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Urban Freight Transport Electrification in Westbank, Palestine: Environmental and Economic Benefits

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Abstract: Recently, due to the industrial and e-commerce revolution, the freight transport sector has grown rapidly and has become one of the key factors for economic development. Coupled with the growth of this sector, significant energy and environmental problems have arisen. Therefore, a huge effort has been made around the world in order to develop some solutions that could mitigate these problems. One of these promising solutions is electrifying the urban freight transport sector including the trucks and freight commercial vehicles fleets. In Palestine, as in other developing countries, the implications of this solution are still unquantified and the efficiency of the application is unpredicted. Therefore, this has necessitated a comprehensive study that considers all the relevant factors, such as the source of the electricity (renewable energy, oils, natural gas, etc.), fuel rates, and electricity rates. In this study, a prediction model has been developed using the historical data for the number of trucks and freight commercial vehicles over the period 2006–2020. Next, the total travelled kilometers, the total fuel consumption, and the total electricity consumption by the urban freight transport sector have been determined based on two scenarios (5% and 20% penetration of electric freight transport modes) during the next 10 years. Finally, the amounts of reduction in GHG emissions and the energy cost have been determined. The results have shown a significant reduction in the amount of GHG emission during the next 10 years by electrifying 20% of the freight transport sector in Westbank, Palestine. Moreover, an annual reduction of 66 million U.S $ could be achieved in total energy costs in this region.

Keywords: sustainability; sustainable urban freight transport; electric trucks; sustainability in Palestine; Westbank Palestine; truck electrification; environmental impacts

Citation: Hassouna, F.M.A. Urban Freight Transport Electrification in Westbank, Palestine: Environmental and Economic Benefits. *Energies* **2022**, *15*, 4058. https://doi.org/10.3390/en15114058

Academic Editors: Elżbieta Macioszek and Maria Cieśla

Received: 26 April 2022
Accepted: 10 May 2022
Published: 1 June 2022

1. Introduction

During the last four decades, transportation systems have significantly contributed to the socio-economic development of countries around the world, and the extensive global road network serves a key role in the facilitation of moving people and goods. Freight transport by trucking has been the backbone of the industrial revolution by facilitating access to raw materials and goods, comprising the main distribution channels of export and import. However, the freight and passenger transport sector has been considered as one of the main key roles of industrial and economic development, but it is also one of the main carbon dioxide (CO_2) pollutant source and, more specifically, it is responsible for nearly a quarter of the global CO_2 emissions [1]. For example, in 2017, the transport sector was responsible for about 27% of the European Union's (EU) total greenhouse gas (GHG) emissions and light commercial vehicles produced around 9% of the transport GHG emissions [2]. Whereas, in 2019, in China, the nitric oxide (NOx) emissions of heavy-duty trucks made up more than 74% of the total vehicle emissions, and their particulate matter (PM) emissions exceeded 52.4% of total vehicle emissions [3].

Freight and passenger transport sectors, which were responsible for 19% of the total global energy consumption in 2013, have been considered major energy consumers. These sectors are expected to account for 97% of the increasing amount in total fossil fuel consumption between 2013 and 2030. Due to the huge amounts of energy consumption and GHG

emissions of the transport sector, especially the freight trucking modes, which produce emissions per unit much higher than private and passenger vehicles, several environmental and socio-economic problems have arisen. Therefore, reducing fuel consumption in this sector has become one of the highest priorities for all countries around the world [4].

Transport electrification is one of the promising solutions with the greatest potential for the sustainability of transport systems. Transport electrification covers a wide range of modes and processes, including battery electric vehicles (BEVs), fuel cell-powered vehicles and hybrid vehicles, which are typically composed of one of the mentioned technologies combined with conventional internal combustion engines [5].

During the last decade, electric vehicles (EVs) have been increasing their market penetration, and the passenger cars category has attracted most of the user's attention, offering a greater number of models from various manufacturers. Similar to passenger cars, the commercial vehicles category has shown an increasing trend in terms of newly registered vehicles [2]. In Norway, an ambitious transport plan has been set for the introduction of zero-emission commercial freight vehicles to fulfil CO_2 reduction objectives by 2030. By applying this plan, in 2025, all new lighter vans are expected to be zero-emission vehicles. By 2030, all new heavy vans and 50% of new heavy freight vehicles are expected to be zero-emission [6].

