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A new perspective on public transportation systems investments after the COVID-19 pandemic effect: Bus rapid transit (BRT) for the metropolis, small & medium-scale cities

COVID-19 pandemi etkisinden sonra toplu taşıma sistemleri yatırımlarına yeni bir bakış açısı: Metropol, küçük & orta ölçekli şehirler için metrobüs

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Abstract

Public transportation is one of the sectors most affected by the COVID-19 pandemic and consequently public transportation ridership has decreased in the ratio of 50%-90% during this period. Some of these passengers are expected not to use public transportation even if the pandemic is stable. Due to the high risk of infection in public transportation and the fact that the social distance-face mask rule is not obeyed to a certain extent, new regulations in public transportation should be made evident. Bus rapid transit (BRT) is a high-quality public transportation system that has been widely preferred in both metropolis and medium-scale cities in recent years because of its low investment cost and short construction period. In this study, the economic effects of BRT system that is planned with the consideration of social distance according to the requirements of the pandemic were examined in terms of the country's economy and investor/operating institutions. Calculations were performed for the metropolis and small & medium-scale cities as two different types of cities. With the aim to find an urgent solution to the damaged image of public transportation due to the pandemic and the increasing traffic density, the effects of 1, 2 and 3 years of the implementation period on feasibility studies were investigated. In order to minimize the effect of the pandemic, occupancy rates during peak hours were assumed as 70%, which is the value specified for social distance in the literature, and the value of 90% used in feasibility studies. Four different scenarios were created by determining the number of passengers per square meter as 4 and 6. It was determined that the implementation period of BRT in one year could give more profitable results in terms of the country's economy and investor/operating institutions for both types of cities (the metropolis and small & medium-scale cities). In terms of the country's economy, it was determined that the scenario of 70% occupancy-4 passengers/m^2 could be applied for both cities. In terms of operating institutions, although the scenario of 70% occupancy-4 passenger/m^2 did not give profitable results for both cities, the findings have shown that this scenario could be applied by considering profitability in the country's economy. The results of this investigation show that BRT is a preferable system that could be applied both in the metropolis and small & medium-scale cities, and to minimize the impact of the pandemic on public transportation.

Keywords: COVID-19, Social distance, Public transportation systems, Bus rapid transit (BRT), Economic evaluation.

Öz

COVID-19 pandemisinden en çok etkilenen sektörlerden biri de toplu taşımadır ve toplu taşıma kullanan yolcu sayısı bu süreçte %50-%90 oranında düşmüştür. Bu yolculardan bir kısmının pandemi stabil olduğunda bile toplu taşıma kullanmaması beklenmektedir. Toplu taşımada bulaş riskinin fazla olması, sosyal mesafe ve maske kuralına belirli oranda uyulmamasından dolayı toplu taşımada yeni düzenlemelerin belirlenmesi gerekmektedir. Metrobüs, düşük yatırım maliyeti ve kısa yapım süresi sayesinde son yıllarda hem metropol hem de orta ölçekli şehirlerde yaygın olarak tercih edilen yüksek kaliteli bir toplu taşıma sistemidir. Bu çalışmada, pandemi koşullarına göre sosyal mesafe dikkate alınarak planlanan metrobüsün ülke ekonomisi ve yatırımcı/işletmeci kurumlar açısından ekonomik etkileri incelenmiştir. Hesaplamalar metropol ve küçük & orta ölçekli şehirlere göre iki ayrı şehir tipi için yapılmıştır. Pandemiden dolayı toplu taşımanın kaybettiği imaja ve artan trafik yoğunluğuna acil çözüm bulunması amacıyla öncelikle 1, 2 ve 3 yıllık yapım süresinin fizibilite çalışmalarına etkisi araştırılmıştır. Pandeminin etkisini en aza indirmek için yoğun saatlerde doluluk oranları, literatürde sosyal mesafe için belirtilen %70 ve fizibilite etüdlerinde kullanılan %90 olarak alınmıştır. Metrekare başına yolcu sayısı ise 4 ve 6 olarak belirlenerek dört farklı senaryo oluşturulmuştur. Her iki şehir türü (metropol ve küçük & orta ölçekli şehirler) için de ülke ekonomisi ve yatırımcı/işletmeci kurumlar açısından metrobüsün bir yılda yapılmasının daha uygulanabilir sonuçlar verebileceği belirlenmiştir. Ülke ekonomisi açısından, %70 doluluk-4 yolcu/m^2 senaryosunun iki şehir için de uygulanabileceği belirlenmiştir. İşletmeci kurumlar açısından, %70 doluluk-4 yolcu/m^2 senaryosunun her iki şehir için de kârlı sonuçlar vermese de ülke ekonomisindeki kârlılık düşünülerek uygulanabileceği tespit edilmiştir. Bu araştırmanın sonuçları, metrobüsün hem metropol hem de küçük & orta ölçekli şehirlerde uygulanabilir ve pandeminin toplu taşımaya etkisini en aza indirmek için tercih edilebilir bir sistem olduğunu göstermektedir.

Anahtar kelimeler: COVID-19, Sosyal mesafe, Toplu taşıma sistemleri, Metrobüs, Ekonomik değerlendirme.

