

Second-hand renovated trams as a novel decision strategy for public transport investment

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ABSTRACT

The public transport system is one of the cities' primary services, classifying the city as modern, livable, accessible, and sustainable. Accordingly, cities are trying to develop sustainable public transport systems even with limited budgets and funds. In this study, a novel decision strategy for public transport investment is investigated for a tramway system that implements several local decision strategies, and it gave the ability to launch the system using second-hand renovated trams as the rolling stock. The operation period's financial sustainability for ten years and the effect of the second-hand trams are assessed. The results show that renovated tram cars decreased the project's initial investment costs by 53.88% and realized 4.5 M €/km total cost, which is one-fifth of the average total cost in Europe. The system became a self-sufficient system after the 3rd year of operation and is profiting with incremental positive cash flow since that year without having any compensation from the national or local government. The study shows that the cities' financial resources could be sufficient to cover sustainable transportation modes with locally adapted strategies. The paper also contributes to decision strategies that renovated trams can be a solution for cities with limited budgets and are planning to construct tramway lines to improve public transport systems and eager to create sustainable cities.

1. Introduction

Travel demands in urban areas are increasing continuously and forcing cities to implement sustainable public transport systems, such as public buses, trams, light rail, underground or metro which are essential components to create sustainable cities and to mitigate climate change effects. Transportation is the second most polluting sector behind industry (Cano et al., 2021). Beyond urban mobility, tramway systems have broader transformative effects. They help improve the quality of life, urban regeneration, and environmental problems (Turnheim and Geels, 2019). Because of these reasons, tramways are generally targeted by politicians as a means of modernization and urban renewal in order to reduce traffic congestion and ensure the integration of urban environments (Beier, 2020).

Several studies on tramway systems are concerned with the economic and environmental efficiency and impacts of trams on urban traffic (Bhattacharjee and Goetz 2012; Kenworthy 2008; Litman 2007). The development of new technologies and clean energy control methods for the propulsion of vehicles are encouraging energy efficiency and renewable energy usage in tramway systems (Cano et al., 2021). As promising technology fuel cells that convert the chemical energy of the

fuel into electricity without combustion are expected to become a viable solution for tramways (Li et al., 2015). The use of fuel cells, as the main propulsion component, in tramways results in a considerable reduction in both pollutants and noise emissions (Piraino and Fragiaco, 2020). The energy management systems for hybrid tramways are studied for the real driving cycle of the tramways (Fernandez et al., 2010). The comparison is done for two alternative systems having the effective combination of supercapacitors, lithium-ion batteries, and proton exchange membrane fuel cells on board to supply the traction power of a tramway in Ecuador (Arevalo et al., 2020). In China, a tramway's system model is established to evaluate its longitudinal dynamics performance. The model includes multiple masses point connecting together powered by the catenary and a hybrid energy-storage system which consists of a battery pack and ultracapacitor pack. The effectiveness and validity of the proposed model are verified by a real tramway and a real driving cycle (Yang et al., 2019). The results show that the proposed strategy can reduce daily operation costs by 12.2% and 14.6%, and lower batteries degradation costs by 40% for all, which will effectively prolong the batteries' life span and reduce the replacement cost. The eco-driving trajectory for a tramway system is investigated in France (Boukal and Enjalbert, 2019).

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There are studies for Paris, Amsterdam, Gothenburg (Gonzalez-Feliu, 2016, Arvidsson and Browne, 2013; Delaitre and De Barbeyrac, 2012) which presented the tramway system as a low emission concept for urban freight distribution. Some of the others are investigated the new or substituted tramway lines' effects for the development of sustainable cities in France for Paris (Prud'homme et al., 2011) and Nantes, Grenoble, and Strasbourg (Stambouli, 2005). Some of them are thought that the introduction of subsidized public transport is not necessarily accompanied by a significant mode switch (De Witte et al., 2006, 2008). Another one is discussed their efficiency comparing with the required high investment and supplementary measures. It is analyzed that tramway projects' medium-term impact dealt with the strongly negative externalities of congestion: travel time losses and is concluded that the subsidization of public transport is partially efficient since these negative externalities has an impact mainly on intra-urban commutes (Tivadar and Heddebaut, 2017).