Despite the high ownership cost of electric freight vehicles and trucks, the expected saving in the operating cost and GHG emissions is relatively significant over time based on the region. The indirect CO_2 emissions from commercial vehicles and trucks vary significantly among regions, based on the source of electricity. However, commercial vehicles powered by hydropower-based electricity could significantly decrease CO_2 emissions. Vehicles powered by coal-based electricity could increase CO_2 emissions by 7.3 percent, compared to internal combustion engine vehicles (ICEV) [7]. Furthermore, the U.S Department of Energy has expected a decrease in the battery pack cost, so the expected new cost will be around \$125/kWh in the short term and about \$100/kWh in the long term [8], and this could decrease the ownership cost of the commercial vehicles and trucks significantly.

In Palestine, electric freight commercial vehicles have penetrated the market two years ago. Electric trucking, which is a very promising freight transport mode, is expected to penetrate the market very soon. Therefore, there is an urgent need to determine the expected economic and environmental implications of using electric trucks and freight commercial vehicles, which is highly required for setting future transportation plans and policies. For this purpose, this study has been conducted in Westbank, Palestine, which is composed of 11 main cities, and the expected economic and environmental implications of using electric trucks and freight commercial vehicles during the next 10 years have been determined based on the relevant factors such as source of the electricity (renewable energy, coal, natural gas, etc.), fuel rate, and electricity rate. This study is the first study that addresses the implications of using electric trucks in Palestine. Moreover, it takes into consideration the electricity mix in Palestine which is different from other regions around the world and, therefore, the results of the other regions are inapplicable in Palestine.

The rest of the paper presents the literature review that includes the relevant global studies. Then it presents the methods and the applied processes, including the developed model, which is followed by the analysis of the data and results for different scenarios. Finally, the paper ends with a discussion of the results and the conclusions of the study.

2. Literature Review

Although several vehicle manufacturers have intended to start producing electric trucks during the last decade, few of these manufacturers have recently opened sales for different series of heavy electric trucks, like Volvo. The majority of the manufacturers have focused on producing electric freight commercial vehicles. Thus, very few studies have addressed the economic and environmental implications of using electric trucks and freight commercial vehicles around the world.

One of these studies has been conducted in Norway by Hovi et al. [6]. The study has investigated the experiences with electric trucks, focusing on various performance aspects such as technology, costs of ownership, and socio-economic costs compared to internal combustion engine trucks. The study has shown that the results of the experiences have been positive. Moreover, electric trucks could replace internal combustion engine trucks to a specific extent. Based on costs, the electric truck market could compete with the internal combustion engine trucks when technology reaches mass production.

In Switzerland and Finland, a study has been conducted by Liimatainen et al. [9] in order to develop a new methodology for estimating the potential of electric trucks. The continuous road freight survey data have been analyzed. The results of the study have indicated that in both countries the potential of electric trucks varies widely between commodities. More specifically, medium-duty rigid trucks have been expected to have a high potential for electrification. Moreover, electric trucks lead to an increase in electricity consumption by around 1–3%, which in turn, leads to a large impact on the electricity grid stations and logistics centers.

In China, a study has been conducted by Song et al. [10] in order to develop a method for extending the battery working time of electric refrigerated trucks. For this purpose, a simulation of the working conditions of these trucks has been performed for a whole day, and a genetic algorithm has been used to optimize the operating parameters of the trucks. The results of the study have indicated that after optimization, the total expected energy consumption of trucks could be reduced by 0.5 kW, and as a result, the operating cost will be reduced as well.

Another study has been conducted in China by Sun et al. [11] in order to determine the economic implications of using urban electric commercial vehicles. The study has used real-world driving cycle data in order to simulate the electric consumption of freight commercial vehicles. Different operating parameters have been selected, including, transmission, vehicle body, batteries, and tires. The collected data have been analyzed using Advanced Vehicle Simulator Software. By combining both the optimization range of the parameters and coefficients of electricity saving, the results have shown a promising economic benefit.

In France, a novel methodology for reducing the total cost of plug-in hybrid electric truck ownership has been introduced by a study conducted by Huin et al. [12]. In this study, the best powertrain component sizes have been determined with optimal energy management, and a cost model of the truck has been developed by considering the variation in costs between conventional diesel trucks and electric trucks. The results of the study have expected a reduction in operating costs by 38%. Whereas, the expected reduction in CO_2 has been about 38% compared to conventional diesel trucks.