1 Introduction

Bus rapid transit (BRT) is a public transportation system with rubber wheels that operates similar to rail systems, an economical alternative to trams, light rail transit (LRT) and the metro [1],[2]. It was first applied in Curitiba, Brazil in 1974, and has since been chosen in many cities for the public transportation system, especially in developing cities [3]-[5].

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The BRT is a public transportation system that can meet high passenger demands. For example, Istanbul BRT is used by 750 thousand passengers per day. While there were 3,828 km long BRT in 105 cities in 2010 around the world, it reached 5,331 km in 177 cities on 6 continents in 2020 [6]. Although BRT was developed for large cities, it is seen as an effective public transportation option for many medium-scale cities [7],[8]. It is crucial to be an economical solution to different city scales because the urban population is expected to increase by 3.5 billion between 2000-2050, and the majority of this increasing to be in medium-scale cities [9], [10].

The cost per km of a BRT system is 4 to 20 times cheaper than a Light rail transit (LRT) system and 10 to 100 times cheaper than a metro system [11]. However, the cost of a BRT in an exclusive lane and a low-cost LRT are closer [12]. For example, İstanbul, Turkey, BRT cost per km is $ 5.5 million [11],[13], Bursa LRT cost per km is $ 18 million [14] and the cost of the İstanbul metro per km is $ 44 million [15]. These costs show that there are important differences in cost between low-budget rail systems and BRT in an exclusive lane. This difference is more important for especially developing countries or municipalities which have insufficient financial resources. It is not possible for a public transportation system to have profitable results to all cities. High-cost transportation systems, which are valid for developed country cities with sufficient financial resources, might not be valid for developing countries with insufficient financial resources. If high-cost systems are chosen, the investments might not be completed for many years [1]. Low cost and short implementation periods (one to three years) are some of the important advantages for BRT [5]. The BRT system can be used as a trunk line or a feeder line for a rail system. These choices must be made very carefully because the transportation systems are expensive and many municipalities have financial constraints [2],[16]. BRT can also be constructed open (BRT can enter or leave at some intermediate points) or closed (BRT only operates on its path)[17]. The fact that any public transportation system and/or BRT is not determined according to the needs and conditions brings many problems. Especially in developing countries, transportation-related problems are extremely high because car dependency is high and public transportation quality is insufficient [18],[19]. For example in São Paulo, it is estimated that around 8,000 people die each year due to transportation pollution [18].

Another issue to be considered in public transportation plans after December 2019 must be the COVID-19 pandemic. As public transportation is a high-risk environment for the infection of pandemic [20], usage of public transportation fell seriously between 50% and 90% [21],[22]. Also, a number of governments instructed to close public transportation completely [21]. Passengers who could afford to shift to private transportation increased traffic congestion and impaired air quality. For the low-income group, increased traffic density and poor air quality aggravated the effect of COVID-19 on public transportation [23]. As a solution to public transportation problems, governments obligated limited capacity and face mask rule. However, studies showed that the passengers using public transportation do not obey the social distance and face mask rule to a certain extent [20]. Therefore, the negative effect of COVID-19 on public transportation should be solved with national social distancing regulations [21]. The study showed that public transportation capacity should have 70% occupancy rate for social distancing. It was also stated that this situation would lead to negative financial consequences for the operating institutions [20]. Finally, the survey results showed that even if the pandemic is stable, almost 25% of public transportation passengers consider that public transportation will be unsafe. Therefore, the damaged image of public transportation due to pandemic needs to be provided by transportation policies [24]. Public transportation, which has an important place for a sustainable city, needs to be adjusted by considering the pandemic. A limited number of studies were found in the literature on public transportation about pandemic [21].

The system that might be least affected by the effect of COVID-19 on public transportation could be BRT because of low investment cost and short construction period. BRT has attracted the attention of many researchers recently and studies stated that BRT can be a preferable alternative to traditional public transportation systems [4],[14],[25]. Akman and Alkan (2016) studied the metro, BRT, tram, LRT and the monorail as an alternative to the Izmit, Turkey Public Transportation system. LRT and BRT were determined as the most suitable alternatives. Ingvardson and Nielsen (2018) studied the effects achieved by 86 transit systems around the world, including BRT, LRT, metro and heavy-rail transit systems. Results showed that major strategic impacts can be achieved by implementing BRT systems at a much lower cost. Some researchers discussed increasing the efficiency of the BRT system. Converting share lanes to exclusive lanes BRT and adding buses to the BRT line were the best options in these studies [19],[28]. Lee (2018) studied BRT, LRT and Bimodal Tram (BT) and a hierarchical structure was developed for the decision-making process. It also divided the new city types into metropolis city type and small & medium city type. BRT was ranked first in terms of infrastructure investment costs, vehicle purchase cost, applicability, operation and maintenance costs in the metropolis and small & medium-scale city.