Local or national governments are usually subsidizing public transport systems. In most countries, the state or local governments or municipalities are responsible for the public transport systems' financing and operation because public transportation is often an unprofitable business activity and usually has deficits (Ubbels et al., 2001). These funds for the public transportation systems come mostly from general taxation or municipal revenues as the other public services. Some new finance mechanisms are tried to subvance the public transport systems, such as parking fees, charges for the use of road space, and development levies (Ubbels et al., 2001). Public authorities subsidize the public transportation systems as they are vital systems for the cities and have positive environmental and social effects. High investments are needed for high-capacity transportation systems such as tramways and metros for a sustainable city. However economic efficiency is disregarded by the public transport authorities (PTAs) in many tramway investments. A study in Sweden has searched to which extent PTAs assess economic efficiency in planning operations and infrastructure. The main result is that most PTAs do not use economic efficiency as decision support but primarily for investments in payment systems and major line or traffic changes (Vigrena and Ljungberg, 2018).

In most countries, the central or local governments have limited budgets and are trying to make these initial investments using long-term loans or various funding sources. However, decision-makers cannot find practical ways to decrease the initial investment and operational costs. Despite this result, public transportation systems are essential for the cities, and the tramway is one of the main modes. Many cities are making high investments in transportation systems, and these investments restrict the budgets of cities and delay the provision of some other services. Most of the PTAs are searching for models to decrease the initial investments and to have social, financial, and environmentally sustainable public transportation systems in their cities.

Previous studies have mostly focused on analyzing the technical and economic efficiency of the tramway systems as energy consumptions, propulsion improvements, breaking energy recovering, renewable energy usage, and battery packs. Accordingly, the climate change effects and decreasing greenhouse gas (GHG) emissions for urban mobility and tramway systems have been widely researched. Tramway systems have been examined as an excellent solution to urban transport problems, decrease private car usage and increase the streets' capacity in the city centers. Additionally, the quantity of the investments and transportation modal shift percentages are compared. However, in the literature review, there is no known study about the technical, environmental and economic assessment of renovated old trams.

In this study, a novel model for a tramway system using second-hand trams instead of brand new ones is investigated and presented as a solution for limited budgets. A case study from Gaziantep, Turkey, with a population of more than 2 million, is chosen to expose how the city has achieved to launch its first public rail system and which strategies are effective. The study will search whether the cities' financial resources may be sufficient to cover these modern city transportation modes with

locally adapted strategies or not. The proposed funding method and decision strategies could be a good model for the countries planning to have rail systems for public transportation but have constraints for the initial investment costs and could fill in any gaps in the literature.

2. Literature review

The tramway systems were first used and popular in Western Europe between 1895 and 1935 (López, 2003). For the Western European countries, the number of urban locations with a population greater than 150,000 and served by electric trams was 886 during the 1930s. 192 of them were in the British Isles, 162 were in West Germany, and 146 were in France, and the others were in other countries of Europe. After the 1st and 2nd World War, the cities declined the tramway systems following the automobile industry's progress (Souter, 2001) and the economic, industrial, and policy changes. It was generally accepted from their first appearance that buses were cheaper than trams in terms of capital cost. This was broadly true, and when tramways became due for renewal in the 1920s, the inflated costs of reconstruction compared very unfavorably with the low first cost of buses (Buckley, 1987).

Since the late 1970s, tramways were being rediscovered again as a solution to urban transport problems. Tramway systems are considered as an excellent solution to decrease private car usage and increase the streets' capacity in the city centers. Also, they are presenting solutions for improving air quality and urban sprawl and the need to support the regeneration of unplanned districts (Souter, 2001).

The rise and decline of the British street tramway industry are broadly contained within the single century 1860 to 1960. Tramways were still in usage for the transport systems in many European cities after the first generation of city tramways closed and returned where excluded before (Souter, 2001).

In France, although tram systems were not 'new to the world' in the 1970s, they were new to French cities after they had disappeared entirely in the 1950s–1960s. During these years, tramways were declined against the rise of motorized transport in France. So when 'modern trams' appeared in the 1970s they were a radical innovation compared to the dominant private car alternative (Turnheim and Geels, 2019). The historical overview of tramway development during the last 100 years is shown in Fig. 1.

In Germany, after the 2nd World War, the roads of the cities were totally destroyed, and tramways were the only means of transport in the devastated cities, and they remained the primary public transport system in the cities until the early 1960s. Afterward, most German cities replaced the tramway systems with buses as part of a common trend in Western Europe. During the 1980s, what transport experts call the 'renaissance of the tramway', the replacing period ended, and tramways began to reappear again. By the 1990s, tramways had become an essential modern public transport system in the cities (Schmucki, 2010). New 'second generation' light rail projects have been successfully introduced to the cities which left their first tramway systems in Europe, Canada, and the United States. Many surviving first-generation tramways have also been found and renewed (Souter, 2001). Consequently, after the 1970s, the tramway systems became popular for the cities again, and during the 2000s, the old tramway rolling stock changed with the new ones or new light rail systems (LRT).