An economic feasibility study for using electric trucks has been conducted in the United States by Vijayagopal and Rousseau [8]. The study has determined the total ownership cost for medium and heavy-duty electric trucks with respect to the cost of fuels and batteries. The results of this study have concluded that the light HD trucks had the highest economic benefits. Whereas, the class 8 long haul trucks had the lowest economic benefits in the case of truck electrification. In Sicily, Italy, a study conducted by Pinchasik et al. [6] investigated the use of electric vehicles in freight distribution. The study has addressed the integration of electric commercial vehicles in logistics systems. The results have indicated that the use of aluminum for producing electric vehicles has made it possible to decrease frames' overall weight, which allows installing an additional upper body. Moreover, the batteries made from lithium polymers lead to a nominal range compared to their segment.

A study by Iwan et al. [13] investigated the potential for the implementation and development of electric vehicles in city logistics, based on the activities recognized by the Electric urban freight and logistics (EUFAL) project, realized under the ERA-NET Cofund Electric Mobility Europe. The study indicated that 72% of participating fleet operators considered electric vans and trucks viable alternatives to their combustion engine vans and trucks.

An innovative approach to estimate the baseline values for a set of Key Performance Indicators (KPIs) in the Electro-Mobility Sector was introduced by Silvestri et al. [14] The proposed approach makes use of data retrieved from different suitable sources, such as surveys, questionnaires, etc.

In Rome, Italy, a study by Carrese et al. [15] introduced an aggregate approach to the freight system, transport demand and supply, to support the design of a distribution system based on electric vehicles using an accessibility indicator that considers the supply of facilities, vehicle performances, and freight demand patterns.

Generally, many studies have been conducted around the world, especially in Europe and China in order to investigate the expected implications of using electric freight transport modes. Some of these studies addressed the electric commercial freight vehicles, while other studies focused on the electric light and heavy-duty trucks, based on the sources of electricity in each of these regions.

In Palestine, no studies have investigated electrifying freight transport such as trucks and freight commercial vehicles, since this market is still very emerging. Therefore, it is highly required to quantify the expected implications of using these modes of transport based on the relevant factors, so that the results can be used for setting the long-term transport strategies.

3. Data and Methodology

In this study, different types of data have been acquired from several sources. These data have included the total number of commercial vehicles and trucks for the period 2006–2020, the total travelled kilometers by commercial vehicles in 2014 (the only available governmental data), the fuel consumption rate of freight commercial vehicles and trucks, the percentages of the different sources of electricity in Palestine (natural gas, diesel, coal, wind and solar-based electricity), the average GHG emissions produces by each source of electricity, the electricity rates in Palestine for the period 2009–2020, and the fuel rates in Palestine for the period 1999–2020.

Based on the collected data, a prediction model has been developed in order to determine the expected number of commercial vehicles and trucks in Westbank, Palestine during the next 10 years. Moreover, the expected total travelled kilometers, the fuel and electricity consumptions, and the expected GHG emissions by freight commercial vehicles and trucks have been determined, based on two scenarios: scenario 1 with 5% penetration for electric commercial vehicles and trucks in case the application of the governmental sustainable transportation plan faces unexpected obstruction and scenario 2 with 20% penetration for electric commercial vehicles and trucks in case of the firm application of the new sustainable strategy in the freight transport sector. As a result, the economic and environmental implications of applying the two scenarios have been determined, as illustrated in Figure 1.

3.1. Freight Commercial Vehicles and Trucks Prediction Model

Based on the total annual number of registered commercial vehicles and trucks for a period of 15 years (2006–2020) in Westbank, Palestine, a prediction model has been developed using a Statistical Package for the Social Sciences (SPSS) in order to determine the expected number of commercial vehicles and trucks during the next 10 years. For this purpose, an exponential smoothing model has been developed, since it is the most appropriate model for this type and amount of data (annual data for 15 years). For example, ARIMA prediction models require annual data for more than 24 years in order to get a reasonable accuracy [16], which is not applicable in this study.

The basic of the exponential smoothing model is to smooth the original time series of data and use the smoothed series in predicting the expected future values of data. In this method, the recent data in the time series have a greater effect on the predicted future values than the more distant data in this series. Therefore, the present observations have the highest forecast weight. Mainly, there are three types of Exponential Smoothing

Models: Simple Smoothing, Holt's Exponential Smoothing, and Winters' Exponential Smoothing [17]. In this study, Holt's Exponential Smoothing method has been used, as presented in Equation (1).

$$F_{t+m} = s_t + mb_t \quad (1)$$

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

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

where β is the trend factor, $(0 < \beta < 1)$, α is the factor of smoothing, $(0 < \alpha < 1)$, F is the x estimated value for time t + m, b_t is the best estimate of trend for specific year t, x_t is data sequence, s_t is the smoothed value for t year, and $m > 0$.