This study first ever investigates the coupling between economic (national economy) and financial (investment/operational) relations because of a 70% occupancy rate in public transportation capacity in order to solve out social distance problems and as well as new requirements in public transportation planning due to pandemic. In this study, the BRT was evaluated in terms of the national economy and investment/operating institutions for various scenarios which could satisfy public transportation demand during the pandemic. For achieving the social distance, the number of passengers per square meter was determined as 6 and 4. Calculations were performed by reducing the occupancy rates from 100% to 90% and 70% during peak hours. Calculations were performed by using the line data which have Istanbul for metropolis city and Eskişehir for small & medium-scale city in Turkey were used. In terms of urgent recovering from the damaged image of public transportation due to the pandemic and to examine the effect of the implementation period for BRT, the implementation period was changed to 1-2 and 3 years. Thus, the effect of the implementation period on the transportation economy was examined. For investigating economic-financial effects, benefit-cost in different scenarios was determined. Benefit-cost ratio (B/C), net present value (NPV) and the internal rate of return (IRR) values of the scenarios were calculated for all scenarios.

2 Methodology

Economic and financial feasibility studies must be taken into account when evaluating transportation projects. Benefits and costs in feasibility studies are determined according to the economic conditions of the country and the project. In this study, travel data of Sefaköy-Halkalı-Başakşehir for Istanbul and SSK-Otogar line for Eskişehir were used. Calculations were performed according to the principle of preferring a BRT instead of a bus on the line.

2.1 Economic feasibility study

The aim of the economic feasibility study is to evaluate the project in terms of the national economy. Figure 1 shows the economic feasibility steps and factors. An economic feasibility study determines the economic benefits and costs of the project [15]. The subtraction of taxes from price is called shadow price and the shadow price coefficient is used to convert financial investment and operating costs into economic costs. The shadow price was taken as 0.70 as in similar projects [2],[30]. For BRT projects, net present value (NPV), benefit-cost ratio (B/C) and internal rate of return (IRR) were calculated. NPV is the conversion of each of the benefits and costs of the project over time to its present value at the rate of return. If the result is positive when the total costs are subtracted from the total benefits, the project is profitable. B/C is the ratio obtained by dividing the benefits of a project by its costs. The fact that the result is one and above indicates that it is profitable. IRR is the rate of return that sets the net present value of all cash flows from the project equal to zero. If the result obtained is above the country's rate of return, the project is profitable.

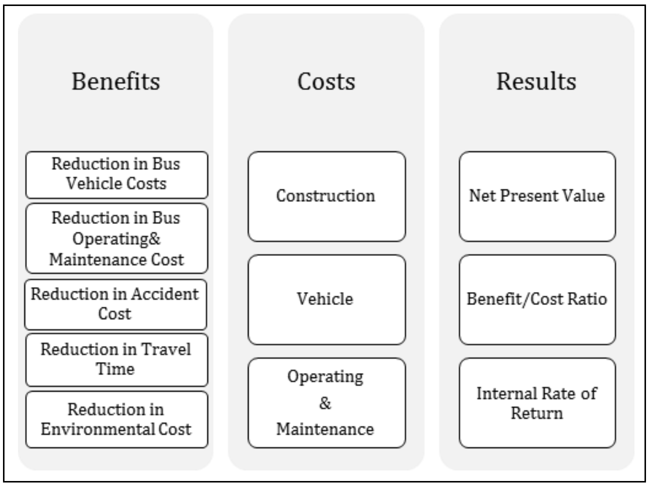

Figure 1. Economic feasibility steps and factors.

Benefits and costs were calculated with 2021 fixed prices. Costs and benefits were converted into constant 2021 net present value and 10% was used as the discount rate [2],[30]. The economic benefits of the project are as follows:

- "Reduction in bus vehicle costs" refer to the reduction in vehicle purchases on the bus in the case of preferring BRT. The number of buses required is determined for each year according to the number of passengers and the headway. The reduction in bus vehicle costs is calculated by multiplying the number of buses and the unit bus cost,
- "Reduction in bus operating&maintenance (O&M) cost" refers to the reduction in O&M cost on the bus in the case of preferring BRT. The kilometer traveled by the buses for each year is determined according to the headway and the length of the line. The reduction in O&M cost is calculated by multiplying this kilometer and the unit O&M cost,
- "Reduction in accident cost" refers to the cost of the reduction in accidents in the case of preferring BRT. It is calculated by multiplying the kilometer traveled by the buses for each year and the unit accident cost determined by the general directorate of highways,
- "Reduction in environmental cost" refers to the cost of the reduction in emission in the case of preferring BRT. The kilometers traveled by BRT for each year are subtracted from the kilometers traveled by buses. This value is multiplied by the value determined by the general directorate of highways,
- "Reduction in travel time" refers to the time difference provided by a BRT compared to the bus. The time difference is calculated for each passenger depending on the operating speed of the BRT and the bus. This value is multiplied by the unit time value for the passenger.

The economic costs of the project are as follows: Construction cost, vehicle cost and O&M cost. Unit costs and benefits included in the economic evaluation are given in Table 1. Construction, vehicle and O&M costs were taken from Istanbul BRT costs [3],[11],[13],[31]. Eskisehir BRT construction costs may be lower than Istanbul because Eskişehir BRT was considered to have shared&exclusive lanes. However, assuming that this situation could not affect the costs significantly, the only construction data for Turkey (5.5 million $/km) was also used for Eskişehir [11],[13]. Benefit values were taken from feasibility studies [2]. The construction period of the projects was different (1-2-3 years) and the operation period was taken as 25 years in all scenarios [2],[15],[30].