In 2007, the European Commission published its Green Paper 'towards a new culture for urban mobility' to promote sustainable urban mobility. According to the Paper, urban road transport's negative environmental impact is 40% of CO₂ emissions and 70% of other pollutants due to congestion. The congestion cost is estimated at 100 billion Euros per year (European Commission, 2007) (Tivadar and Heddebaut, 2017) (Chiaccchia et al., 2015). Also, the United Nations goals are set for sustainable development, and countries are trying to adapt their own goals to these (United Nations, UN, 2015).

Tramway systems are considered green solutions to decrease greenhouse gas (GHG) emissions. According to the EU25 Electricity

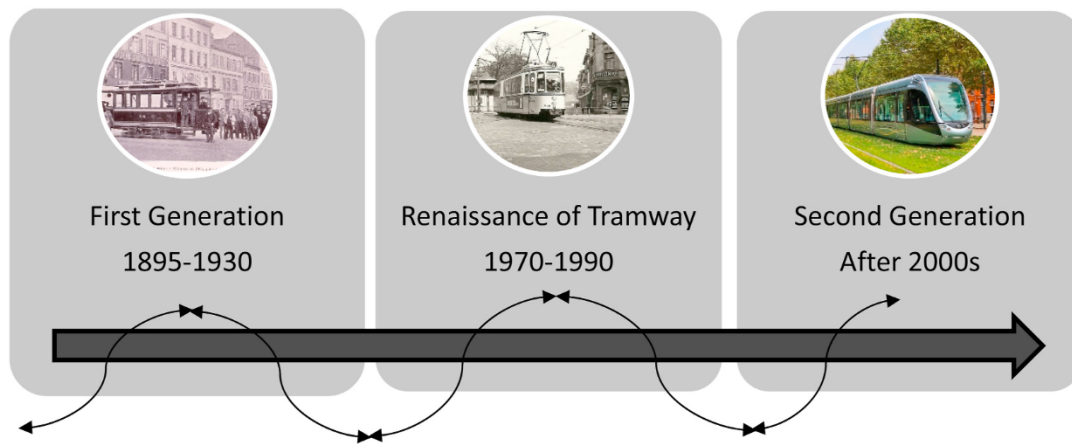


Fig. 1. Historical overview of tramway development during the last 100 years.

calculation model, the travel emission for a passenger car is 45 g CO₂/km, 15 g CO₂/km for a bus, and 5.45 g CO₂/km for a tram (Chiacchiarini et al., 2015). In Europe, each person undertakes approximately 2.7 journeys per day, mainly using private vehicles by 49% of total journeys (EC, 2011). Tramways are considered eco-sustainable, reliable, fast, and can satisfy high mobility demand levels with more than 6000 passengers/h per direction (Guerrieri, 2019).

Despite the required high public investment levels, many more cities are investing in tramway systems for public transportation regarding these figures. The average cost for the tramway infrastructure is changing between 20.0 and 23.5 M€/km (Vuchic, 2017; Alpkokin et al., 2016; Swanson and Smatlak, 2015; Guieri, 2019) where 20 M€/km in Africa, 22.5 M€/km in Europe, 23.5 M€/km in North America. Even though higher costs are required for ‘catenary-free systems’, each tram vehicle’s average cost is 2.5–3.5 M€ (Guerrieri, 2019). In a study in Italy, the construction of a new tram network costs 9 M €/km while the reconstruction of a track would cost 2.8 M €/km. (Chiacchiarini et al., 2015).

As the common trend to the new second generation of trams, an old bus line in Paris has been replaced by a modern tramway. 444 M € investment is made for the project. According to the study results, some 12–16 M€ per year benefits are represented but could not justify the investment. The net present value of the flow of costs and benefits over 30 years with a social rate of return of 4% was still negative, at 226 and 164 M€, respectively (Prud’homme et al., 2011).

These budgets are very high for the developing countries. They are usually implementing the tramway projects by long-term loans from the local or international investment banks. Such as Casablanca Tramway upgraded the infrastructure and modernized the city of Morocco by the World Bank recommendations and French institutions supports. Moroccan authorities preferred tramways because they seemed to fit better with the aspired image of ‘world class’ and Western modernity. However, the public agency Casa Transports, jointly formed out of local and central state agencies in 2009, compensates for the losses that the tramway generates. Each tramway journey receives subsidies at the level of 40% (Beier, 2020).