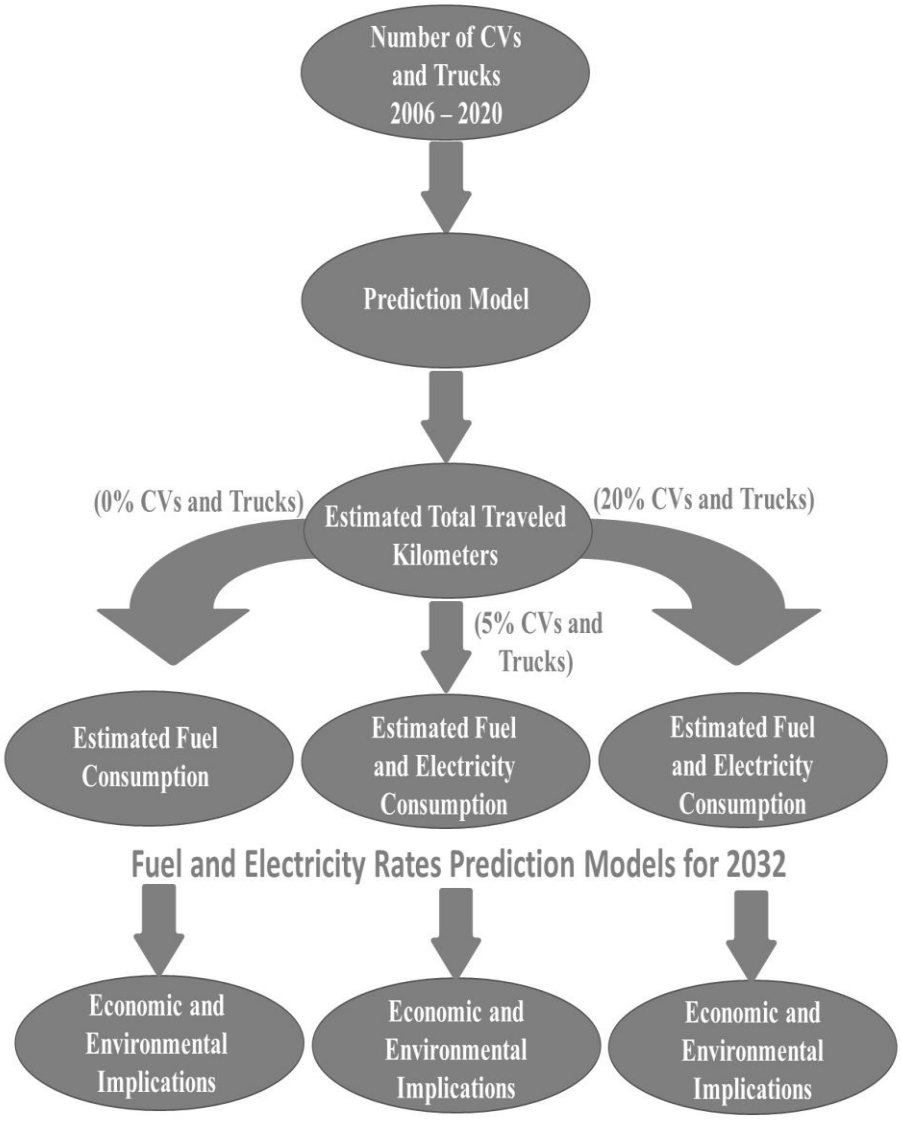

Figure 1. The methodology and processing steps that were applied in this study.

3.2. Total Travelled Kilometers by Freight Commercial Vehicles and Trucks

By using the total predicted number of freight vehicles and trucks in 2032 (the result of the prediction model) and the total number of these subject vehicles in 2014, the percentage of the increase in a number of these vehicles has been calculated. Next, the expected number of travelled kilometers by commercial vehicles and trucks in 2032 has been determined based on the total annual travelled kilometers in 2014 (which is the only available data) and the percentage of the increase in a number of commercial vehicles and trucks for the period 2014–2032.