Table 1. Considered values in benefits and costs.

		UNIT PRICE
Construction	COST	$ 5,500,000/km
Vehicle		High capacity $ 780,000/vehicle Low capacity $ 405,000/vehicle
O&M		$ 2.15/km
Reduction in Bus Vehicle	PROFIT	$ 165,000/vehicle
Reduction in Bus O&M		$ 1.68/km
Reduction in Accident		$ 35,020/million-km
Reduction in Environmental		$ 0.051/km
Reduction in Travel Time		İstanbul $ 4.85/passenger/hour Eskişehir $ 3.03/passenger/hour

2.2 Financial feasibility study

The aim of the financial study is to evaluate the project in terms of investor/operator institution [15]. Figure 2 shows the Financial feasibility steps and factors. NPV, B/C and IRR were calculated according to 2021 fixed prices of revenue-expense and discount rate 10%. Revenues consist of the ticket and advertisement revenues. Since the contribution of advertisement revenues on project applicability is negligible [2], it was not considered in this project. The expenses are the same as the cost of economic feasibility. As in the study for Eskişehir, the average ticket fare for Istanbul and Eskişehir was taken as $ 0.37 per passenger [2]. The construction period of the projects was different (1-2-3 years) and the operational period was taken 25 years in all scenarios.

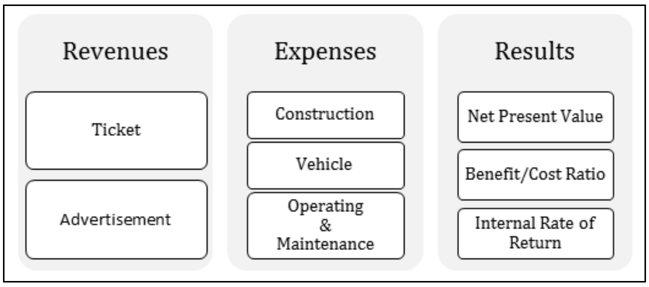

Figure 2. Financial feasibility steps and factors.

2.3 Metropolis city, Istanbul

Lee (2018) identified cities that have populations of more than 1 million as metropolis cities. Istanbul has a population of 15,462,452 (for the year 2020) and calculations were performed using travel data of Sefaköy-Halkalı- Başakşehir line of Istanbul. Figure 3 shows the Sefaköy-Halkalı-Başakşehir line. The line length is 14.948 km. The daily number of passengers is 323591 in 2022, 423214 in 2030, 547744 in 2040 and 647368 in the year 2048 [30].

Figure 3. Sefaköy-Halkalı-Başakşehir line [30].

High capacity BRT vehicle which has a capacity of 193 passengers (44 seating, 149 standing for 4 passenger accounts per square meter) was used [3],[32]. The number of passengers per square meter, the occupancy rate at peak and non-peak hours, the number of passengers per vehicle, and operating speed are given in Table 2.

Table 2. Operating characteristics of the Istanbul line.

Passenger/m^2	Occupancy rate in peak/non peak hours	Number of passenger in vehicle for peak/non-peak hours	Operating Speed (km/h)
4	70/68.5	135/132	25.3
4	90/88	174/170	23
6	70/68.5	187/183	22.77
6	90/88	241/235	20.7

The operational characteristics were determined to have an exclusive lane similar to the existing BRT in Istanbul. It is expected that when the vehicle occupancy rates are reduced, the headway is shortening. Therefore, it is expected that the passengers' get on and get off time at the stations are shorten. Lastly, it is assumed that dwell time for BRT is shortened and increases the operating speed. It is assumed that the operating speed increased by 10% as the occupancy rate decreased, taking into account the operating speeds of BRT in the literature [33]. The increase in operating speed could be less than 10%, but could be achieved with express-limited services. Since the decrease in the number of passengers per vehicle due to pandemic could adversely affect the operating institutions, it is very important to increase the operating speed in terms of economic feasibility (national economy). In this way, travel time could be shortened and the risk of pandemic could be reduced.

2.4 Small & medium-scale city, Eskişehir

Lee (2018) identified cities that have populations less than 1 million as small & medium scale cities. Eskişehir has a population of 888,828 (for the year 2020) and calculations were made using the travel data of the SSK-Otogar line of Eskişehir. Figure 4 shows the SSK-Otogar line. The line length is 10.5 km. The daily number of passengers is 45852 in 2022, 48998 in 2030, 52705 in 2040 and 55751 in the year 2048 [2].

