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To cite this article: Fady M A Hassouna 2023 *Environ. Res. Commun.* **5** 015001

Environmental Research Communications

PAPER

Sustainability assessment of public bus transportation sector in westbank, palestine

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OPEN ACCESS

RECEIVED
11 August 2022

REVISED
14 December 2022

ACCEPTED FOR PUBLICATION
4 January 2023

PUBLISHED
13 January 2023

Keywords: public transportation, public buses, sustainable transportation, transportation emissions, sustainability in palestine, GHG emissions, westbank

Abstract

Urban transportation is considered one of the main sources of Greenhouse Gas (GHG) emissions. Therefore, there has been an essential need to develop a sustainable transportation system that could mitigate the environmental impacts by using high-capacity transportations modes, such as public buses. This study has aimed to assess the expected sustainability of the public bus sector in Westbank, Palestine, in case of developing this sector and increasing the number of buses to meet the minimum global requirements (number of buses/1000 population), by developing prediction models for number of buses and passenger cars. Then, the expected reduction in total travelled kilometers by passenger cars has been quantified. After that, the expected reduction in GHG emissions has been determined and the effects on traffic congestion have been investigated. After analyzing the results, the study has concluded that the public bus transport sector in Palestine suffers from the lack of number of buses compared to the number of population, with a value of 0.38 bus/1000 population, which is considered one of the lowest values among the world's countries. Moreover, by increasing the number of buses to meet the minimum global requirement, there has been a significant expected reduction in CO_2 emissions (94,628.56 ton) compared to the total CO_2 emissions from other sectors in Palestine, and there has been an expected reduction in traffic congestion up to 5.84%.

1. Introduction

Urban transport has played a key role in the proper functioning of the city, satisfying the communication needs of city inhabitants, trading development, and enhancing societies in general. The rapid development of the urban areas during the last two decades has led to a continuous increasing demand on public transportation systems, more specifically the high-capacity modes of transportation such as bus and subway [1].

As a result of the rapid urbanization, more energy has been consumed by the transportation systems and therefore, several environmental problems have arisen, such as the continuous increasing of Greenhouse Gas (GHG) emissions. Due to expected shortage of fossil fuel and the urgent need to reduce GHG emissions, huge investments and intensive efforts have been made in order to develop sustainable urban transportation systems [2].

Generally, there are several different modes of urban transportation. Some of them are environment friendly and the others may contribute to environmental pollutions, noise, and life difficulties for residents due to congestions. Using new vehicles technologies and high-capacity modes of transport, such as subway and buses have been widely applied as a solution in order to reduce congestions, energy consumption, and GHG emissions [3].

In developing countries, public bus transportation system is considered one of the most preferable sustainable systems that can provide service to a large number of users due to the high capacity of this system, less GHG emissions, energy consumption compared to other alternative systems like *t*axis. However, the fuel consumption of a public transport bus depends on several different factors, such as speed, acceleration and

deceleration modes, stopping times at bus stops, and number of passengers; the public bus transportation systems is still relatively an efficient solution that is used widely in the most populated cities around the world [4].

Despite of the expected environmental benefits of the public bus services, the number of passengers has decreased in some regions, because private cars can provide a higher quality of transport. Moreover, the demand for public bus services is not constant during the day or even the week, which in turn makes problems for transport carriers because they have to decide for vehicles capacity planning [5]. Therefore, making public transportation convenient can be a good way for transportation planners to increase the ridership by applying several techniques, such as dedicated lanes, reducing travel time, and fixed predictable schedules [6].

In Palestine, due to the years of Israeli occupation and unstable socio-economic status, the public bus sector has not been developed for decades, and this can be recognized from the number of registered buses, which is around 1100 buses in Westbank, Palestine, that has a population of more than 3 million [7]. Moreover, there has been no noticeable increase in number of buses during the last 5 years, due to the lack of investments in this sector, since it is managed by few companies, which are mainly family-owned companies. Therefore, currently, there is an intensive effort made by the government in order to restructure and rehabilitate this sector and to increase the number of public buses to satisfy the demand to match the minimum local and global requirements. Therefore, this study aims to assess the expected sustainability of the public bus sector in case of developing this sector and increasing the number of buses to meet the minimum global requirements (minimum number of buses/1000 population), by quantifying the expected reduction in GHG emissions, total traveled kilometers by passenger cars, and the expected effects on traffic congestion.

