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Exploring Hybrid Vehicle Integration in Nablus Urban Shared-Taxis: Cost-Benefit and Exhaust Emissions Assessment

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Abstract: There is a worldwide concern about the increase in vehicles' exhaust emissions of traditional fuels and the rise in fuel prices. Nablus city is a major city in the West Bank, Palestine with peculiar topography and traffic congestion. This increases fuel consumption and the gas emission of the diesel operated public transport (PT) shared-taxi vehicles. This paper investigates the viability of introducing hybrid vehicles to the urban shared-taxis in highly congested areas with peculiar topography. Interviews were conducted and questionnaires were distributed among PT drivers and route managers to obtain the operational and cost characteristics of each route. The existing expenses and revenues and gas emissions of diesel vehicles were analyzed. Expenses-revenues analysis revealed that there is no immediate urgency in switching all diesel-fuel shared-taxis to hybrid; therefore, two scenarios were developed. The first was replacing old PT cars (2009 or older) with hybrid vehicles, which provided an average financial saving of 20.9% with a reduction in exhausts emission of CO2-equivalent by 33%. The second scenario included replacing PT vehicles with production dates from 2009-2014, which produced financial savings of 15% and reduction of exhaust emissions by 35%. The comparison showed a preference for the first scenario at the current time, while implementing other scenarios gradually. The first scenario is simple and close to reality; as old vehicles should typically be replaced. The study recommends using hybrid vehicles for new shared-taxis introduced to the service, and establishing national level policies to encourage the use of alternative fuels for the transportation sector, focusing on PT. However, several critical factors must be considered, including topography and route characteristics.

Keywords: Hybrid, Diesel-Fueled, Public Transport, Shared-Taxi, Financial, Environment, Feasibility, Developing Countries, Nablus City, West Bank, Palestine.

NTRODUCTION

The transportation sector plays a pivotal role in national development, prompting authorities to prioritize its enhancement and service quality. Despite this, the transport sector remains heavily reliant on conventional fuels, contributing to global air pollution. Although there is no definitive timeline for the depletion of conventional fuels worldwide, studies generally indicate an impending fuel economy. At the same time, nations are striving to promote easier access to alternative fuels. This strategy shift is motivated by the expectation that over time, these alternative fuels might become more cost-effective due to increased availability, unlike conventional fuels that are nearing depletion, leading to increased scarcity and higher costs.

There is no doubt that hybrid cars have proven to save fuel and reduce exhaust emissions. These vehicles depend on two sources of energy, the first is an electric motor fed by a battery usually made of lithium ion and the other source is an internal combustion engine of gasoline working together in order to reach the best fuel consumption and the lowest production of exhaust emission [1].

Public transportation (PT) within the transportation sector serves as a means of mobility, granting individuals access to their intended destinations. It offers advantages to both voluntary users who opt for PT and to those who rely on it as their only available option (referred to as captive users). PT vehicles cover longer distances, consume more fuel, and thus produce higher gas emissions compared to regular passenger cars. To ensure the continuity of providing services and achieving sustainable development, it is necessary to make optimal use of the available resources. One way to achieve this is by managing the use of fuel in a way that ensures its durability for a longer period and provide good performance for the vehicles.

In Palestine, the Ministry of Transport (MOT) holds responsibility for overseeing and managing services within the transportation sector. It issues permits and licenses for PT vehicles as well as for drivers, and regulates ticket fees. In 2023, the total number of vehicles in the West Bank (WB) of Palestine has reached close to 335,269, with PT vehicles accounting for around 10,085 (approximately 3.0%), consisting of various sized buses and two types of cars [2]; 4-passenger cars used for intra-city PT services and 7-passenger cars (mini-vans) typically used for inter-city trips, albeit with limited usage for intra-city service.

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The PT system operates under private ownership, where the drivers may either be the vehicle owners themselves or hired.

In 2022, the WB witnessed an increase in new vehicle registrations, totaling over 32,800 vehicles, with 860 of these as PT vehicles [3]. Comparatively, back in 2020, these figures stood at approximately 20,100 vehicles in total, with 640 PT vehicles [4]. This notable rise in both regular and PT vehicle registrations signals a surge in demand, consequently implying an expected increase in emissions within the region.

In addition, the escalating fuel prices in Palestine impose financial strain on citizens, prompting them to seek ways to economize on fuel expenses and other costs. Furthermore, the transportation sector is one of the most contributors to the environmental exhaust emissions, accounting for over 40% of the national energy consumption. Although, hybrid cars have been introduced to the Palestinian market in recent years, their presence remains very limited, representing only a small fraction. Approximately 99% of vehicles in use rely on traditional fuel sources, and PT vehicles entirely operate on conventional fuel, predominantly diesel [3].