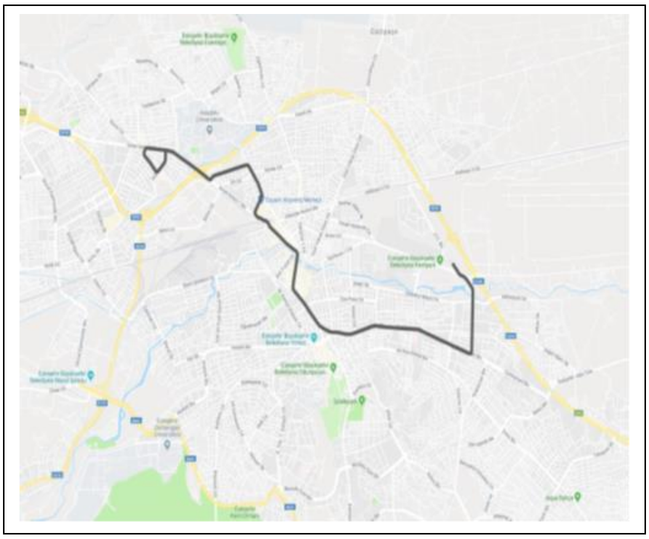

Figure 4. SSK-Otogar line [2].

Low capacity BRT vehicle which has a capacity of 136 passengers (25 seating, 111 standing for 4 passenger accounts per square meter) was used [32],[34]. The occupancy rate, number of passengers per vehicle and operating speed values at peak and non-peak hours are given in Table 3.

Table 3. Operating characteristics of the Eskişehir line.

Passenger/m^2	Occupancy rate in peak/non peak hours	Number of passenger in vehicle for peak/non-peak hours	Operating Speed (km/h)
4	70/68.5	95/93	23
4	90/88	122/120	20
6	70/68.5	134/131	19.55
6	90/88	172/168	17

The operational characteristics were determined to have an exclusive&shared lane similar to the existing street tram in Eskişehir. The operating speed of the existing street tram is

17 km/h and 90% occupancy-6 passengers/m² have similar characteristics [2]. Therefore, the operating speed of %90 occupancy-6 passengers/m² was determined as 17 km/h for BRT. It is assumed that the operating speed increased by 15% as the occupancy rate decreased, taking into account the operating speeds of BRT in the literature [33]. This increase in operating speed could be performed by increasing the extension of exclusive lanes similarly in the literature [19] and/or express-limited services. In order to minimize the public transportation problems caused by pandemic, increasing the operating speed could be a substantial parameter.

3 Results and discussions

Economic and financial feasibility results, benefit and cost distributions were calculated separately for each scenario.

3.1 Economic feasibility study results

Table 4 and Table 5 show the economic feasibility results of the BRT Istanbul and Eskişehir.

Table 4. Economic feasibility results for Istanbul BRT.

Construction Time/Occupancy rate/Passenger per m²	NPV ($)	B/C	IRR (%)
1 year - %70 - 4	1,222,653,283	4.15	182.45
2 year - %70 - 4	1,108,887,085	4.12	115.99
3 year - %70 - 4	985,716,521	4.04	86.98
1 year - %90 - 4	1,165,066,202	4.64	186.07
2 year - %90 - 4	1,056,535,193	4.60	116.66
3 year - %90 - 4	939,218,949	4.50	86.71
1 year - %70 - 6	1,184,140,726	4.93	193.38
2 year - %70 - 6	1,073,875,669	4.88	119.59
3 year - %70 - 6	954,663,704	4.77	88.60
1 year - %90 - 6	1,096,881,419	5.34	188.38
2 year - %90 - 6	994,549,027	5.28	116.48
3 year - %90 - 6	884,032,473	5.14	86.77

Table 5. Economic feasibility results for Eskişehir BRT.

Construction Time/Occupancy rate/Passenger per m²	NPV ($)	B/C	IRR (%)
1 year - %70 - 4	26,366,551	1.36	16.98
2 year - %70 - 4	22,132,092	1.32	15.75
3 year - %70 - 4	17,237,192	1.27	14.58
1 year - %90 - 4	22,392,197	1.33	16.04
2 year - %90 - 4	18,505,899	1.30	14.91
3 year - %90 - 4	13,993,344	1.24	13.81
1 year - %70 - 6	23,062,256	1.36	16.25
2 year - %70 - 6	19,128,187	1.31	15.09
3 year - %70 - 6	14,556,338	1.25	13.97
1 year - %90 - 6	15,833,478	1.26	14.37
2 year - %90 - 6	12,556,571	1.22	13.42
3 year - %90 - 6	8,660,647	1.16	12.43

As the implementation period shortened, positive results were obtained in all scenarios. For Istanbul, decreasing the implementation period from 3 years to 1 year was increased the NPV by more than $ 200 million in all scenarios. For Eskişehir, decreasing the implementation period from 3 years to 1 year was increased the NPV between $ 7 and 9 million in all scenarios. Results show that the implementation period of public transportation projects could increase its importance in metropolis cities. BRT projects have a short implementation period; For example, BRT Istanbul 18.3 km was constructed in 1 year and 10 months [31], BRT Rio de Janeiro 51.0 km in 2 years and 2 months [35]. In this study, the significance of the short implementation period of BRT was showed in numerical terms. In addition, these results could be drawn that the results of public transportation systems which have high cost and long implementation time could be difficult to profitable. It could be very valuable to complete the project in a short implementation period in order to compensate damaged image of public transportation due to pandemic and to get better results in economic feasibility.

