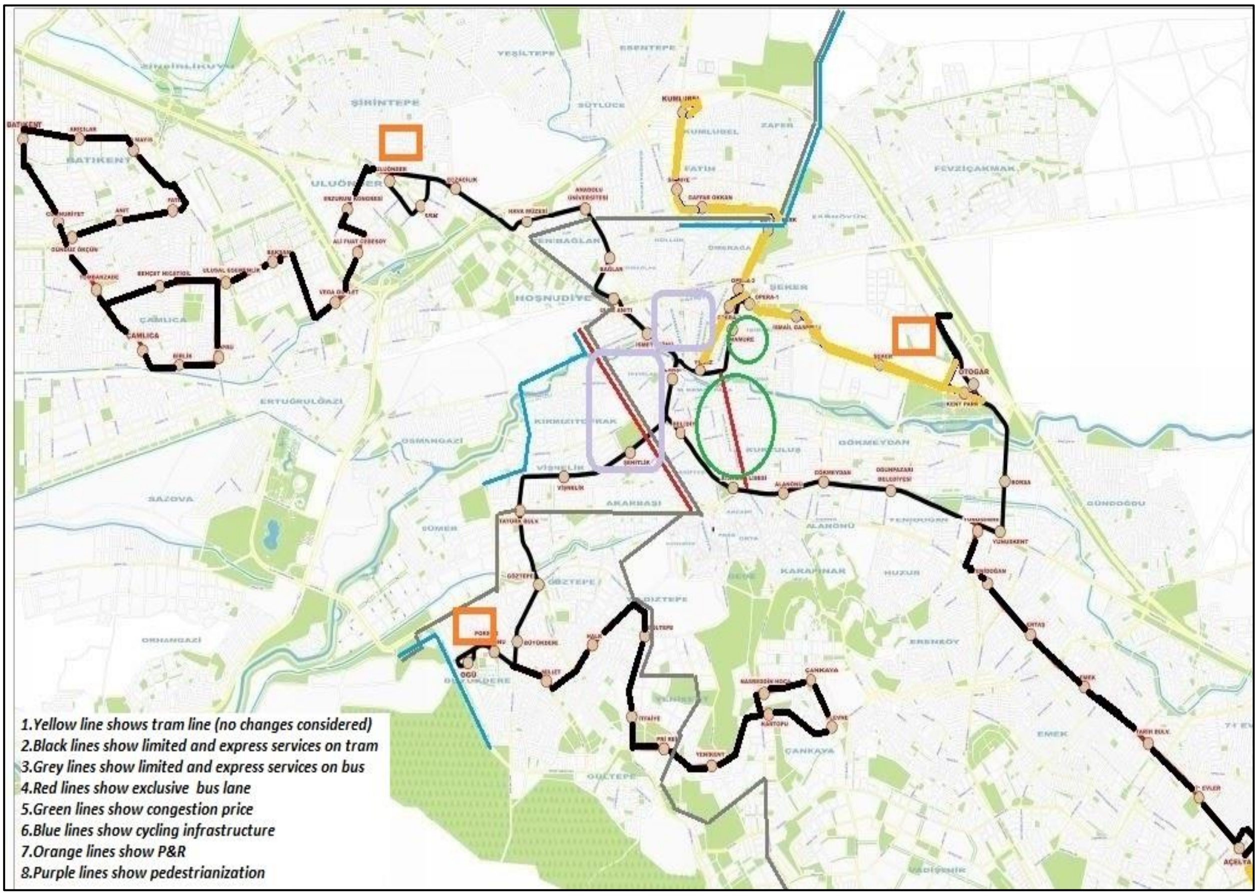

Figure 6. *Recommended locations of policies for Eskişehir [51]*

As seen in Figure 6, limited-stop and express service plans for public transportation were planned between 07:00-09:00 am and 17:00-19:00 pm (peak hours) on the specified routes. Batıkent, Çankaya and Açelya tram lines were planned as one (in the morning to the center and from the center in the evening) in different directions, and the Eskişehir Osmangazi University-Otogar-SSK tram line was planned as 10 limited and express services per hour. Eskişehir Osmangazi University, TOKI and Eskişehir Technical University bus lines were planned as 2 limited and express services per line/hour on peak hours. Exclusive bus lane was planned as 1.88 km on M.Kemal Atatürk Street and 1.01 km on Yunus Emre Street. Congestion pricing was planned in some CBD. Bike, bike-sharing and e-scooter infrastructure were planned in the campus of Eskişehir Osmangazi University (2.20 km), between Eskişehir Technical University and Gaffar Okkan Street (4.20 km), and between the train station and the city center (2.60 km). P&R were planned at Eskişehir Osmangazi University, Uluönder Street and Bus Terminal. These locations are regions that have high mobility and sufficient transportation network. Pedestrianization was planned in some CBD.