Trams ensure the improvement of urban mobility and air quality as well as the creation of more livable, sustainable and modern cities. They are accepted as the symbol of modernity since the 2000s and many developing cities want to construct tram systems. Developed countries have mostly concluded their tramway systems while developing ones are trying to find some useful models for the investments. The limited budgets and the subsidies for operation are critical decision criteria for investment. The public deficit is occurring mainly from the tramways’ operation period and to pay back the initial investment. So, some cities tried to find a solution to decrease the initial investments accordingly to decrease the loan payments and thought to use the old trams discarded

in the stockyards. The first implementation is in Gaziantep, Turkey, in 2011. These old trams were exported from Frankfurt, Germany, then renovated and put into service in Gaziantep. Some other cities followed this idea, such as Alexandria in 2015 (Christeller, 2019), Sofia in 2017 (Rail Railway pro, 2017), and Ukrainian Cities in 2018 (Zasiadko, 2019). Alexandria modernized and re-painted, in red and blue-white, some of the DUEWAG GT6 trams and they are now in service. In Sofia, 10 s-hand trams compatible with Sofia’s Iskar tram depot were contracted with an estimated value of 395,000 levs (202,000 euros). Five new trams also contracted for Swing, from Pesa, for EUR 8.5 million in 2016. Eighty-four of second-hand rolling stock from European countries, still in good condition, was delivered to Ukrainian cities in 2018. It seems that using second-hand rolling stock on a limited budget could be an alternative for the investment.

3. Methodology

3.1. Case study and decision strategies

Gaziantep city in Turkey has 2.1 M inhabitants by 2020 (Turkstat, 2020) and is located on the Historical Silk Road. Gaziantep holds an essential place in the Turkish economy with its robust industrial and economic structure. Gaziantep Metropolitan Municipality (GMM) is one of the main authorities and decision-makers in the city. GMM prepared the first regional sustainable energy and climate change action plan in Turkey and led various projects to provide a higher life quality. In 2006, according to the 1st Transportation Master Plan (Gaziantep Metropolitan Municipality, GMM, 2006) results, the city’s decision-makers decided to have a railway system hoping that it will also increase the city’s vision.

A tramway line connecting the residential areas with the city center via University is planned to be constructed due to the 2006 transportation master plan (Fig. 2). This tramway line was 14.5 km long, having 18 stops and one depot-maintenance-repair facility. It has been expected that the system’s capacity will be sufficient for passenger demand in the 2025 target year. All intersections are signalized and provide priority to trams in the city center. Pre-boarding fare collection with fenced-off platforms is constructed at stops. The route is designed as an exclusive separated corridor with grooved rails separated from the general traffic through horizontal lining curbstones as the obstacles accessible only to pedestrians.

Unfortunately, the municipality did not have sufficient finance for a new light rail system. To find a solution for constructing the system, GMM modified the route and adapted decision strategies to achieve a sustainable mobility system. The first strategy was to change the system from LRT to a street tramway. The second strategy was to divide the 1st 14.5 km line into two steps, 9.5 km and 5 km. The third strategy was to

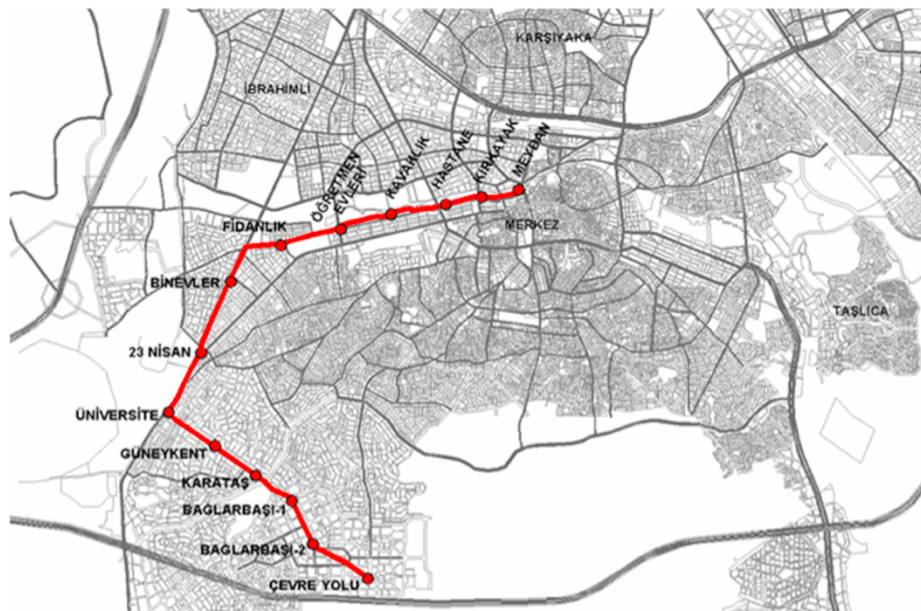


Fig. 2. Tramway line and stops.