The rest of the article introduces the literature review section, which includes the relevant global studies. Then the methodology section, which includes the applied processes and the developed prediction models, is introduced. After that, the data have been analyzed and the results have been presented. Finally, the article ends with a discussion of the results and the conclusions and recommendations.

2. Literature review

Despite the fact that public bus transport system is one of the main sustainable transportation systems that lead to less traffic congestion and GHG emissions, in Palestine, the future of this sector has not yet been investigated by any comprehensive study. However, many global studies have addressed the sustainability and the implications of this sector.

One of these studies has been conducted in Sweden by Ammenberg and Sofia [8] in order to assess the implications of different bus technologies. The study has introduced and developed a multiple-criteria assessment method, which consists of twelve indicators and 4 key areas. This method can be used to select the best transport or fuel technology that can be used in the future. Moreover, the study has indicated that there is a need for a smart combination of technologies that could achieve the suitability in bus transport sector.

Another study has been conducted by Nanaki *et al* [9] in order to assess the environmental impacts of nine European public bus systems. The study has investigated the factors that affect the amounts of produced GHG emissions by diesel and CNG bus fleets in the European cities under the study. As a result of this study, the environmental benefits of using these different 9 systems have been determined in terms of CO_2, CO, HC, PM, and NO_x emissions reductions.

In Japan, a study by Abe [10] has been conducted in order to quantify the potential benefits of autonomous buses. The study has provided an overview of the impacts of introducing autonomous buses on metropolitan transport systems by determining the cost of travel. The study has investigated the factors that affect the vehicle costs, the labor costs, and the stress reduction for private car users. The study has concluded that bus automation is more flexible and could benefit metropolitan residents and transit industry.

In Shenzhen, China, a study by Wang *et al* [11] has been conducted in order to assess the effects of the quality of bus service on passengers' taxi-hiring behavior based on the records from Global Position Systems (GPS) equipped *t*axis and buses. In this study, nonparametric, semiparametric, and parametric models have been developed. The study has indicated that headway, bus speed, and stoppage time have been the main factors affecting passengers' taxi-hiring behavior.

In Brazil, a study has been conducted by Leichter *et al* [12] in order to determine the expected environmental impact of the public bus transportation system based on different scenarios. For this purpose, the current and the future environmental profiles have been defined, by considering a case study of Porto Alegre public transport system. The results of the study have indicated that, although the transportation system management relies on the municipalities, the significant environmental impacts depend mainly on the national policy for using biodiesel, which may lead to an increase in CO_2 emissions up to 9.4% in 2030.

In Michigan, United States, a study by Merlin [13] has been conducted in order to investigate the cost and the environmental implications of shared *t*axis and conventional bus transit. Three different scenarios have been compared in this study. The first one is the conventional bus transit, the second scenario consists of an automated taxi system that allows only one passenger at a time, and the third scenario consists of an automated tax system with up to four passengers. The results of the study have showed that the automated shared taxi system could provide a higher level of service at lower cost.

In Europe, Iwan *et al* [14] investigated the status and attempts of improvement of electric mobility in urban freight and logistics. The study presented the potential for the development and implementation of electric vehicles in urban logistics, based on the realized activities by Electric Urban Freight and Logistics (EUFAL).

Silvestri *et al* [15] has conducted a study in order to evaluate baseline values for the introduced Key Performance Indicators (KPIs) in the electro-mobility sector. The suggested approach makes use of data acquired from different sources, such as questionnaires and surveys; comparing them with existing data in similar context to estimate KPIs baseline values.

In Rome, Italy, a study by Carrese *et al* [16] was conducted in order to analyze the accessibility of urban freight transport with electric vehicles. In this study, an aggregate approach to the freight system, transport supply, and transport demand was introduced.

However, numerous studies have addressed the sustainability of the public buses systems around the world and have determined the cost and environmental implications of these systems compared to other transit and *t*axis systems, but in Palestine this issue has not yet been addressed by any comprehensive study. Therefore, this study has been conducted in order to assess the sustainability of public buses system and to determine to what extent the environmental implications of this system are significant. In this study, two prediction models have been developed in order to determine the expected number of passenger cars and buses during the next 15 years. Next, the expected total annual traveled distances by passenger cars and buses have been collected. After that, the expected GHG emissions for passenger cars and buses have been determined based on two factors. Finally, the expected reduction in GHG emissions and the potential effects on traffic congestion have been determined considering the normal growth rate for both passenger vehicles and buses and the increase in number of buses due to the application of new government policies in order to reconstruct and develop the public bus transport sector in Westbank, Palestine. Therefore, the results could be helpful for setting the future strategies and the policies in this field, since the global results vary from region to region based on several factors such as number of bus fleets, type of fuels, and bus occupancy rate.