The environmental challenges posed by air pollution and high fuel consumption have spurred considerations for alternative solutions, notably hybrid and electric cars. However, electricity sources in Palestine are limited and not sufficient to meet the citizen's needs as they are controlled and provided by the Israeli authority, thereby limiting the capacity for widespread adoption of electric vehicles as a viable alternative at present. In the event that new electrical loads, such as the electric car, are added, this will weaken the electric network.

In contrast, diesel-fueled vehicles are cheaper than electric vehicles, while maintenance requirements for both systems vary. Furthermore, the diverse topography in Palestinian cities, ranging from level to mountainous terrains, undoubtedly affect the fuel consumption rates for conventional fuel, electric, or hybrid vehicles. Similar variations in these parameters are expected between different regions worldwide; what proves successful in one country may not yield the same outcomes in another. Therefore, there is a need to strike a balance between the existing conventional system, with all its limitations, and the pursuit for a more advance, cost-effective, and eco-friendly alternative.

Consequently, the primary objective of this paper is to conduct a financial and environmental feasibility study (in terms of expenses-revenues and gas emissions) of replacing diesel-fueled vehicles with hybrid alternatives for PT services within a major Palestinian city in the WB, specifically Nablus City. The focus on this city is due to its distinctive topographical features (further details are discussed in Section 4), as a case study for Palestinian cities and other similar cities in the world. The study will further explore various scenarios and recommend the most viable option(s) for implementing hybrid vehicles in PT services.

Literature Review

There is a wealth of research addressing the use of alternative fuels in the transport sector. A selected sample related to the scope of this study is presented here.

Studies indicated that the world population will increase from 7 billion in 2020 to 9.8 billion by 2050, which means that we would have billions of new vehicles. The question is what if all these vehicles run on diesel fuel or gasoline? Certainly, there will be faster depletion of traditional fuels and huge amounts of emissions [5].

The increasing trends of fuel prices in the world as it approaches the penetration and the significant increase in carbon dioxide emissions has become a worrying matter that needs a realistic and viable solution. Furthermore, the transport sector is linked to the development of the global economy. Research has established that starting with the study of light vehicles is a good idea because they constitute 23% of the total transport sector, about 600 million vehicles traveling on the road daily, consuming more than 77 million barrels of oil per day, and it is expected that 800 million people will own new vehicles within the next 40 years. The results showed that the use of hybrid vehicles would reduce fuel consumption and pollutant emissions by 30% [6]. Somewhat similar results were reported by Singh [7] who indicated that hybrid cars, on average, emit 25-30% less carbon dioxide. On the other hand, Bozo et al. [8] estimated that with the introduction of 5% electric hybrid vehicles into circulation for 21 Dhjetori" intersection in Albania, the level of pollution can be reduced by over 22% and the reduction of carbon dioxide to 12%.

The entry of hybrid vehicles to the car market is in increasing numbers, and tax cuts helped increase the spread of hybrid vehicles in Switzerland. A survey of 367 second-generation Toyota Prius hybrid buyers in Switzerland in the first nine months after entering the market was conducted. As a control group, questionnaires were also sent to 250 Toyota Corolla buyers and 250 Toyota Avensis buyers. The main findings were that the increase in vehicle volume for hybrid car buyers was lower than both the market trend and the control group. The increase in vehicle size was less for hybrid car buyers than for the control group and market trend [9].

In a study conducted in 2007, it was shown that approximately 41% of emissions were emitted from vehicles, and this was a very high percentage, as Meireles et al. [10] indicated. Therefore, governments in Europe and America decided to reduce this percentage by imposing more taxes on fuel and vehicles that operate using traditional fuels. The increase in taxes reduces the demand for vehicles because of their high prices. Vehicle manufacturers had taken three directions, hybrid vehicles (use both fuel and electricity), fully electric vehicles, and vehicles based on fuel cells 'hydrogen' [10].

Hossain et al. [11] has established that the aggregate effect of the economic activity, population, economic structure, and energy intensity factors were responsible for the increase in CO_2 emissions in Bangladesh. Therefore, the adoption of the five-year development plan, whereby working to replace part of the vehicles from fossil fuels to hybrid engines, and by jointly activating road transport, reducing trains, and publishing policies to reduce energy consumption, would significantly reduce the rate of CO_2 emissions in Bangladesh. The research recommended that the Bangladesh Government should proliferate mass responsiveness programs and cope with economic development through emphasizing quality of development rather than quantity, which will ensure sustainable transport sector development.