4. STEPS OF RECOMMENDED POLICIES FOR ESKİŞEHİR

The recommended policies were mentioned in the third section. Because many of the policies are interconnected, these policies should be applied step by step and in a certain order. Recommended sustainable transportation steps within the scope of the study are given in Figure 7. Policies should be performed in the following order:

- ✓ Step 1: Regulation of the existing public transportation service plan. In this way, the trust of the passengers could be regained.
- ✓ Step 2: Improvement of existing public transportation with exclusive lanes and intelligent transportation systems. Thus, the ridership could be increased even more.
- ✓ Step 3: Implementation of traffic congestion price. It is crucial to provide revenue for local municipality. In addition to this, some of the automobile users could shift to existing and/or improved public transportation systems.
- ✓ Step 4: Implementation of cycling infrastructure. In this way, bike, bike-sharing and e-scooter could increase the quality of urban transportation by being preferred for short distances, and feeder lines of public transportation.
- ✓ Step 5: Implementation of P&R scheme. In this way, the demand for public transportation could increase and traffic congestion could be reduced.
- ✓ Step 6: Implementation of pedestrianization. Implementation of this policy can be simplified by removing barriers to pedestrianization thanks to the development of public transportation and bicycles. In this way, pedestrianization which is the most environmentally friendly type of urban transportation could be applied at the desired level.