3. Data and Methodology

In order to perform this study, data from several sources have been acquired. The data have included the annual number of registered passenger cars for the period 2004–2020 [17], the annual number of registered buses for the subject period, the average annual traveled distance by passenger cars [18], the average annual traveled distance by buses [16], the average emissions factors for buses [19], and the average emission factors for passenger cars in Westbank, Palestine [20].

Based on the historical data for annual number of registered passenger cars and buses in Westbank, Palestine, two prediction models have been developed in order to determine the expected number of passenger cars and buses during the next 15 years. Next, the expected total annual traveled distances by passenger cars and buses have been collected. After that, the expected GHG emissions for passenger cars and buses have been determined based on two factors, considering the normal growth rate for both passenger vehicles and buses and the increase in number of buses due to the application of new government policies in order to reconstruct and develop the public bus transport sector in Westbank, Palestine. Finally, the expected reduction in GHG emissions and the potential effects on traffic congestion have been determined, as shown in figure 1.

3.1. Buses and passenger cars prediction models

Based on the collected data for number of passenger vehicles and buses for the period of (17 years) 2004–2020 in Westbank, Palestine [17], two prediction models have been developed using Exponential Smoothing method in order to determine the expected number of passenger cars and buses during the next 15 years. The computer program used in developing the two models and obtaining the forecast values for the next 15 years has been the Statistical Package for the Social Sciences (SPSS).

Exponential Smoothing is a technique used in time series in order to smooth exponentially the data over a period by assigning either exponentially increasing or decreasing weight to the data values. In this method, the recent time series data will have more effect on the predicted values than the farther back data in the prediction process [1]. Exponential Smoothing methods are mainly divided in three categories: Winters' Exponential Smoothing, Holt's Exponential Smoothing, and Simple Exponential smoothing. If data have no trend or

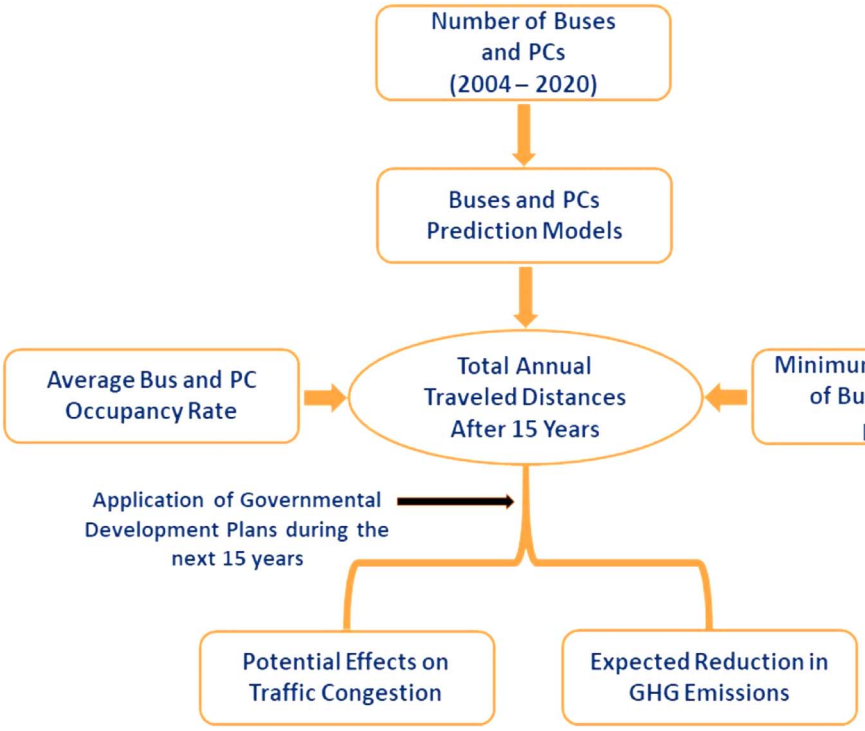

Figure 1. Methodology applied process.

seasonal patterns, then Simple Exponential Smoothing Method is appropriate; if the data exhibit a linear trend, Holt's Exponential Smoothing is appropriate; and if the data are seasonal, Winters' Exponential Smoothing is appropriate. Therefore, Holt's method was used in this study, as illustrated in equation (1) [2, 21].