Table 4 shows that the effect of the decrease in the number of passengers per vehicle on the economic feasibility results for Istanbul. The fact that the B/C ratio is greater than four in all scenarios shows how profitable it could be for the country's economy. The IRR results of over 100 show how profitable BRT could be applied. In another study, the 21,020 km metro project for Istanbul was calculated according to 90 occupancy-6 passengers/m² at peak hours [15]. Although the number of Istanbul BRT project passengers was more than twice, the IRR result was found to be 25.39% and B/C was found to be 2.25. Because the construction cost was approximately 44 million dollars and the vehicle cost was 1.6 million dollars for the metro project [15]. For the Istanbul BRT project, in the case of 90 occupancy-6 passengers/m², even if the implementation period is 3 years the IRR calculated as %86.77, B/C calculated as 5.14. The results show that BRT could be more profitable than high-budget public transportation systems. For pandemic, results show that it could be regulated with 70% occupancy-4 passengers/m² to solve the social distance problem in public transportation.

Table 5 shows that the social distancing can be achieved by decreasing occupancy rate and passenger per m² for Eskişehir. For all scenarios, the value of B/C greater than 1 indicates that BRT could be a profitable project. The IRR value of the 70% occupancy-4 passenger/m² scenario is between 14.58 and 16.98. Due to the 10-12% discount rate in Turkey, 70% occupancy-4 passenger/m² could be regulated to achieve social distancing for small & medium scale cities.

Figure 5 presents the cost distributions of the Istanbul economic feasibility study. Since the number of passengers was high, the majority of the costs belonged to the O&M costs in all scenarios. As the occupancy rate/passenger per m² decreased, O&M costs increased. In metropolis cities, reducing O&M costs should be considered in the first factor to reduce total cost. If the O&M cost per passenger of the BRT is reduced to a value close to systems such as metro, which have low O&M costs per passenger, it might reduce the share of O&M costs. For example, construction cost had a share of 64%, O&M cost had a share of %19 in the metro feasibility project [15].

Figure 6 shows the cost distributions of Eskişehir economic feasibility study. In Eskişehir, construction costs accounted for more than half of the total cost. The share of the vehicle and O&M costs was low due to the low number of passengers. The low construction cost could be significant in terms of applicability for small&medium-scale cities. For this reason, the implementation of projects such as LRT and metro, which are much more expensive for construction cost than BRT, could give unprofitable results for the country's economy. In addition, pandemic could worsen these results.

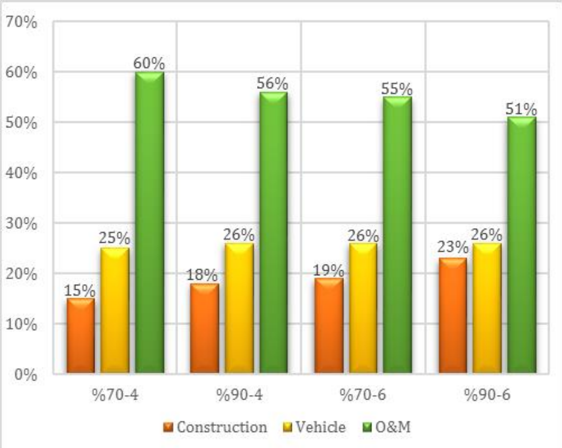

Figure 5. Cost distribution of Istanbul BRT.

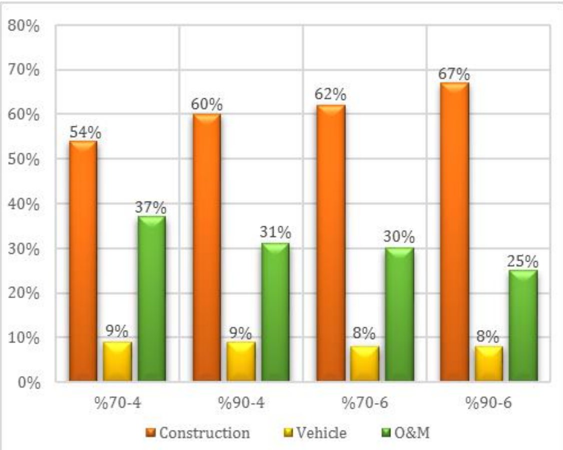

Figure 6. Cost distribution of Eskişehir BRT.

Figure 7 shows the percentage distribution of benefits in Istanbul. For Istanbul, travel time reduction and bus O&M reduction had the largest share in benefits 49-58% and 35-41% respectively. For the Istanbul metro project, the time saving was the first rank and had a share of 73.2% due to the operating speed of 40 km/h. In the second rank, bus O&M reduction had a share of 14.2% [15]. The results show that in metropolis cities, time savings and bus O&M costs should be important factors to be considered during the project phase. Accident and environmental costs had a share of 1% as in the metro project [15]. Hidalgo et al. (2013) examined the effects of TransMilenio BRT system in Bogota. Researchers stated that time-saving had share of 52% and bus O&M reduction had share of 37%. These results are almost the same as the Istanbul BRT.

Figure 8 shows the percentage distribution of benefits in Eskişehir. Due to the short line length, operating speed and a low number of passengers in small&medium-scale cities, the travel time reduction share was lower than metropolis cities. Therefore, this gain could be increased by increasing the operating speed. The high share of bus O&M reduction (46-61%) shows that preferring BRT instead of buses or minibusses in small & medium-scale cities could increase efficiency.