3.3. Expected Total Electricity and Fuel Consumption by Freight Commercial Vehicles and Trucks

Based on the predicted total travelled kilometers by freight commercial vehicles and trucks in 2032 and the average fuel consumption rate (l/km) for freight transport modes in Palestine, the total amount of fuel consumption has been calculated. Similarly, based on the predicted total travelled kilometers by commercial vehicles and trucks in Palestine in 2032, and the electricity consumption rate by the electric freight commercial vehicles and trucks (kWh/km), the total expected amount of the electricity consumption by electric freight commercial vehicles and trucks in 2032 has been determined. The calculations have been done based on two different scenarios. In the first scenario (scenario 1), the percentage of the electric freight commercial vehicles and trucks has been assumed to be 5% of the total number of freight commercial vehicles and trucks (95% conventional freight commercial vehicles and trucks). On the other hand, in the second scenario (scenario 2), the percentage of electric commercial vehicles and trucks has been assumed to be 20% of the total number of freight commercial vehicles and trucks (80% conventional freight commercial vehicles and trucks).

3.4. Expected GHG Emissions by Freight Commercial Vehicles and Trucks

By considering the two proposed scenarios and based on the predicted total fuel consumption by conventional freight commercial vehicles and trucks in 2030 and the average amounts of GHG emissions produced by fuel combustion (mass of emissions per litre of fuel gm/L) in engines of these vehicles, the expected total amounts of CO_2, N_2O, and CH_4 emissions have been determined. Similarly, by using the total amount of electricity consumed by electric freight commercial vehicles and trucks and the average amount of GHG emissions that are produced in the electric power plants in order to generate the required amount of electricity (gm/kWh) based on the source of electricity in Palestine (oil, coal, natural gas, and others), the expected total amounts of CO_2, N_2O, and CH_4 emissions have been determined.

3.5. Expected Energy Cost Consumed by Freight Commercial Vehicles and Trucks

In order to determine the electricity rate (U.S $/kWh) in 2032, a prediction model has been developed using the exponential smoothing method and based on the electricity rate data for the period 2009–2020. Next, the total cost of the consumed electricity by electric freight commercial vehicles and trucks in 2032 has been determined based on the predicted electricity rate and the total expected amount of consumed electricity by electric freight commercial vehicles and trucks in 2032.

Similarly, a prediction model has been developed in order to determine the fuel rate (U.S $/l) using the exponential smoothing method and based on the fuel rates data for the period 1999–2020. Next, the total cost of the consumed fuel by conventional freight commercial vehicles and trucks in 2032 has been determined based on the predicted fuel rate and the total expected amount of consumed fuel by freight conventional commercial vehicles and trucks in 2032.

3.6. Environmental and Economic Implications of Using Electric Freight Commercial Vehicles and Trucks

By comparing the total expected produced amounts of CO_2, N_2O, and CH_4 by electric and conventional freight commercial vehicles in 2032 for the two scenarios (scenario 1 with 5% electric commercial vehicles and trucks and scenario 2 with 20% electric commercial vehicles and trucks) with the control scenario (0% electric freight commercial vehicles and trucks), the amount of reduction in GHG emissions by the two scenarios could be estimated.

Similarly, by comparing the total expected cost of fuel and electricity consumed by electric and conventional freight commercial vehicles in 2030 for the two scenarios (scenario 1 and 2) with the control scenario (0% electric commercial vehicles and trucks), the amounts of reduction in energy cost in 2032, by the two scenarios, could be estimated.

In this study, several constraints were faced during the data collection and data analysis steps. One of these constraints was the difficulty in quantifying the extent of the development that could be achieved in the efficiency of fuel and electricity consumption by conventional and electric trucks during the next 10 years due to the newly used technologies in engine and battery manufacturing. Since the efficiency of both conventional and electric vehicles is expected to be improved to specific extents, simultaneously, the difference in the economic and environmental impacts of both could maintain the same level. Therefore, future development was ignored in this study.

4. Analysis and Discussion

By analyzing the data related to the annual number of registered freight commercial vehicles and trucks, fuel rates, electricity rates, source of electricity (coal, natural, renewable energy, etc.), and average annual travelled kilometres by freight commercial vehicles and trucks in Westbank, Palestine, a prediction model for the number of commercial vehicles and trucks has been developed. Finally, future energy and environmental implications of electrifying the urban freight transport sector have been determined based on the two proposed scenarios.

4.1. Freight Commercial Vehicles and Trucks Prediction Model

Based on the number of commercial vehicles and trucks data for a period of 15 years (2006–2020), acquired from the Palestinian Central Bureau of Statistics [18], a prediction model has been developed using Holt's Exponential Smoothing method, in order to determine the expected number of these subject vehicles during the next 10 years (2032), which is required to calculate the expected total travelled kilometres by these vehicles. In this study, the SPSS software has been used for developing the best-fit prediction model, as illustrated in Figure 2.