$$F_{t+m} = s_t + mb_t \tag{1}$$

$$s_t = \alpha x_t + (1 - \alpha)(s_{t-1} + b_{t-1})$$

$$b_t = \beta(s_t - s_{t-1}) + (1 - \beta)b_{t-1}$$

Where F is an estimate of the x value at time t + m, s_t is the smoothed value for year t, m is a value greater than zero, b_t is the best estimated trend at time-specific year t, , α is the smoothing factor, $(0 < \alpha < 1)$, x_t is the sequence of data , and β is the trend factor, $(0 < \beta < 1)$.

3.2. Expected total annual traveled distances by passenger cars and buses

By using the predicted future number of buses and passenger cars during the next 15 years (the results of the prediction models) and the average traveled distance for passenger cars and buses in Westbank, the expected total traveled distances for the next 15 years for passenger cars and buses have been determined by assuming that the current situation will continue for the next 15 years without applying any new developing polices and strategies related to public bus transport sector.

Next, by assuming that the government restructuring and developing plans will be applied to the public transport sector, and the number of buses will be increased during the next 15 years in order to meet the minimum global requirements (minimum number of buses/1000 population), the expected total travelled distances for passenger cars and buses have been determined by considering the expected average occupancy rate (average number passengers in buses and passenger cars trips).

In order to determine the expected total travelled distances by buses in 2037 in case that the government restructuring and developing plans are applied to the public bus transport sector, the minimum number of buses required by World Bank (number of buses/1000 population) has been used [22]. After that, the increase in the total travelled distances by buses has been converted to an equivalent reduction (based on number of passengers) in total travelled distances by passenger cars using the average occupancy factors for buses and passenger cars (a bus can carry passengers more than a passenger car does), as shown in figure 2.

3.3. Expected GHG emissions by buses and passenger cars

By using the expected total annual traveled distances by passenger cars and buses during the next 15 years in case that the current situation will continue for the next 15 years without applying any new developing polices and

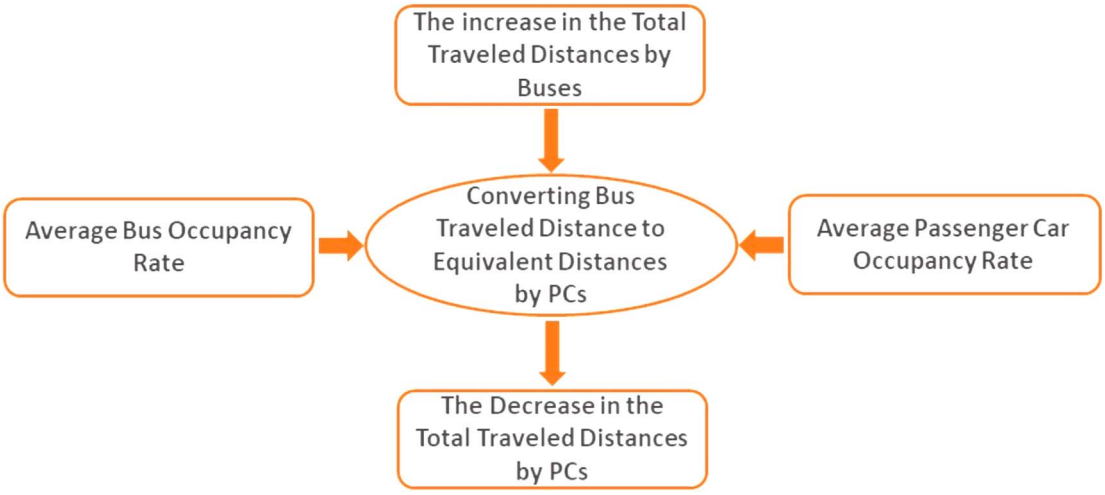

Figure 2. Converting traveled distances by buses to equivalent traveled distances by passenger cars.

the average emission factors (gm of emissions/km) for buses and passenger cars in Palestine, the total GHG emissions have been determined.

Similarly, by using the expected total annual traveled distances by passenger cars and buses during the next 15 years in case that the government restructuring and developing plans are applied to the public transport sector and the average emission factors (gm of emissions/km) for buses and passenger cars in Palestine, the expected GHG emissions have been determined. The emissions determined in this study are based on the produced amounts of CO_2, CO, HC, and NO_x gases.