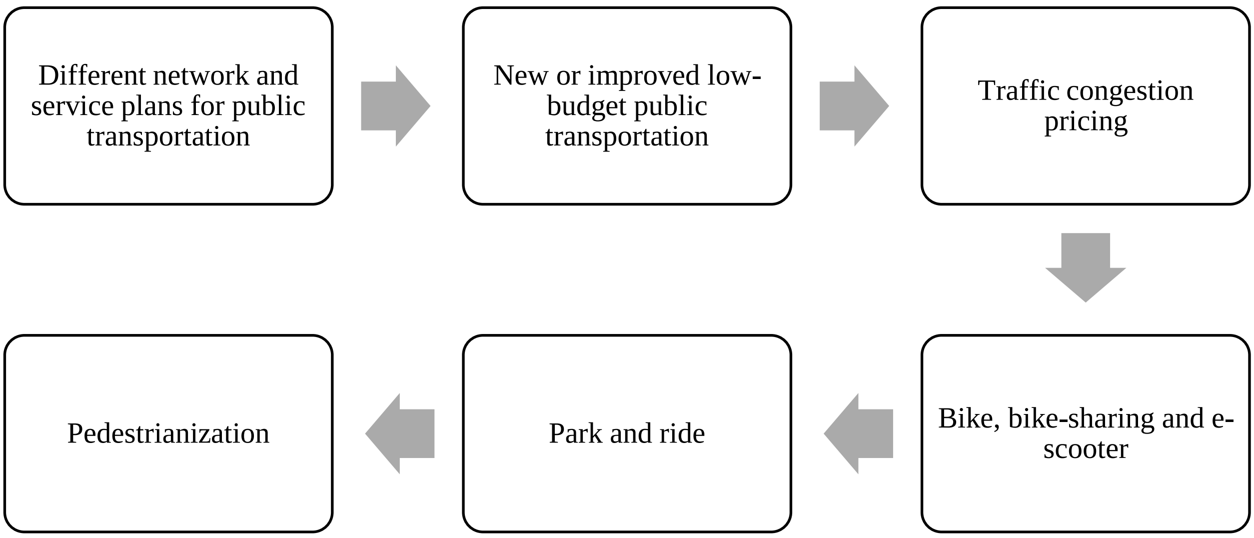

Figure 7. *Steps of recommended policies*

4.1. Potential Financial Consequences of Recommended Policies in Eskişehir

The recommended policies would include revenues and costs for municipality. Every policy could significantly benefit the national economy such as environmental, accident, time. However, national economy was not taken into account in this study because it is much more difficult to calculate, and requires specific data than the municipality (operating institution or government). The status of implementation of policies in terms of expected revenue-cost for municipality is given in Figure 8. Different network and service plans for public transportation are expected to increase ridership, but increase O&M costs. Improved low-budget public transportation is expected to increase ridership, but bring investment costs. Traffic congestion pricing is expected to provide revenue for municipality, but bring investment costs. Bike, bike-sharing and e-scooter are expected to provide a feeder line for public transportation and decrease travel time in public transportation. However, bike, bike-sharing and e-scooter bring infrastructure and maintenance costs. P&R is expected to increase the ridership, but bring investment cost. Pedestrianization has no costs or benefits for municipality.

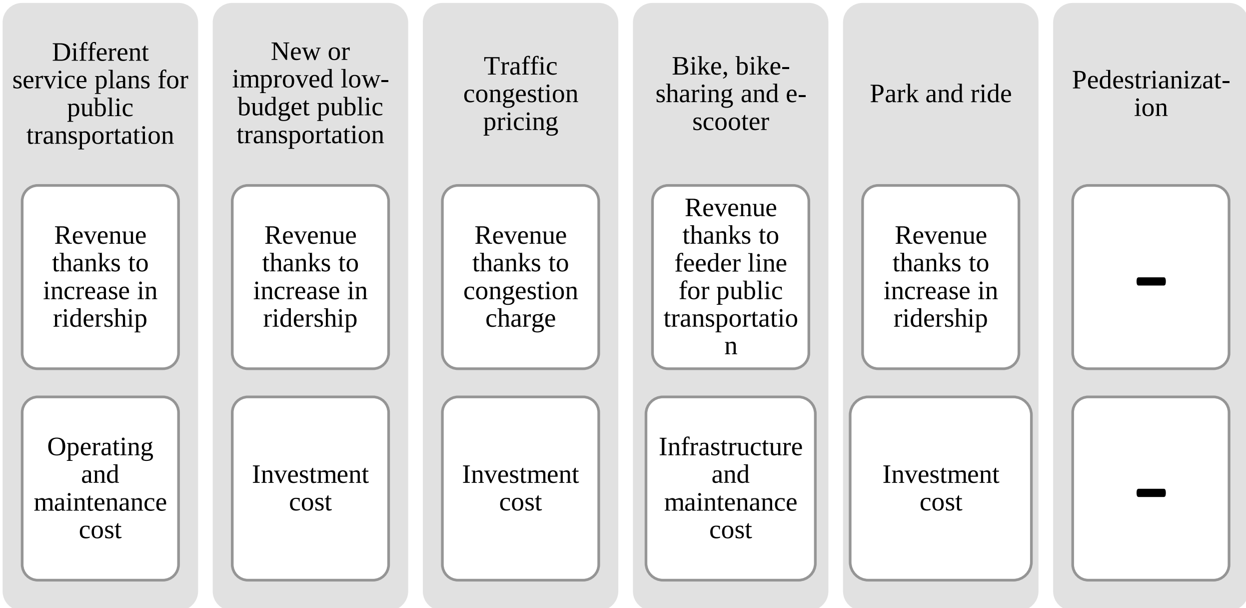

Figure 8. *Expected revenues and costs of policies for the municipality /operating institution*

As stated in Figure 5, the financial loss of decreasing ridership caused by COVID-19 was total $19.69-24.87 million for 2020 and 2021 in Eskişehir. Revenues-costs of the recommended sustainable policies were calculated to compensate these financial losses and provide sustainable urban transportation. Some values were taken from studies in the literature and assumptions were made for others. Three scenarios were performed for ridership as 5%-10% and 15% increasing. Because these increases are considerably lower than pre-COVID-19, they are considered to have the potential to occur. In addition, recently rising oil prices could decrease automobile usage and lead passengers to these policies. The values and assumptions considered in the calculations are as follows:

- ✓ Different network and service plans for public transportation:
  Benefit: 2.5%-5%-10% increase in ridership
  Cost: Extra daily 52 trips for the tram, 24 trips for the bus. O&M costs were taken as $ 1.68/km for bus, $ 4.81/km for tram [27]

- ✓ New or improved low-budget public transportation:
  Benefit: 2.5%-5%-10% increase in ridership
  Cost: Total delineator and paint cost is $ 87000 for exclusive lane (2.89 km). Assumption in total cost of intelligent transportation systems were taken as $ 500,000 including occupancy sensor to vehicles and real-time information to some stations. Already some stations where high travel demand have real-time information.