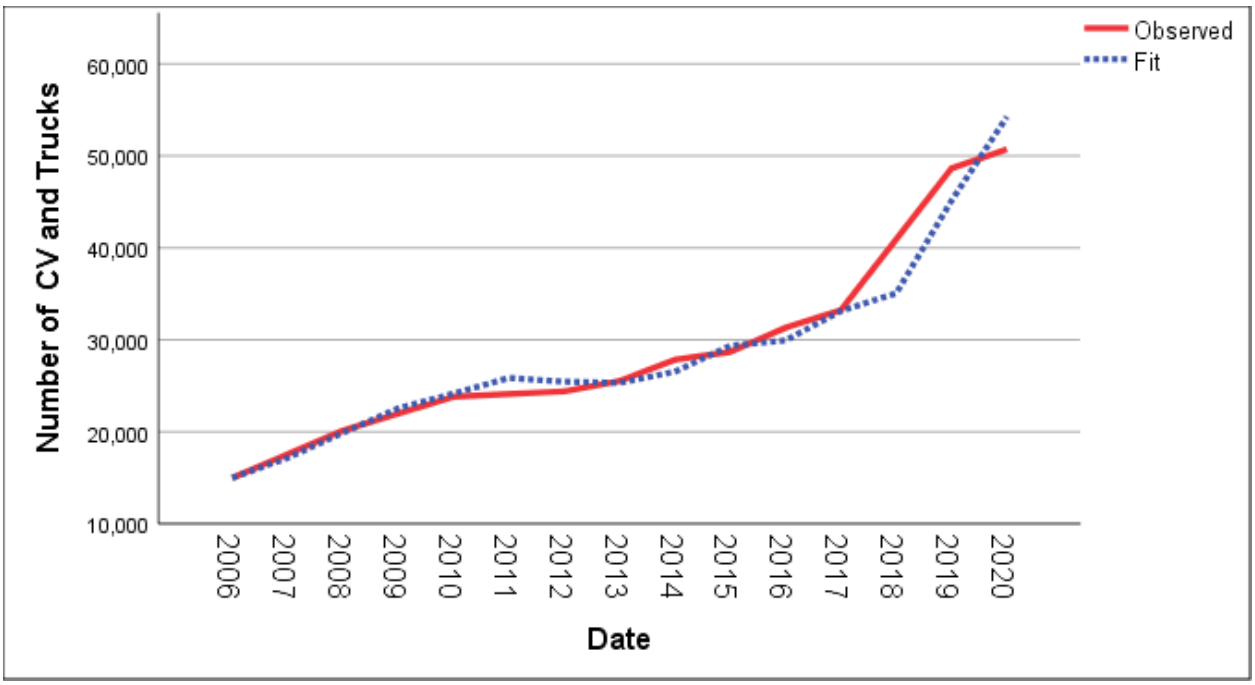

Figure 2. Observed and fit values of the developed prediction model.

The results of the developed model have shown a reasonable prediction accuracy and the model can be used without reservations, based on the values of R-Squared and Absolute Percentage Error (MAPE), which are 0.956 and 4.021, respectively. As shown in Table 1. By applying the developed prediction model, the results have shown that the

expected number of freight commercial vehicles and trucks at the end of 2022 and 2032 will be 59,083 and 100,942, respectively.

Table 1. Statistics and parameters of developed model.

Model	Model Fit Statistics		
	R-Squared	MAPE	MAE
Holt's Model	0.956	4.021	1398.706
Prediction Model Parameters			
Parameters	Estimate	SE	t
Alpha (Level)	1.0	0.482	2.076
Beta (Trend)	0.4	0.455	0.880

4.2. Total Travelled Kilometers by Freight Commercial Vehicles and Trucks

Based on the statistics of transportation in Westbank in 2014 (the only available governmental data for total travelled kilometers), the total travelled kilometers by freight commercial vehicles and trucks have been 1425 million km, whereas, the total number of commercial vehicles and trucks has been 26,532 [19].

By comparing the predicted number of commercial vehicles and trucks in 2022 and 2032 (using the developed prediction model) with the one in 2014, the increases in the number of commercial vehicles and trucks have been 112.2% and 262.6% in 2022 and 2032, respectively. Finally, by using the total travelled kilometers in 2014 and the same percentages of increases in the number of vehicles, the expected total travelled kilometers by commercial vehicles and trucks in 2022 and 2032 could be estimated. These values are 3023.9 and 5167.1 million km, respectively.