3.4. Sustainability assessment of public bus transport system

Based on the difference between the expected GHG emissions in case that the current situation will continue for the next 15 years without applying any new developing polices and the case that the government restructuring and developing plans are applied to the public transport sector, the amounts of reduction in GHG emissions have been determined.

Moreover, based on the expected increase in the total annual traveled distances by buses, the expected reduction in the total annual travelled distances by passenger cars, and the average value of passenger car equivalent of buses (the impact of a bus on a road by expressing it as the number of equivalent passenger vehicles based on traffic density), the effects on the traffic congestion have been determined.

4. Data analysis and results

After analyzing the historical data of the registered passenger cars and buses, two prediction models have been developed in order to predict the number of these vehicles during the next 15 years. Next, the expected total traveled distances by these types of vehicles have been determined. After that, the expected GHG emissions have been determined based on the average emission factors (gm of emissions/km). Finally, the expected sustainability of the public bus sector has been assessed in case that the government restructuring and developing plans are applied to the public transport sector.

4.1. Buses and passenger cars prediction models

In order to determine the expected number of passenger cars and buses during the next 15 years, two prediction models have been developed by using the annual historical records acquired from the Palestinian Central Bureau of Statistics [17] for the period 2004–2020. Best-fit Holts Exponential Smoothing Models for predicting number of buses and passenger cars have been developed using SPSS computer program as illustrated in figures 3 and 4, respectively.

Based on the values of R-Squared which is a measure of how a model fits a dataset and Mean Absolute Percentage Error (MAPE) which is the sum of the individual absolute errors divided by the demand for buses prediction model, which are 0.932 (R-Squared greater than 90% indicates a good-fit model) and 3.482 (a MAPE less than 5% is considered as an indication that the forecast is acceptably accurate. A MAPE greater than 10% but less than 25% indicates low, but acceptable accuracy. Whereas, MAPE greater than 25% indicates very low

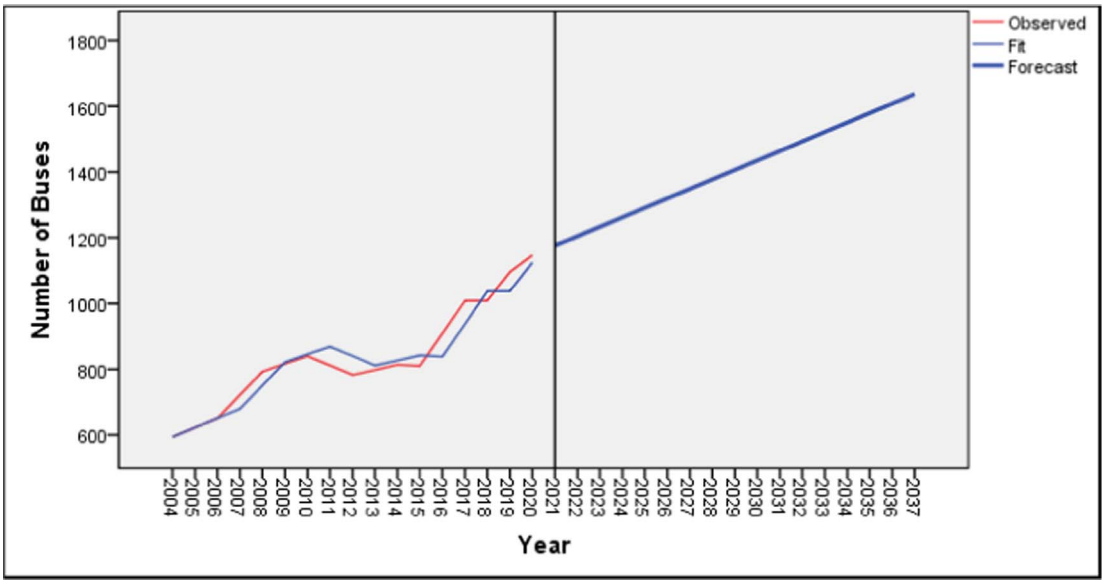

Figure 3. Observed and fit values for number of buses prediction model.