- ✓ Traffic congestion pricing:

Benefit: Assumption in 500 and 1000 vehicles daily, and assumption in average hour was taken as 1 and 2. Congestion charge was taken as $ 1.231 [37]
Cost: Cost per camera $ 800. Twenty cameras required

- ✓ Bike, bike-sharing and e-scooter:
Benefit: 2.5%-5%-10% increase in ridership
Cost: 9 km bike path and construction per km is $ 40,000. $ 2,000 maintenance cost for per year. These values were calculated for the asphalt pavement width of 2.4 m. Price information was obtained from the municipality.

- ✓ Park and ride:
Benefit: 2.5%-5%-10% increase in ridership
Cost: 3 stations and $ 150,000 per station (each station has 250 park space) [52].

- ✓ Pedestrianization
Profit: -
Cost: -

The 2020 total net present value (NPV) of the benefits and costs of each policy is shown in Table 2. Calculations were performed according to the values in literature and assumptions. Three scenarios were performed based on 2.5%, 5% and 10% ridership increase for 4 policies and congestion price assumptions (500 and 1000 vehicles daily - 1 and 2 hour). Benefit-costs were made at fixed prices of 2020 and the discount rate was 10% [27]. 2022 year was taken into account as the implementation period of the policies. The 10-year period between 2023 and 2032 was considered the operational period.

The NPV cost of all policies was calculated as $5.86 million at the end of the 1-year implementation and 10-year operational period. The cost of these policies was calculated as approximately 24-30% of Eskişehir's two-year financial losses (19.69-24.87 million dollars) on public transportation due to COVID-19. In other studies in the literature, the cost of the 11.1 km tram system project was calculated as 221.78 million dollars, and the cost of the BRT (Bus rapid transit) project was calculated as 95.40 million dollars for Antalya at the end of 20-year operational period [53]. The cost of the 10.5 km monorail feasibility study was calculated as 266.91 million dollars for Eskişehir at the end of 25-year operational period [27]. The costs of the policies recommended within the scope of this study were quite lower than the costs of tram, BRT and monorail projects. The reasons for this are the operation period was short, there is no vehicle costs and lower construction costs (only cycling infrastructure). In addition, it is very important to provide low costs in projects related to transportation and/or logistics. In the study conducted to determine priority criteria of the factors affecting logistics outsourcing, cost was found to be the most important criteria among six criteria [54]. While different network and service plans accounted for the majority of costs, traffic congestion pricing had the least cost.

The total NPV revenue of all policies was calculated as $7.31-29.22 million at the end of the 1-year implementation and 10-year operational period. The revenue of these policies could compensate some or all financial losses in Eskişehir (19.69-24.87 million dollars) on public transportation due to COVID-19. In other studies in the literature, the revenue of the 11.1 km tram system project was calculated as 280.47 million dollars, and the revenue of the BRT (Bus rapid transit) project was calculated as 278.27 million dollars in Antalya at the end of 20-year operational period [53]. The revenue of the 10.5 km monorail feasibility study was calculated as 52.03 million dollars for Eskişehir at the end of 25-year operational period [27]. The revenue of the policies recommended within the scope of this study were quite lower than the revenue of tram, BRT and monorail projects. The reason for this is the operation period was short and quite lower ridership. Traffic congestion pricing benefits were between $1.14-4.56 million, while revenues from other policies were calculated as $1.54-6.16 million end of the 10-year operating period.

Table 2. *Net present value of the revenues and costs of each policy*

Policies	Costs	Revenue (Scenario-1) 2.5% rid.-500 veh.-1 h.	Revenue (Scenario-2) 5.0% rid.-500 veh.-1 h.	Revenue (Scenario-3) 10.0% rid.-1000 veh.-2 h.
Different service plans	$ 4,599,341	$ 1,541,221	$ 3,082,442	$ 6,164,884
Improved public transportation	$ 485,124	$ 1,541,221	$ 3,082,442	$ 6,164,884
Traffic congestion pricing	$ 13,223	$ 1,140,846	$ 1,140,845	$ 4,563,382
Bike, bike-sharing and e-scooter	$ 388,927	$ 1,541,221	$ 3,082,442	$ 6,164,884
P&R	$ 371,901	$ 1,541,221	$ 3,082,442	$ 6,164,884
Total	$ 5,858,516	$ 7,305,730	$ 13,470,614	$ 29,222,920