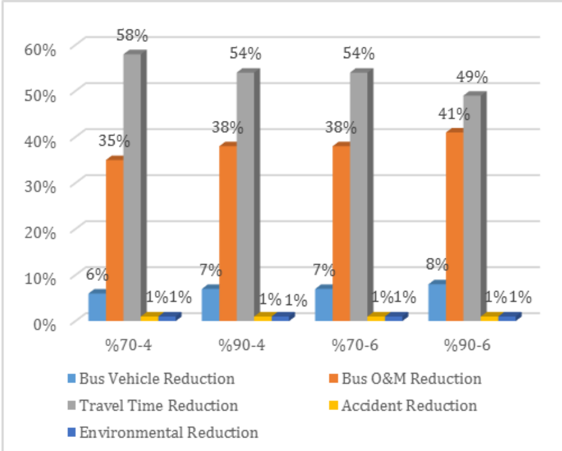

Figure 7. Benefit distribution of Istanbul BRT

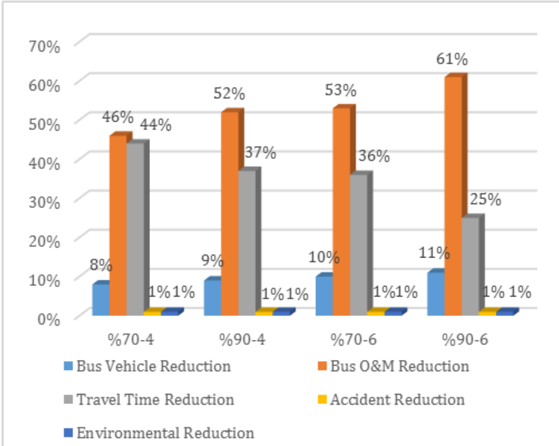

Figure 8. Benefit distribution of Eskişehir BRT.

3.2 Financial feasibility study results

Table 6 and Table 7 show the financial feasibility results of the BRT İstanbul and Eskişehir. Since financial analysis depends on the system's self-repayment, it is the point that needs to be very careful in public transportation projects. Many municipalities and the operating institution have a problem at this point [2]. According to the financial feasibility results, the best results in the two city types were obtained at 90% occupancy-6 passengers/m² scenario. Although the change in the implementation period affected the NPV result of BRT, it did not affect the applicable result (profit or loss) of the BRT in terms of investment/operations institutions. The implementation period in public transportation projects should be taken into consideration, especially considering the profitability of the economic feasibility results.

Table 6 shows the effect of the decrease in the number of passengers per vehicle in the financial feasibility results for Istanbul. While 90%-6 passenger/m², which was taken into consideration in feasibility study Turkey [15], was profitable for Istanbul, 70% occupancy-4 passenger/m² was an unprofitable investment. Although profitable results were obtained in the 70% occupancy-6 passenger/m² scenario, having 6 passengers per square meter could be a problem in terms of social distance. In the metro project (90%-6 passenger/m²) [15], although the average ticket price was $ 0.75, the financial feasibility NPV result was calculated as $118 million loss.

Table 6. Financial feasibility results for Istanbul BRT

Construction Time/Occupancy rate/Passenger per m²	NPV ($)	B/C	IRR (%)
1 year - %70 - 4	-106,283,628	0.81	2.71
2 year - %70 - 4	-100,358,480	0.80	2.67
3 year - %70 - 4	-94,858,739	0.80	2.63
1 year - %90 - 4	-9,410,765	0.98	9.35
2 year - %90 - 4	-12,292,241	0.97	9.11
3 year - %90 - 4	-19,622,595	0.95	8.41
1 year - %70 - 6	17,165,014	1.04	11.18
2 year - %70 - 6	11,867,558	1.03	10.85
3 year - %70 - 6	2,043,376	1.01	10.16
1 year - %90 - 6	86,286,439	1.24	16.11
2 year - %90 - 6	74,705,217	1.22	15.45
3 year - %90 - 6	59,347,011	1.19	14.66

Even if BRT is completed in 3 years, at the same occupancy rate 90-6% passenger/m², the NPV result was calculated as $59 million profit. The results show that BRT could be considerably more economical than the metro. For satisfying public transportation demand during the pandemic, BRT could be implemented quickly and it could be an economical solution. Also, more feasible results could be obtained by reducing the occupancy rates in projects which has an average ticket price of more than $ 0.37 (different countries or routes where the passengers using discount tickets are less).

Table 7 shows the effect of the decrease in the number of passengers per vehicle in the financial feasibility results for Eskişehir.