split the tender type and to have higher competition for the offered prices. The fourth strategy was to reduce the rolling stock cost by exporting particular 15 Duewag trams and “recycled” them, the first examples in Turkey. The average cost for tram cars for similar projects constitutes 50% in Turkey (Pektaş, 2019). The second-hand trams are available in the market because of the renewing period of the European cities’ systems. After implementing these strategies, GMM could afford the construction cost for the infrastructure of the 1st tramway line by using its finances in 2009 and the next two lines in 2013 and 2014. The city exported 38 more second-hand trams from Germany and France and completely renovated them in Turkey (Tercan Hengirmen, 2011).

The city’s climate is very hot; the temperature can go up to 45 C degrees in summers and –10 C degrees in winters. The city does not have rich water resources and is in a highly affected region by climate change. It would be costly to imply the green areas for the tramway route. The decision-makers decided to remove the green areas for the tramway route and applied artificial green grass instead (Fig. 3). This



Fig. 3. The artificial green grass on the route of the tramway (World Trams and Traleibus Systems, ymtram.mashke.org, 2013). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

decision results in savings for the irrigation and drainage systems and operation and maintenance costs for the green areas.

3.2. Technical specifications and renovation of trams

In the last decade, the cities with more than 1 M population are improving their public transportation services by tramway or light rail systems in Turkey. More than eight rail systems constructed in the Turkish cities for public transport since 2004 (Table 1), and all of them used first-hand rolling stock except Gaziantep. National companies started to produce rolling stock since 2015, and some cities are choosing them for the extension of the fleet.

The first group of 15 s-hand trams was exported from Frankfurt, Germany, in 2009 and heavily renovated (Fig. 4). The trams are Duewag Pt, have 234 total passenger capacity, were produced in the 1970s, and served on the line until the 1990s in Frankfurt. The second group, ten trams, was exported in 2013. Duewag Ptb, with the same characteristics, is bought from Frankfurt, Germany, too. The trams have 28.5 m in length and 2.35 m in width. Tram type is changed from 600 V DC to catenary 750 V DC. The average tram acceleration is 1.1 m/s² and deceleration is 1.2 m/s². The third group is bought from Rouen, France, Alstom TFS2 brand and has 244 total passenger capacity. The third group was produced in 1994 and exported in 2013. Gaziantep has 53 trams by 2018 with an operational velocity of 22 km/h and a maximum velocity of 70 km/h (Pektaş, 2019). The access doors are widened for all exported trams, the floor is lowered, and all seats are renewed. The air conditioning, digital passenger information system, and free wi-fi systems are installed in the trams.

3.3. Financial sustainability assessment

The tramway line’s financial sustainability as an urban public transport authority will be assessed using the EU’s methodology (EC, 2014). The financial and economic analyses of this methodology based on cost-benefit analysis of major investments. The financial and economic analyses of this methodology based on cost-benefit analysis of major investments. The key assumptions are incremental approach for cost-benefit analysis and consolidation of cash flows for Municipality as the Transport Authority (owner of all project assets and bearing replacement cost) and the Transport Operator (using project assets against payment of a lease and bearing Operation & Maintenance costs).

Table 1
Urban rail systems in Turkish cities (Pektaş, 2019).

| City | Population (2019) | Opening Year | Number of Stops | Lenght (Km) | Brand and Number of Rolling Stock | Modal Split % |
|-----------|-------------------|--------------|-----------------|-------------|--|---------------|
| Eskişehir | 840,000 | 2004 | 61 | 45 | Bombardier (33), Skoda (14) | 14 |
| Kayseri | 1,4 M | 2009 | 55 | 37 | Ansaldo Breda (38), Bozankaya(TR) (31) | 7 |
| Antalya | 2,3 M | 2009 | 30 | 30 | CAF (14), H.Eurotem (18) | 2 |
| Samsun | 1,3 M | 2010 | 36 | 29 | Ansaldo Breda (16), CNR (5), Durmazlar(TR) (8) | 4 |
| Adana | 2,2 M | 2010 | 13 | 13,5 | H.Eurotem (36) | 1 |
| Gaziantep | 2, 1 M | 2011 | 29 | 26 | Duewag-Siemens (25), Alstom (28) | 2 |
| Konya | 2,2 M | 2015 | 42 | 56 | Skoda (72), Düevag (39) | 3 |
| Kocaeli | 1,8 M | 2017 | 11 | 7,3 | Durmazlar (TR) (12) | 2 |



Fig. 4. Renovation of second-hand trams.