4.3. Expected Total Electricity and Fuel Consumption by Commercial Vehicles and Trucks

Despite the fact that the electric vehicles market in Palestine is still an emerging market, due to the socio-economic factors and the restrictions on vehicle import by the Israeli occupation during the last 20 years, the future of the electric vehicles market is very promising due to the recent government policies that offer a tax reduction for this type of vehicles. Moreover, the target of these new policies is to have 100% electric vehicle penetration for all imported brand-new vehicles during the next 13 years. As a result, there is an expected revolution in the freight transport market due to the electrification technology.

In order to determine the amount of fuel and electricity consumption by vehicles in 2022, it should be noticed that the percentage of the electrification in freight transport could be ignored (less than 1%). Therefore, 0% electric and 100% conventional commercial vehicles and trucks can be considered. The total diesel fuel consumption can be determined based on the predicted total travelled kilometers by commercial vehicles and trucks (3023.9 million km) and the average fuel consumption (km/L) in Palestine for freight transport vehicles (6.2 km/L) [19].

In 2032, in order to determine the total fuel and electric consumption by the freight transport sector, the two proposed scenarios (5% and 20% electrification) have been considered in addition to the control scenario (scenario 0), which has been used for estimating the implications of these scenarios. The total diesel fuel consumption can be determined based on the predicted total travelled kilometers by freight transport modes (3023.9 million km) in 2032 and the average fuel consumption (km/L) in Palestine for the urban freight transport modes (6.2 Km/L) [19]. The total electricity consumption can be determined based on the predicted total travelled kilometers by freight transport modes (3023.9 million km) and the average electricity consumption rate by the electric freight modes. Since the freight transport sector in Palestine depends mainly on the commercial and light trucks, medium-duty trucks (high usage), and heavy-duty trucks, and in absence of any clear governmental details about the percentage of each, the medium-duty Volvo FL Electric Truck with GCW

of 16.7 tones and 300 km range with a battery capacity of 395 kWh has been used in order to determine the expected total electricity consumption, as shown in Table 2.

Table 2. Expected total fuel and electricity consumption by freight transport sector in Westbank, Palestine.

Year	Electrification (%)	Total Traveled Kilometers (Million km)	Average Diesel Fuel Consumption Rate (km/L)	Average Electricity Consumption Rate (km/kWh)	Total Diesel Fuel Consumption (Million L)	Total Electricity Consumption (GWh)
2022	0%	3023.9	6.2	-	487.7	-
2032	Control Scenario (0%)	5167.1	6.2	-	833.4	-
	Scenario 1 (5%)	5167.1	6.2	0.76	791.7	339.9
	Scenario 2 (20%)	5167.1	6.2	0.76	666.7	1359.8

4.4. Expected GHG Emissions by Freight Commercial Vehicles and Trucks

The expected GHG emissions produced by freight modes of transportation in 2022 (calculated based on the amounts of CO_2, N_2O, and CH_4) have been determined based on the predicted total annual fuel consumption (487.7 million L) and the average GHG emissions produced by diesel combustion engines in conventional freight transport vehicles in Palestine (2976 gm/L of CO_2-equivalent) [15].

Similarly, the expected GHG emissions by conventional freight modes of transport in 2032 have been determined for the two scenarios, based on the total fuel consumption and the average amounts of GHG emissions produced by diesel combustion engines in freight transport vehicles in Palestine. The expected GHG emissions by electric freight modes of transport have been determined based on the total electricity consumption and the average amounts of GHG emissions produced in power plants (gm of CO_2-eq per MWh)/in order to provide the required amounts of electricity, which is about 2965.8 gm of CO_2-eq/MWh for the source of electricity in Westbank (2% renewable energy, 21% coal, 35% natural gas, 42% oil-based electricity) [16], as shown in Table 3.

Table 3. Total amounts of GHG emissions produced by conventional and electric freight transportation modes.

Year	Electrification (%)	Fuel-Based GHG Emissions (Tons of CO_2-eq)	Electricity-Based GHG Emissions (Tons of CO_2-eq)	Total GHG Emissions (Tons of CO_2-eq)
2022	0%	1,451,395.2	-	1,451,395.2
2032	0%	2,480,198.4	-	2,480,198.4
	5%	2,356,099.2	1008.1	2,357,107.3
	20%	1,984,099.2	4032.9	1,988,132.1

4.5. Expected Cost of Energy Consumed by Commercial Vehicles and Trucks

Based on the total predicted fuel consumption by freight modes of transportation in 2022 (487.7 million L), and the average diesel fuel rate in 2022, which is about 1.86$ [20], the total expected energy cost by freight transport modes in 2022 has been determined.