The cost-benefit analysis results of the recommended policies are given in Table 3. Sensitivity analyses were also performed by taking 10% and 20% more for costs. Even if the revenues were calculated at the lowest (scenario-1) and the costs were 20% more (sensitivity analyses), the results of NPV $275,511 and B/C (benefit-cost ratio) 1.04 at the end of the 10-year evaluation period show that these policies could be performed for the municipality. More profitable results were obtained in Scenario-2 and Scenario-3. In other studies in the literature, the results of the cost-benefit analysis were calculated as NPV $ 58,691,765 and B/C 1.26 for the Antalya tram project, and NPV $ 182,861,599 and B/C 2.92 for the Antalya BRT (Bus rapid transit), respectively [53]. The results of the cost-benefit analysis of monorail feasibility study was calculated as NPV $ -214,876,105 and B/C 0.20 [27]. The cost-benefit analyses of the policies recommended within the scope of this study, especially in scenario-3, gave profitable results like the new tram and BRT project. Finally, it should be considered that these policies can contribute much more to the national economy.

Table 3. *NPV and B/C results of recommended policies*

Scenario	NPV	B/C
Scenario-1 and cost	$ 1,447,214	1.25
Scenario-1 and cost %10 more	$ 861,363	1.13
Scenario-1 and cost %20 more	$ 275,511	1.04
Scenario-2 and cost	$ 7,612,099	2.30
Scenario-2 and cost %10 more	$ 7,026,247	2.09
Scenario-2 and cost %20 more	$ 6,440,396	1.92
Scenario-3 and cost	$ 23,364,405	4.99
Scenario-3 and cost %10 more	$ 22,778,553	4.53
Scenario-3 and cost %20 more	$ 22,192,702	4.16

5. CONCLUSION

This study presents sustainable recommendations to the problems in urban transportation due to the negative impact of the COVID-19 pandemic on public transportation. First of all, for investigating the negative impact of COVID-19 on public transportation, change in ridership on the tram and bus between the years 2018-2021 in Eskişehir-Turkey was determined, and the financial losses for the municipality (operator institution/local government) were calculated. Some recommendations were prepared for compensating financial losses of public transportation and providing sustainable urban transportation. With this approach, six policies (i) different network and service plans for public transportation, (ii) new or improved low-budget public transportation, (iii) congestion pricing (iv) bike, bike-sharing and e-scooter

(v) park and ride, (vi) pedestrianization were recommended. Crucial points in the implementation of policies, at which stage they should be performed and their financial results were calculated for Eskişehir. According to the recommended policies and calculations in this study, the following conclusions can be drawn.

For 2020, when the impact of COVID-19 has started to be seen in Turkey, ridership decrease 53.97% in trams and 53.49% in buses, respectively, compared to the previous year. In 2021 compared to the previous year, there was an increase of 18.09% in trams and a decrease of 3.24% in buses, respectively. According to the ridership per trip, ridership decreased 45.41% in trams and 53.16% in buses, respectively in 2020. In 2021 compared to the previous year, whereas the ridership per trip for tram increased by 17.49%, this rate was 1.95% for the bus. These findings show that tram is less affected than bus by COVID-19 thanks to high speed and reliability. These findings should be taken into account in public transportation plans and/or new regulations after COVID-19.

The reduction in ridership was found 37,966,310 for 2020 and 34,976,847 for 2021, respectively, compared to pre-COVID-19. Although the ridership increased slightly in 2021, it was much less than pre-COVID-19. The financial losses of the reduction in ridership compared to pre-COVID-19 were performed by sensitivity analysis (10% less and 10% more). The financial losses were calculated at approximately $10.25-12.95 million for 2020 and $9.44-11.93 million for 2021. This numerical view of financial losses in public transportation due to COVID-19 shows that public transportation financing is a challenge to be concerned about, as noted in the literature. Also, it should be considered that the national economy (such as accident, environmental, time) losses caused by some ridership shift to automobile, need to be solved urgently (it was not taken into account in this study).