Total inflows and outflows for the Municipality after the implementation of the project have been compared. The financial sustainability analysis aims to investigate whether the project can balance out its positive and negative cash flows during the reference operation period. It is usually expected that negative cash flows will be generated during project operations in the EU region. The balance between inflows and outflows must be reached either by the project revenues or by means of compensations given from the national budgets within the legal frameworks to implement a sustainable project. In this study, the operation period for ten years is assessed by financial sustainability assessment, and the effect of the second-hand trams is investigated. (EC, 2014).

4. Results and discussions

4.1. Transportation master plans figures

In the transportation master plans (TMP) of the city before tramway line, 2006 and after tramway line, 2016, the transport demand analyses are carried out based on a multi-modal network and the well known four stages transportation model, trip generation, trip distribution, modal split, traffic assignment (Salter, 1989). The percentage of travelers/passengers using a particular type of transportation is calculated by the third stage of the travel demand modelling, modal split, and

Table 2
Modal Split before and after the tramway system (2006 and 2016).

| Transportation Modes | 2006 (%) | 2016 (%) |
|----------------------------------|----------|----------|
| Pedestrian | 53,68 | 46,15 |
| Bicycle | 0,28 | 0,11 |
| Private car | 9,51 | 18,71 |
| Taxi | 0,07 | 0,43 |
| Motorcycle | 1,04 | 1,03 |
| Services | 13,43 | 16,38 |
| Municipal Bus | 2,97 | 3,12 |
| Minibus and private bus | 18,18 | 11,28 |
| Tramway (started in 2011) | – | 2,07 |
| Other (vans, tractor, truck,etc) | 0,84 | 0,72 |
| TOTAL | 100 | 100 |

shown in Table 2. The model is calibrated with data from the comprehensive traffic studies from the city. These results are useful to have an overview of the situation of the city before and after launching the tramway system. According to the results in Table 2, approximately half of the total daily trips, 53.68% and 46.15%, are pedestrians, which mean that the city has an adequate level of sustainable mobility. The average daily total trip rate per person is 1.07 in 2006 and 1.59 in 2016. The results also show that car ownership is 66 vehicles per 1000 people in 2006 and increased to 117 per 1000 people in 2016.

4.2. The challenges of the project and decision strategies

After concluding the transportation master plans, authorization should be received from the government to use the national or international loans for the cities' railway systems. The requirements concerning this authorization could not be justified, and the municipality could not use loans or credits from the development banks. After recognizing that the planned system would never be constructed under the current situations, the municipality decided to implement some strategies to construct the tramway line by its finance which will be the first rail public transport in the city.

4.2.1. Modification of the lines

Despite all opposite ideas, the municipality started to construct the infrastructure for a tramway line in September 2009 with some necessary modifications on the first planned line. The technical team divides the project into two steps, 9,5 km and 13 stations for the first step and the remaining part, the second step, which will be built after the new financial resources are found. The depot and the maintenance facility are moved to another area that stands in the middle of the first planned line but at the modified line's second station. This was a critical decision, but the city found sufficient land for the depot area and achieved the strategy successfully.

Gaziantep currently has three tram lines of 21.5 km with 29 stops. Because of the limited budgets, the city constructed these lines stage by stage. The first line started to operate in March 2011. The second stage of 5.5 km was started to build in June 2011, and operation started in September 2012. The third line of 5.5 km was also built in 2013 and

started operating in March 2014. In 2016 the length of stops was widened to 70 m for the multi-articulated trams.

4.2.2. Purchasing the second-hand trams

Purchasing second-hand trams was an ambitious decision strategy to implement. There was no known successful example before in the World or Turkey. The city was very keen on constructing such a sustainable public transport system for their community and was trying to find novel solutions for funding the first tramway line in the city. Second-hand trams would be a good solution for the achievement of the project. The result is an excellent example for developing countries. Exporting and renovating second-hand trams from Frankfurt, Germany, decreased the total project costs by reducing the rolling stock percentage to 18.83%. The cost of vehicles in a light rail system constitutes typically 50% of the similar projects in Turkey’s other cities. The second-hand twenty-five Deuwig brand trams purchased from Frankfurt are still under operation in Gaziantep. In parallel with the expansion of the rail system network, twenty-eight Alstom vehicles were added to the fleet. Some tramways are used only with a slight renovation while most of them are heavily renovated, as in Fig. 5.