Similarly, by considering scenarios 1 and 2, and based on the total predicted fuel and electricity consumption by freight modes of transportation in 2032 and the predicted diesel fuel rate (1.7 U.S $/L) and electricity rate (0.16 U.S $/kWh) for the subject year, which have been predicted in a study by Hassouna and Al-Sahili [7], the total electricity and fuel consumption by freight transport modes have been determined, as illustrated in Table 4.

Table 4. Total energy costs for freight transport modes in Westbank, Palestine.

Year	Electrification (%)	Total Diesel Fuel Cost (Million U.S $)	Total Electricity Cost (Million U.S $)	Total Energy Cost (Million U.S $)
2022	0%	907.1	-	907.1
2032	0%	1416.8	-	1416.8
	5%	1346.0	54.4	1400.4
	20%	1133.4	217.6	1350.8

4.6. Environmental and Economic Implications of Using Electric Freight Commercial Vehicles and Trucks

The results of the analysis in Tables 3 and 4 show that the total GHG emission in 2032 for scenario 0 (0% electrification), scenario 1 (5% electrification), and scenario 2 (20% electrification) have been 2.48, 2.36, and 1.99 million tons of CO_2-equivalent, respectively. In other words, there could be an insignificant reduction in GHG emissions (4.84%) by using 5% freight modes electrification. On the other hand, there could be a significant reduction in GHG emissions (19.8%) by using 20% freight modes electrification.

Similarly, the results show that the total energy costs in 2032 for scenario 0, scenario 1, and scenario 2 have been 1416.8, 1400.4, and 1350.8 million U.S $, respectively. In other words, 16.4 million U.S $ could be saved by using 5% freight modes electrification. 66 million U.S $ could be saved by using 20% freight modes electrification, which is almost equal to the GDP from the transportation sector in Palestine for the last quarter of 2021

As a result, the partial replacement of the conventional freight modes of transport with the electric ones during the next 10 years could save a considerable amount of money that can benefit the unstable economic sectors. Moreover, an expected significant reduction in GHG emissions could be achieved, despite the fact that the source of the electricity in Palestine is mainly fossil fuel.

5. Conclusions

Despite the fact that passenger vehicle electrification has started 20 years ago, the electric trucks market is still an emerging market, and the energy and environmental implications of electrifying the freight transport sector are still unquantified in developing countries like Palestine. Moreover, these implications vary considerably around the world based on the source of the electricity (coal, natural gas, renewable energy, etc.), electricity rates, and fuel rates. Therefore, this has necessitated conducting a comprehensive study in Palestine in order to quantify these implications. Despite the fact that there is a government strategy to stop importing the new conventional vehicles during the next 10 years and to import the new electric ones instead, these strategies may face several obstructions that could slow down their application. Moreover, due to the absence of relevant data for the whole of Palestine, the study has been conducted for the Westbank region only and excluding Gaza Strip. As a result of this study, the following conclusions were offered:

- The urban freight transport sector in Palestine is considered one of the main sources of GHG emissions, since this sector depends mainly on an old fleet of diesel internal combustion engines vehicles, which include a considerable number of heavy and mid-duty trucks that could produce about 2.5 million tons of CO_2-equivalent of GHG emissions in 2032, in Westbank, based on the prediction of this study, in case of the continuous relying on conventional vehicles only.
- Despite the main source of electricity in Westbank being a fossil fuel, there is still an expected significant reduction in GHG emissions during the next 10 years in case of the partial electrification of the freight transport sector. More specifically, this reduction in GHG emissions could be around 19.8% in 2032, in the case of 20% freight transport modes electrification.

- Based on the fuel and electricity rates in Westbank, the partial replacement of the conventional freight modes of transport by the electric ones during the next 10 years could save a considerable amount of money that can benefit the unstable economic sectors. The amount of money that could be saved in 2032 by 20% electrification of the freight transport sector is up to 66 million U.S $, which is almost equal to the GDP of the transportation sector in the last quarter of 2021.
- This study has been conducted considering the current technology of the electric vehicle, which has a specific range and battery capacity limitations that could be developed during the next 10 years. Therefore, it is highly recommended to conduct a new study in the future in case a significant development in range and battery capacity has been achieved.
- For any further future work, it is recommended that the ownership and maintenance costs be considered in addition to the energy cost since these factors are influential on truck operator decisions.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: All relevant data were included in this article.

Conflicts of Interest: The author declare no conflict of interest.

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