Certain points should be considered in the implementation of each of the six policies recommended in this study, these points were detailed in the third part. The common point of all of these policies is that cities should be planned according to pedestrian, cycling and public transportation, not automobiles. The success of these policies is interdependent, so holistic approaches are crucial for sustainable urban transportation and quality of life in cities. Policies within the scope of the study were planned in the following order: (i) different network and service plans for public transportation, (ii) new or improved low-budget public transportation, (iii) traffic congestion pricing, (iv) bike, bike-sharing and e-scooter, (v) park and ride, (vi) pedestrianization.

According to the calculations performed by considering the 1-year implementation and 10-year operational period for the recommended policies, the following results were obtained. The cost of these policies was calculated as NPV $5.86 million. This value was 24-30 percent of public transportation financial losses caused by COVID-19. Revenues of these policies were calculated as $ 7.31-29.22 million according to different scenarios.

The cost-benefit analyses of the recommended policies were performed with sensitivity analyses (costs were taken as 10% and 20% more). According to the calculations of different scenarios and sensitivity analysis, NPV was calculated as 0.28-23.36 million $ and B/C as 1.04-4.99. These findings show that these policies could give profitable results for municipalities and could solve public transportation problems caused by COVID-19. Considering the national economy, much more important gains could be achieved thanks to these policies. Also, these findings show that there is a very suitable time for the implementation of sustainable policies.

The data used and calculations were investigated at a particular time and in a particular region in this article. Therefore, the general applicability of the results is limited. Despite this limitation, the results in this article could be beneficial to municipalities for compensating financial losses and providing sustainable transportation. In future studies, the choice of policies could be detailed according to the survey results, the type and implementation of policies could be selected according to the location and surveying data, and calculations could be performed for cities of different scales. Also, it could be studied by taking into account not only the impact on municipalities but also national economy.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

REFERENCES

[1] Parajuli, A., Pojani, D., “Barriers to the pedestrianization of city centres: Perspectives from the Global North and the Global South”, Journal of Urban Design, 23(1): 142–160, (2018).

[2] Zhao, C., Carstensen, T.A., Nielsen, T.A.S., Olafsson, A.S., “Bicycle-friendly infrastructure planning in Beijing and Copenhagen—Between adapting design solutions and learning local planning cultures”, Journal of Transport Geography, 68: 149–159, (2018).

[3] Grava, S., Urban Transportation Systems. Choices for Communities, McGraw-Hill, New York, (2003).

[4] Saghapour, T., Moridpour, S., Thompson, R.G., “Public transport accessibility in metropolitan areas: A new approach incorporating population density”, Journal of Transport Geography, 54: 273–285, (2016).

[5] Yassin, H.H., “Livable city: An approach to pedestrianization through tactical urbanism”, Alexandria Engineering Journal, 58(1): 251–259, (2019).

[6] Haghshenas, H., Vaziri, M., Gholamialam, A., “Evaluation of sustainable policy in urban transportation using system dynamics and world cities data: A case study in Isfahan”, Cities, 45: 104–115, (2015).

[7] Redman, L., Friman, M., Gärling, T., Hartig, T., “Quality attributes of public transport that attract car users: A research review”, Transport Policy, 25: 119–127, (2013).

[8] Soni, N., Soni, N., “Benefits of pedestrianization and warrants to pedestrianize an area”, Land Use Policy, 57: 139–150, (2016).

[9] Atabani, A.E., Badruddin, I.A., Mekhilef, S., Silitonga, A.S., “A review on global fuel economy standards, labels and technologies in the transportation sector”, Renewable and Sustainable Energy Reviews, 15(9): 4586–4610, (2011).

[10] Lin, B., Du, Z., “Can urban rail transit curb automobile energy consumption?”, Energy Policy, 105: 120–127, (2017).

[11] Umar, M., Ji, X., Kirikkaleli, D., Alola, A.A., “The imperativeness of environmental quality in the United States transportation sector amidst biomass-fossil energy consumption and growth”, Journal of Cleaner Production, 285: 124863, (2021).

[12] Bel, G., Holst, M., “Evaluation of the impact of Bus Rapid Transit on air pollution in Mexico City”, Transport Policy, 63: 209–220, (2018).

[13] Pamucar, D., Deveci, M., Canıtez, F., Paksoy, T., Lukovac, V., “A Novel Methodology for Prioritizing Zero-Carbon Measures for Sustainable Transport”, Sustainable Production and Consumption, 27: 1093–1112, (2021).