Table 7. Financial feasibility results for Eskişehir BRT

Construction Time/ Occupancy rate/ Passenger per m²	NPV ($)	B/C	IRR (%)
1 year - %70 - 4	-52,282,755	0.50	-2.36
2 year - %70 - 4	-50,154,777	0.49	-2.30
3 year - %70 - 4	-48,140,706	0.48	-2.24
1 year - %90 - 4	-42,817,354	0.55	0.35
2 year - %90 - 4	-41,549,867	0.54	0.34
3 year - %90 - 4	-40,314,972	0.52	0.33
1 year - %70 - 6	-39,888,605	0.57	1.13
2 year - %70 - 6	-38,887,368	0.55	1.10
3 year - %70 - 6	-37,897,607	0.53	1.06
1 year - %90 - 6	-32,944,811	0.62	2.86
2 year - %90 - 6	-32,574,828	0.60	2.76
3 year - %90 - 6	-32,158,934	0.58	2.66

No feasible results were obtained for Eskişehir BRT in any scenario. In the 90% occupancy-6 passengers/m² scenario where the best results were obtained, the ticket revenues were able to cover 62% of the costs. In the 70% occupancy-4 passengers/m² scenario, 50% of the costs were covered. Therefore, considering the results in economic feasibility, 70% occupancy-4 passengers/m² scenario could be applied to satisfy public transportation demand during the pandemic. Governments could support financially for operating institutions, taking into account their national economic gains (economic feasibility). Also, if the average ticket price is more than $ 0.37 for different countries or routes where the passengers using discount tickets are less , more or all of the costs could be covered. Within the two cities, the distribution of expenses in the feasibility study is the same as in the economic study. In revenue distributions, all share belongs to ticket revenues.

4 Conclusions

This article deals with public transportation problems caused by the COVID-19 pandemic. In this study, the BRT scenarios for different vehicle occupancy rates at peak hours is assumed to be %70 (in the literature, the recommended rate for social distance)- is taken as %90 (considered rate in feasibility studies), the number of passengers per square meter is considered 4-6 and implementation period 1-2-3 years are examined. Economic (national economy) and financial feasibility (investment/operating institution) studies are performed in each scenario for metropolis and small & medium-scale cities. The following results can be drawn based on feasibility studies concerning the proposed solution to satisfy public transportation demand during the pandemic.

For the implementation period effect and urgent solution to the effect of COVID-19 on public transportation, the cases of construction in 1-2 and 3 years were examined. 1 year gave more profitable results in economic-financial feasibility for all scenarios. The implementation period for the economic feasibility study varying between 1 year and 3 years did not change the profitable result. However, the amount of profit increased by NPV to more than $ 200 million for metropolis cities and between $ 7-9 million for small & medium-scale cities. Especially in metropolis cities, the effect of the short implementation period could be more valuable for economic feasibility. The implementation period in the financial feasibility study did not change the applicable result (profit or loss) of the project. However, considering the serious profits in economic feasibility, a short-time implementation period could be crucial.

According to the results of the economic analysis (national economy), 70% occupancy-4 passenger/m² scenario gave profitable results in two city types. According to the implementation time in 1 year, while the B/C ratio for the metropolis cities was 4.15, it was found to be 1.36 for small & medium-scale cities. %70 occupancy rate during peak hours could be very crucial for social distance as stated in the literature. The only point to be considered is that it is planned to increase the operating speed at the rate specified in the scenario. Considering the cost distributions, O&M costs had a 51-60% share in metropolis cities and construction cost had a share of 54-67% in small & medium scale cities. Considering the distribution of benefits, travel time reduction had a share of 49-58% and bus O&M reduction had a share of 35-41% in metropolis cities, respectively. These values were 25-44% and 46-61% in small & medium-scale cities, respectively. These results show that the distribution of benefits and costs in public transportation projects proposed for implementation could vary significantly depending on the city scale and scenarios.

According to the results of the financial analysis (investment/operating institution), the best results were taken, as expected, the scenario with the highest occupancy 90% occupancy-6 passenger/m². For the metropolis cities, while the B/C ratio of 90% occupancy-6 passenger/m² scenario appeared to be 1.24, the B/C ratio of 70% occupancy-4 passenger/m^2 scenario was 0.81. Although the B/C ratio of 70% occupancy-6 passenger/m^2 scenario appeared to be 1.04, this scenario may not be suitable for 6 passengers per square meter social distance. Considering the profits in the 70% occupancy-4 passenger/m^2 scenario in economic feasibility, operating institutions can be supported financially by governments. For small & medium-scale cities, while the B/C ratio of 90% occupancy-6 passenger/m^2 scenario appeared to be 0.62, the B/C ratio of 70% occupancy-4 passenger/m^2 scenario was found to be 0.50. Profitable results were not obtained in any of the implemented scenarios for small & medium-scale cities. However, BRT scenarios could be performed with the financial support of the government and taking into account the gains from economic analysis. If BRT is not implemented in small & medium-scale cities, increasing the existing public transportation quality (using intelligent transportation applications such as real-time information, traffic signal control, and the like) could minimize the spread of the pandemic. Finally, in cities where the average ticket price is $ 0.37 more for different countries or routes where the passengers using discount tickets are less, more profitable results could be proposed for implementation.

In future studies; optimization of the line can be performed with open-closed line systems, limited-stop and express services. Economic-financial feasibility studies can be prepared in more detail, and the effects of optimization can be examined.

5 Author contribution statements

In the scope of this study, Fatih YILDIZHAN contributed to the formation of the idea, collecting data, literature review, performing analyzes, writing the article.

6 Ethics committee approval and conflict of interest statement

"There is no need to obtain permission from the ethics committee for the article prepared". "There is no conflict of interest with any person / institution in the article prepared."

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