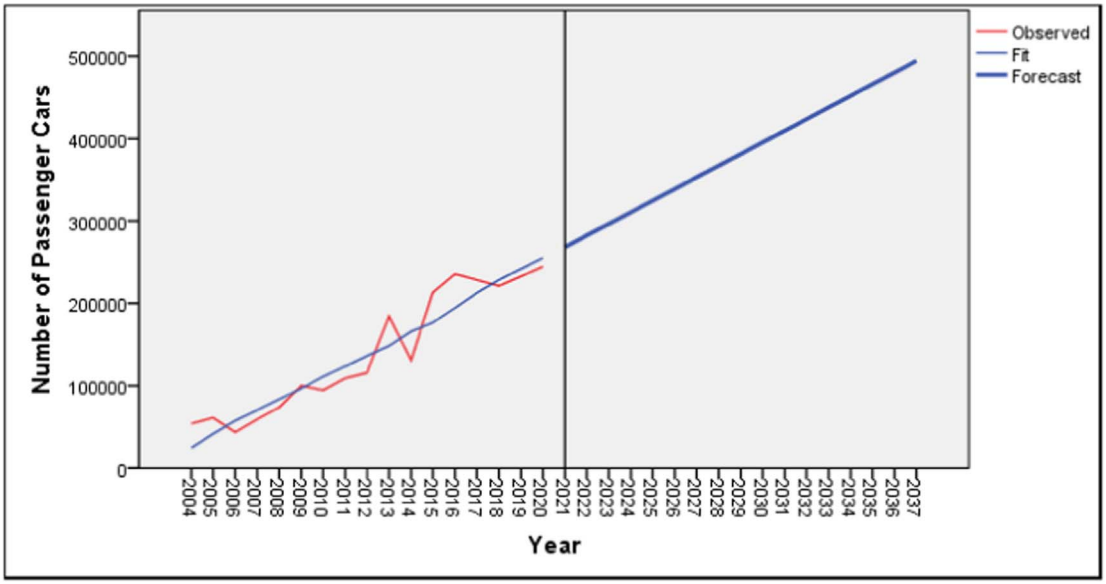

Figure 4. Observed and fit values for number of passenger cars prediction model.

accuracy, so low that the forecast is not acceptable) respectively, the developed model has showed an acceptable prediction accuracy, and therefore, it can be used without reservation, as shown in table 1.

Similarly, the passenger cars prediction model has showed an acceptable accuracy, based on the values of R-Squared and Mean Absolute Percentage Error (MAPE), which are 0.904 and 17.757, respectively, as shown in table 2. Therefore, this model can be used without reservation, as well.

In order to predict the number of passenger cars and buses after 15 years, the two developed models have been applied and the expected number of vehicles has been determined. More specifically, the expected number of buses and passenger cars in Westbank in 2037 will be around 1637 and 494492, respectively, in case that the current situation will continue for the next 15 years without applying any new developing police in public bus transport sector.

4.2. Expected total annual traveled distances by passenger cars and buses

Based on the results of the prediction models for the expected numbers of buses and passenger cars in 2037 and by using the average annual traveled distances by buses and passenger cars, which are 57100 km/bus/year [18]

Table 1. Buses prediction model fit statistics and parameters.

Model	Model fit statistics		
	R-Squared	MAE	MAPE
Holt's Model	0.932	30.622	3.482
Prediction Model Parameters			
Parameters	Estimate	SE	t
Alpha (Level)	1.0	0.278	3.603
Beta (Trend)	0.001	0.124	0.007

Table 2. Passenger cars prediction model fit statistics and parameters.

Model	Model Fit Statistics		
	R-Squared	MAE	MAPE
Holt's Model	0.904	19429.08	17.757
Prediction Model Parameters			
Parameters	Estimate	SE	t
Alpha (Level)	0.098	0.087	1.124
Beta (Trend)	0.001	0.067	0.001

Table 3. Total traveled distances by buses and passenger cars in 2037.

Case	Type of vehicles	Number of vehicles	Total traveled distances (million km/year)
Natural Increase with No Applied Plans	Buses	1637	93.47
	Passenger Cars	494492	11,966.71
Government Restructuring and Developing Plans are Applied	Buses	4920	280.93
	Passenger Cars	—	10,785.72

and 24200 km/passenger car/year [23], the expected total traveled distances by buses and passenger cars in 2037 have been determined with the expected values of 93.47 and 11,966.71 million km, assuming that the current situation will continue for the next 15 years without applying any new developing polices and strategies related to public bus transport sector.