[14] Gkiotsalitis, K., Cats, O., “Public transport planning adaption under the COVID-19 pandemic crisis: Literature review of research needs and directions”, Transport Reviews, 41(3): 374–392, (2021).

[15] Sahraei, M.A., Kuşkapan, E., Çodur, M.Y., “Public transit usage and air quality index during the COVID-19 lockdown”, Journal of Environmental Management, 286: 112166, (2021).

[16] Bandyopadhyay, S., "Public transport during pandemic", Clean Technologies and Environmental Policy, 22: 1755-1756, (2020).

[17] Przybylowski, A., Stelmak, S., Suchanek, M., "Mobility Behaviour in View of the Impact of the COVID-19 Pandemic—Public Transport Users in Gdansk Case Study", Sustainability, 13(1): 364, (2021).

[18] Dzisi, E.K.J., Dei, O.A., "Adherence to social distancing and wearing of masks within public transportation during the COVID 19 pandemic", Transportation Research Interdisciplinary Perspectives, 7: 100191, (2020).

[19] Fridrisek, P., Janos, V., "COVID-19 and suburban public transport in the conditions of the Czech Republic", Transportation Research Interdisciplinary Perspectives, 13: 100523, (2022).

[20] Das, S., Boruah, A., Banerjee, A., Raoniar, R., Nama, S., Maurya, A.K., "Impact of COVID-19: A radical modal shift from public to private transport mode", Transport Policy, 109: 1–11, (2021).

[21] Beck, M.J., Hensher, D.A., Nelson, J.D., "Public transport trends in Australia during the COVID-19 pandemic: An investigation of the influence of bio-security concerns on trip behaviour", Journal of Transport Geography, 96: 103167, (2021).

[22] Marra, A.D., Sun, L., Corman, F., "The impact of COVID-19 pandemic on public transport usage and route choice: Evidences from a long-term tracking study in urban area", Transport Policy, 116: 258–268, (2022).

[23] Bergantino, A.S., Intini, M., Tangari, L., "Influencing factors for potential bike-sharing users: An empirical analysis during the COVID-19 pandemic", Research in Transportation Economics, 86: 101028, (2021).

[24] Orman, A., Düzkaya, H., Ulvi, H., Akdemir, F., "Multi-Criteria Evaluation by Means of Using the Analytic Hierarchy Process in Transportation Master Plans: Scenario Selection in the Transportation Master Plan of Ankara", Gazi University Journal of Science, 31(2): 381–397, (2018).

[25] Mogaji, E., Adekunle, I., Aririguzoh, S., Oginni, A., "Dealing with impact of COVID-19 on transportation in a developing country: Insights and policy recommendations", Transport Policy, 116: 304–314, (2022).

[26] 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).

[27] Yıldızhan, F., Karacasu, M., "Monorail System Feasibility Study for Developing Countries: The Case Study of Eskişehir-Turkey", Journal of Polytechnic, (In press).

[28] Liu, Z., Chen, X., Meng, Q., Kim, I., "Remote park-and-ride network equilibrium model and its applications", Transportation Research Part B: Methodological, 117: 37–62, (2018).

[29] Del Mistro, R.F., Bruun, E., "Appropriate operating environments for Feeder-Trunk-Distributor or Direct road based public transport services in cities of developing countries", CODATU XVI, Istanbul, 2-16, (2019).

[30] Gschwender, A., Jara-Díaz, S., Bravo, C., "Feeder-trunk or direct lines? Economies of density, transfer costs and transit structure in an urban context", Transportation Research Part A: Policy and Practice, 88: 209–222, (2016).

[31] ITDP, The BRT Standard. https://www.itdp.org/2016/06/21/the-brt-standard/, (2016).

[32] Vuchic, V. R., Urban Transit Systems and Technology. John Wiley & Sons, New Jersey, (2007).

[33] Geng, Y., Ma, Z., Xue, B., Ren, W., Liu, Z., Fujita, T., "Co-benefit evaluation for urban public transportation sector – a case of Shenyang, China", Journal of Cleaner Production, 58: 82–91, (2013).

[34] Rizelioğlu, M., Arslan, T., "A comparison of LRT with an imaginary BRT system in performance: Bursa example", Case Studies on Transport Policy, 8(1): 135–142, (2020).