4.2.3. Splitting the tender

By splitting the tender, the best prices for the market in Turkey were obtained. Several tenders have been made instead of one large turnkey tender, but very high competition occurred. It is thought by the author that there has been an advantage of the 2008 economic crisis on the prices, too. The costs for some cities with similar characteristics in Turkey had constructed rail systems for public transportation in 2011 with the overall costs compared in Table 3. According to the overall costs for similar projects in Table 3, the average investment cost is 7.5 M €/km.

The overall costs, including costs for the trams and spare parts purchase, renovation of the trams, electrification and traction system, construction of the infrastructure, construction and the depot area’s equipment, and the various works are 43.093.615,41 € for the 1st line (Table 4). The project’s electrification works included passenger control system (tourniquets), energy and power supply traction system, catenary system, communication system, signalization system, and SCADA (Supervisory Control and Data Acquisition) system. The implemented strategies opened a new era in Turkey and showed that a tramway line could be built at the cost of 4.5 M € per km. The result is approximately one-fifth of that price in the rest of Europe which is 23.5 M €/km and half of Turkey’s rest.

Additionally, if the new rolling stock would be purchased for the project with an average cost of 3 M € for each tram car, the total investment would be increased to nearly 80 M €. The second-hand trams in this project decreased the overall investment cost by 53.88% compared to the brand new rolling stock. The rolling stock consists of 18.83% by the second-hand trams while it would be 56.27% if the new trams chose.

4.3. Financial sustainability for the operation period

The tramway line is assessed by means of the city’s financial sustainability as a transport operator to understand whether the revenues

Table 3

Overall costs of the rail systems for the similar cities in Turkey in 2011.

| City | Line Length | Population | Quantity of Tram | Overall Cost | Cost per km |
|------------------|-------------|------------|------------------|---------------|-----------------|
| Antalya | 11.1 km | 1,789,295 | 14 | 120,000,000 € | 10,800,000 €/km |
| Kayseri | 17 km | 1,165,088 | 22 | 99,000,000 € | 5,800,000 €/km |
| Eskişehir | 15.7 km | 724,849 | 18 | 90,000,000 € | 5,700,000 €/km |
| Samsun | 16 km | 1,228,959 | 16 | 121,000,000 € | 7,500,000 €/km |
| Gaziantep | 9.5 km | 1,560,023 | 15 | 43,000,000 € | 4,500,000 €/km |

Table 4

Investment Cost Allocation of second-hand trams versus brand new rolling stock.

| Second-Hand Rolling Stock | | | Brand New Rolling Stock | | |
|---|-------------------|------------|---|-------------------|------------|
| Tender | Costs (€) | % | Tender | Costs (€) | % |
| Trams and Spare Parts Purchases | 3,100,000 | 7.19 | Rolling Stock | 45,000,000 | 56.27 |
| Trams Modification | 5,015,000 | 11.64 | – | – | – |
| Electrification and Traction System Construction Work | 9,479,191 | 22 | Electrification and Traction System Construction Work | 9,479,191 | 11.85 |
| Depot Storage and Workshop | 10,405,550 | 24.15 | Depot Storage and Workshop | 10,405,550 | 13.01 |
| Various Works | 9,296,853 | 21.57 | Various Works | 9,296,853 | 11.62 |
| Depot Equipment Purchase | 3,519,390 | 8.17 | Depot Equipment Purchase | 3,519,390 | 4.40 |
| Application Projects | 2,005,129 | 4.65 | Application Projects | 2,005,129 | 2.51 |
| Application Projects | 272,500 | 0.63 | Application Projects | 272,500 | 0.34 |
| TOTAL | 43,093,615 | 100 | TOTAL | 79,978,615 | 100 |

for the tramway line are sufficient for the project asset’s operation, ensuring an adequate level of service and standard of maintenance.

The tramway system is under operation since the 1st of March 2011. The passenger percentage is 2.07%. It can be concluded from the modal splits in Table 2, in 2006 and 2016, that the 2.07% for the passengers are mostly shifted from the bus and minibus passengers because of the comfort and less travel time of the separated corridor. In 2011, the daily average number of trams was 21 and increased to 41 in 2019. Accordingly, the annual total number of 3 million passengers in 2011 reached 28.4 million at the end of 2019. The passenger volumes for the operation period 2011 and 2019 are shown in Table 5.

The following incomes and outcomes of the tramway system are considered for the financial sustainability assessment:

- Initial Investment



Fig. 5. Slightly or heavily renovated trams in public transport.