In order to determine the expected total traveled distances by buses in 2037 in case that the government restructuring and developing plans are applied to the public bus transport sector, the minimum number of buses required by World Bank, which is 1.2 buses/1000 population, has been used [22]. The expected number of population in 2037 is around 4,100,000 [24]. Therefore, the minimum required number of buses should be around 4920 buses in 2037. This means an additional increase by 3283 buses (in addition to 1637 buses, which is the number of buses in the first case in 2037). Therefore, the expected total traveled distances by buses in 2037 will be around 280.93 million km.

Likewise, in order to determine the expected total traveled distances by passenger cars in 2037 in case that the government restructuring and developing plans are applied to the public bus transport sector, the average occupancy factors for buses and passenger cars with values of 1.7 and 10.7 passenger/vehicle, respectively [23], have been used, which means that a 1 km bus trip is equivalent to 6.3 km trips done by passenger cars. Therefore, the total traveled distances by passenger cars in 2037 should be decreased by 1180.99 million km, so the expected total traveled distances by passenger cars will be about 10,785.72 million km. The total traveled distances by passenger cars and buses in all cases are illustrated in table 3.

4.3. Expected GHG emissions by buses and passenger cars

The expected emissions by buses and passenger cars in 2037 have been determined for the two different cases. In the first case, the current situation will continue for the next 15 years without applying any new developing polices and strategies related to public bus transport sector, while, in the second case, the government restructuring and developing plans are applied to the public bus transport sector).

Table 4. Emissions factors for buses and passenger cars.

Type of Vehicles	Emissions factors			
	CO_2 (gm km)$^{-1}$	CO (gm km)$^{-1}$	NO_x (gm km)$^{-1}$	HC (gm km)$^{-1}$
Buses	478	0.933	1.447	0.091
Passenger Cars	156	1.379	0.028	0.077

By using the determined total traveled distances by buses in 2037, and the average emissions factors of CO_2, CO, NO_x, and HC for buses, which are 478 [19], 0.933, 1.447, and 0.091 gm km^{-1} [20], respectively, the total emissions by buses in 2037 have been determined.

Likewise, by using the determined total traveled distances by passenger cars in 2037, and the average emissions factors of CO_2, CO, NO_x, and HC for passenger cars, which are 156 [19], 1.379, 0.028, and 0.077 gm km^{-1} [20], respectively, as shown in table 4, the total emissions by passenger cars in 2037 have been determined, as shown in table 5. More specifically, average value for buses CO_2 emissions factors in Netherlands [19], and average emissions factor for passenger cars which was determined by American Bureau of Transportation Statistics [20] were considered in this study due to the absence of related data in Palestine.

4.4. Expected sustainability of public bus transport system

The potential environmental benefits of applying the government restructuring and developing plans to the public bus transport sector can be determined by calculating the difference between the GHG emissions before and after applying the planned development. More specifically, the expected reduction in CO2, CO, and HC emissions are 94,628.56, 1,453.68, and 73.89 ton, respectively. In other words, the expected percentages of reductions are 4.95%, 8.76%, and 7.95%, respectively, whereas, there is an expected increase in NO_x emissions by 238.19 ton. In other words, the expected percentage of the increase is about 50.74%.

As a result, a significant reduction in CO_2 emissions (94,628.56 ton) is expected compared to the CO_2 emissions from other sectors in Palestine. For example, the manufacturing industries and the construction sectors produced 83,000 ton of CO_2 emissions in 2018 [25].

In order to determine the expected effects on the traffic congestion, the passenger car equivalent for bus (coefficient that shows how many passenger cars can replace a bus in terms of traffic density, without any change in road condition or traffic flow), which is 2.5 [26] for the rolling topography of Westbank, has been used to convert all the buses trips to passenger cars trips, as shown in table 5. The results have showed that the total traveled distances in terms of passenger car equivalency will decrease from 12,200.39 to 11,488.05 million km, as shown in table 6, which is expected to lead to 5.84% reduction in traffic congestion.

Due to the old road infrastructures, narrow right of ways, and absence of the efficient urban planning for decades of Israeli occupation, it has been difficult to find any solutions or measures to solve the traffic congestion problems. Therefore, the expected reduction value in traffic congestion is very valuable and it could contribute with other measures to solve relatively the traffic congestion problems.

All the previous values were determined based on the assumption that sources of the increased number of bus passengers are the passenger cars' riders. Whereas, in some cases other sources for this increase should be considered. Therefore, it is worth mentioning that reducing this percentage by 20% due to using buses by bicyclists and other road users in addition to the passenger car riders could lead to expected reductions in CO2, CO, and HC emissions by 3.96%, 7.01%, and 6.36%, respectively. Moreover, this could lead to 4.67% reduction in traffic congestion.