[35] Boisjoly, G., Grisé, E., Maguire, M., Veillette, M.-P., Deboosere, R., Berrebi, E., El-Geneidy, A., "Invest in the ride: A 14 year longitudinal analysis of the determinants of public transport ridership in 25 North American cities", Transportation Research Part A: Policy and Practice, 116: 434–445, (2018).

[36] Cipriani, E., Mannini, L., Montemarani, B., Nigro, M., Petrelli, M., "Congestion pricing policies: Design and assessment for the city of Rome, Italy", Transport Policy, 80: 127–135, (2019).

[37] Çodur, M.Y., Coşkun, H., "A sample scheme of cordon-based congestion charge: Erzurum, Cumhuriyet Street", Pamukkale University Journal of Engineering Sciences, 26(3): 409–418. (2020).

[38] Liu, Z., Meng, Q., Wang, S., "Speed-based toll design for cordon-based congestion pricing scheme", Transportation Research Part C: Emerging Technologies, 31: 83–98, (2013).

[39] de Palma, A., Lindsey, R., "Traffic congestion pricing methodologies and technologies", Transportation Research Part C: Emerging Technologies, 19(6): 1377–1399, (2011).

[40] Liu, H., Szeto, W.Y., Long, J., "Bike network design problem with a path-size logit-based equilibrium constraint: Formulation, global optimization, and matheuristic", Transportation Research Part E: Logistics and Transportation Review, 127: 284–307, (2019).

[41] ITDP, A Global High Shift Cycling Scenario. https://www.itdp.org/2015/11/12/a-global-high-shift-cycling-scenario/, (2015).

[42] Kager, R., Bertolini, L., Te Brömmelstroet, M., "Characterisation of and reflections on the synergy of bicycles and public transport", Transportation Research Part A: Policy and Practice, 85: 208–219, (2016).

[43] Gutiérrez, M., Hurtubia, R., Ortúzar, J.de D., "The role of habit and the built environment in the willingness to commute by bicycle", Travel Behaviour and Society, 20: 62–73, (2020).

[44] Curran, A., "Translink public bike system feasibility study", Quay Communications Inc, Vancouver, (2008).

[45] Caspi, O., Smart, M.J., Noland, R.B., "Spatial associations of dockless shared e-scooter usage", Transportation Research Part D: Transport and Environment, 86: 102396, (2020).

[46] Yalınız, P., Bilgiç, Ş., "Eskişehir Kent Merkezinde "Park Et ve Bin" Uygulamasının Sürdürülebilir Ulaştırma Bağlamında Değerlendirilmesi", 7. Ulaştırma Kongresi, Türkiye İnşaat Mühendisleri Odası, İstanbul, 461-470, (2007).

[47] Aros-Vera, F., Marianov, V., Mitchell, J.E., "P-Hub approach for the optimal park-and-ride facility location problem", European Journal of Operational Research, 226(2): 277–285, (2013).

[48] Mingardo, G., "Transport and environmental effects of rail-based Park and Ride: Evidence from the

Netherlands", Journal of Transport Geography, 30: 7–16, (2013).

[49] Clayton, W., Ben-Elia, E., Parkhurst, G., Ricci, M., "Where to park? A behavioural comparison of bus Park and Ride and city centre car park usage in Bath, UK", Journal of Transport Geography, 36: 124-133, (2014).

[50] Acar, İ.H., "Trafik ve Ulaşım Konularında Kanılar ve Gerçekler", 7. Ulaştırma Kongresi, Kongre Sempozyum Bildiriler Kitabı, (2007).

[51] https://www.estram.com.tr/Cntnt/81. Access date: 01.03.2022

[52] Dündar, S., "Park Et Bin Sistemi ve İstanbul'daki Uygulaması", MSc Thesis, Istanbul Technical University Institute of Science and Technology, Istanbul, (2010).

[53] Kocabaş, N., "Metrobüs Sistemlerinin Ülkemizde Uygulanabilirliğinin Araştırılması ve Antalya Örneği", MSc Thesis, Eskişehir Osmangazi University Institute of Science and Technology, Eskişehir, (2007).

[54] Karamaşa, Ç., Demir, E., Memiş, S., Korucuk, S., "Weighting the factors affectıng logıstıcs outsourcıng", Decision Making: Applications in Management and Engineering, 4(1): 19–32, (2021).