Table 5
Financial sustainability for the operation period of 2011 and 2019.

| YEARS | OUTFLOWS | INFLOWS | | | NET CASH-FLOW |
|-------|---|---|---------------------------|------------------------------|---------------|
| | Operation and Management Costs (€)/Year | Advertisement from the stops and the tram cars/Year | Number of Passengers/Year | Income from Tickets (€)/Year | (€)/Year |
| 2011 | 1,526,246 | 450,000 | 3,117,112 | 623,422 | −452,824 |
| 2012 | 1,917,538 | 450,000 | 4,791,834 | 1,028,291 | −439,248 |
| 2013 | 2,444,444 | 450,000 | 9,137,363 | 2,538,156 | 543,712 |
| 2014 | 2,413,684 | 450,000 | 16,991,345 | 5,961,875 | 3,998,191 |
| 2015 | 3,115,320 | 450,000 | 15,957,352 | 5,851,029 | 3,185,709 |
| 2016 | 3,386,901 | 450,000 | 13,267,413 | 5,940,633 | 3,003,731 |
| 2017 | 2,745,795 | 450,000 | 18,387,058 | 7,483,105 | 5,187,310 |
| 2018 | 2,419,140 | 450,000 | 20,824,591 | 6,073,839 | 4,104,699 |
| 2019 | 3,006,720 | 450,000 | 28,380,612 | 8,732,496 | 6,175,776 |

The initial investment is accepted as a grant from the national government through the municipality depending on the Turkish Laws that the authorities have to provide the transportation systems for the public transport, which means that the public resources should be spent on the public's needs.

- Inflows (Electronic Fare Collection and Advertisement Revenue)

The electronic card system for the fare collection is integrated into the tramway system. 30 thousand people per day benefit from the free transfer facility launched at the end of 2015. There is no charge for the second boarding of public transport within an hour. 10% of daily passengers are disabled, over 65 years old, martyrs and veterans' relatives, and 30% are discounted passengers such as students and teachers. The ticket prices are changing between 0.20 € to 0.40 €. 2020 data for the system is not included in the assessment according to the Covid 19 pandemic situation. The advertisement revenue from the stop stations and in trams is 450,000 €/year averagely.

- Outflows (Operation costs, Management Costs, Spare parts Costs, VAT Costs, Land Cost and Depreciation Rates)

The operation and management costs are including the security, electricity, cleaning, drivers, and other costs. 2 extra trams for each brand are exported as spare parts because the producers of the tramways stopped producing spare parts for these old models. So the maintenance cost for the system is already included in the first investment. The VAT is 18% and is fully recoverable for the city under national legislation. There was no land cost for the project since the tramway line was constructed on the central median green areas, separating the main arterials and dividing the roads by two-way two directions. The depreciation rate for the rail infrastructure is 10% and for the rolling stock is 8.33%.

- Balance and Compensation

Total inflows and outflows after the implementation of the project are shown in Table 5. The project's cash flow table shows that the system is self-sufficient for the operation costs without having compensation from the legal frameworks. The ticket sale and advertisement income balance the operation and management costs, including the security, electricity, cleaning, drivers, and other costs. The system is having a positive net value and does not need any compensation after the third year, which is a contradictory situation according to EU countries. Third year is a realistic time for the acceptance of the new public transportation system by users. The system had a net cash flow of 26 M € during the nine years' operation period, which could be said that roughly 60% of the first investment is recovered.

5. Conclusion

In this study, a novel funding model is presented to achieve sustainable public transportation systems in cities with limited public resources. Some extraordinary local strategies are implemented to achieve the tramway line, such as modifying and constructing the infrastructure stage by stage, using artificial grass for the route, splitting the tender for the whole system, and exporting second-hand rolling stock instead of brand new ones, which is the most cost-effective strategy. The implemented strategies opened a new era in Turkey that a tramway line can be built at the cost of 4.5 M € per km. The result is approximately one-fifth of that price in the rest of Europe and half of the rest of Turkey. The choice of second-hand trams decreased the total investment by 53.88% for this project.

The study is an excellent example of an economical and smart implementation of a tramway project. The decision to purchase and heavily or slightly renovate and have "look-like-new" second-hand trams from Europe made free up funds for additional infrastructure development. The "recycling" of tramways is an economical option to achieve financial sustainability for the transport operator and have a greener and continuously growing tramway system for a rapidly developing city. The project's cash-flow results show that the system is self-sufficient after the 3rd year of the operation period for the operation costs without having compensation from the legal frameworks. According to some other countries, the inflow revenues balance the operational cost, which is a contradictory situation. The study shows that the cities' financial resources may be sufficient to cover these modern city transportation modes with locally adapted strategies. This funding method will be a good model for the countries planning to have rail systems for public transportation but have constraints for the overall costs. Future studies will show the effect of second-hand trams on the life cycle of the rolling stock.

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Declaration of competing interest

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