5. Conclusions

The expected sustainability of the public bus transport sector has been assessed based on the government planned strategies, and by considering the global minimum required number of buses by World Bank (minimum required number of buses/1000 population). In this study, the potential reduction in GHG emissions and traffic congestion has been determined after increasing the number of buses to meet the minimum global requirement. The study has faced several limitations such as the absence of future data related to new renewable energy technologies that could be used in buses and vehicles since this technology is still widely unused in Palestine and there are still no any future clear plans related to this new technology market. Moreover, using this technology in the future in both buses and passenger cars could improve the fuel efficiency of both

Table 5. Gas emissions by buses and passenger cars in 2037.

Case	Type of Vehicles	Total Traveled Distances (million km year)$^{-1}$	CO_2 (ton)	CO (ton)	NO_x (ton)	HC (ton)
Natural Increase with No Applied Plans	Buses	93.47	44,678.66	87.21	135.25	8.51
	Passenger Cars	11,966.71	1,866,806.76	16,502.09	335.07	921.44
Government Restructuring and Developing Plans are Applied	Buses	280.93	134,284.54	262.11	406.51	25.56
	Passenger Cars	10,785.72	1,682,572.32	14,873.51	302.00	830.50

Table 6. Total traveled distances by passenger car equivalent.

Case	Type of Vehicles	Total Traveled Distances (million km year)$^{-1}$	Total Travel Distances (million km -Passenger car equivalent)	Total (million km -Passenger car equivalent)
Natural Increase with No Applied Plans	Buses	93.47	233.675	12,200.39
	Passenger Cars	11,966.71	11,966.71	
Government Restructuring and Developing Plans are Applied	Buses	280.93	702.33	
	Passenger Cars	10,785.72	10,785.72	11,488.05

buses and passenger cars and keep almost the same percentages of reductions in GHG emissions and potential benefits regardless to the values. By analyzing the results of the study, the following conclusions could be offered:

- The public bus transport sector in Palestine suffers from the lack of number of buses compared to the number of population, with a value of 0.38 bus/1000 population, which is considered one of the lowest values among world's countries in this field, due to the absence of any serious investments, since this sector is traditionally controlled and managed mainly by family-owned companies.
- Due to the old infrastructures, poor urban planning during the decades of Israeli occupation, and the rapid growth in number of vehicles during the last 10 years, it has become a big challenge to find efficient solutions and measures in order to mitigate the traffic congestion. Therefore, developing the public bus transport sector has recently arisen as a reasonable and feasible solution that could contribute with other measures to reduce the traffic congestion.
- The absence of subway and train network in Palestine due to the lack of expertise and poor investments makes the development of the public bus transport sector the most feasible measure in order to increase the passenger ridership capacity and to reduce the number of trips travelled by passenger cars and as a result, to reduce the GHG emissions.
- There is a significant expected reduction in CO_2 emissions (94,628.56 ton) compared to the total CO_2 emissions from other sectors in Palestine, such as the manufacturing industries and the construction sectors.
- The expected reduction in traffic congestion is about 5.84%, which is highly considerable in the main congested cities such as Hebron, Ramallah, and Nablus. Whereas, it has less effects on the remaining smaller cities that have less traffic congestion.
- Despite the fact that there are considerable reductions in CO_2, CO, and HC emissions with values up to 4.95%, 8.76%, and 7.95%, respectively, there is an expected increase in NO_x emissions by 50.74%, which are produced mainly by diesel engines and could react with ammonia and other compounds to form nitric acid vapor and related particles.
- By considering that 20% of the increase in number of bus riders is coming from bicyclists and other road users, the expected reductions in CO_2, CO, and HC emissions could be 3.96%, 7.01%, and 6.36%, respectively.It is recommended in the future to conduct a comprehensive study that investigates the expected effects of the bus rapid transit networks on the environment and traffic congestion in the main cities such as Nablus, Hebron, and Ramallah.
- More gas emissions, such as N_2O and CH_4, are recommended to be addressed in future works, since these gases contribute directly to GHG emissions.
- Life cycle analysis is recommended to be considered in the future work in addition to the economic and environmental issues at the operational level in order to present the whole picture, that could not be addressed in this study due to the lack of data.

Data availability statement

All data that support the findings of this study are included within the article (and any supplementary files).

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