The impact of hybrid vehicles on energy and the environment was addressed in a study conducted in China [12]. The study suggested promoting hybrid and electric vehicles as a promising solution to reduce transportation energy consumption and reduce vehicle emissions in the country. It focused on evaluating the environmental impacts of hybrid electric vehicles (HEVs) and electric vehicles (EVs) from 2010 to 2020 using a life cycle cost analysis (LCA), assessing energy consumption per kilometer of gasoline, and converting gasoline into equivalent gas, coal, and oil. The research estimated the use of gas (NG), oil, biomass, litter, and electricity for HEVs and EVs. The findings revealed that EVs and HEVs could nationally reduce vehicle energy consumption by average proportions of 17%-19% and 30%-33%, respectively. Additionally, the study estimated detailed emission factors for sulphur dioxide, nitrogen oxides, volatile organic compounds, carbon dioxide, NH3, PM10, PM2.5, OC (organic carbon), EC (elemental carbon), CO_2, N_2O, methane, lead, and mercury. The study concluded that HEVs could significantly reduce emissions of NOx, volatile organic compounds, and carbon dioxide per vehicle. EVs showed reductions in some emissions, including volatile organic compounds, NH3, CO, and carbon dioxide, but increases in sulphur dioxide, nitrogen oxide, and particles. Consequently, the study recommended widespread use of hybrid and electric vehicles, particularly in areas with high concentrations of pollutants.

Researchers aimed to present total air pollutant emissions through the lifetime of a transit bus with different fuel options. Diesel, biodiesel, compressed natural gas (CNG), liquefied natural gas (LNG), hybrid (diesel-electric), and battery electric (BE) transit buses were analyzed with an input/output-based hybrid life cycle assessment (LCA) model based on different driving cycles. It was found that the BE transit bus caused significantly lower CO_2 emissions than diesel and other alternative fuel options, while some of the driving cycles of the hybrid-powered transit bus caused comparable emissions to BE transit bus. On the other hand, lifetime water withdrawal impacts of the diesel and hybrid options were more feasible compared to other options. The research concluded that although the results indicated that BE and hybrid-powered buses had less environmental emissions, the US's dependency on fossil fuel for electricity generation continues to yield significant lifetime impacts on BE transit bus operation [13].

Hassouna & Al-Sahili [14] stressed that environment is one the most important aspects of the sustainable development in the public transport sector in Palestine. Based on data extracted from the prediction of future conditions, the researchers developed two scenarios for using hybrid vehicles; converting conventional internal combustion engine vehicles to hybrid by 10% and 20%. The results showed that the emissions of carbon dioxide, nitrous oxide, and methane estimated from the transportation sector in 2020 was very high. Furthermore, in 2030 when 20% of internal combustion engines vehicle's (ICEVs) would be replaced by hybrids, this would result in the reductions of 4.66% and 13.31% in carbon dioxide and nitrous oxide, respectively, compared to 100% of ICEVs, while methane emissions would increase. However, the total carbon dioxide equivalent (CO_2eq) would decrease by 5%. Furthermore, Hassouna [15] assessed the sustainability of the public bus sector in the West Bank of Palestine. The study concluded that developing this sector and increasing the number of buses to meet the minimum global requirements is expected to significantly reduce the GHG emissions and traffic congestion up to 5.84%. In addition, Hassouna and Assad [16] investigated the replacement of conventional taxis by a hybrid system in the West Bank, Palestine. The study concluded that replacing 50% of the taxi fleet by hybrid vehicles would reduce N_2O and CO_2 by 42.3% and 28%, respectively, in the next 10 years; however, this would increase the CH_4 by 395%.

Salameh et al. [17] proposed a design and operation of solar-based charging system for battery vehicle to replace 110 existing public transport diesel vehicles with 39 electric or hybrid buses for a 50-km run between Ramallah and Nablus Cities in the West Bank, Palestine. The results showed that the payback period of the system would be 10 years, the CO mitigated, and the social impact were also found acceptable. It was concluded that the proposed system will increase the public transport system's reliability, convenience, and sustainability.

Another research has also established that replacing conventional fuel vehicles with hybrid vehicles is the trend towards sustainable transportation. Transition management is an important prerequisite for enhancing its improvement role in environmental issues. Meanwhile, evaluation is of vital importance for effective management based on life cycle thinking and the example of the transformation of the electric taxi in Beijing [18].

Researchers also focused on the processes involved in the shift toward electric buses, emphasizing operational challenges associated with these vehicles. They highlighted the necessity to not only establish a network of charging stations but also to enhance the current servicing infrastructure. A comparative analysis among electrical, hybrid, and traditional fuel vehicle infrastructures was conducted, revealing the need for a specialized station dedicated to servicing e-vehicles with a structured maintenance routine, including daily maintenance procedures [19].

Based on the reviewed literature, it is generally agreed that hybrid vehicle use leads to more efficient fuel consumption and reduced emissions. However, several uncontrollable factors in each country, such as driving style, topography, fuel and vehicle prices, and maintenance costs, significantly impact vehicle performance. Furthermore, there are limited scientific articles specifically addressing the use of hybrid vehicles in PT (buses and taxis). The available literature mainly consists were of project reports, newspaper articles, or information provided by manufacturers and interested entities, primarily focusing on hybrid buses.

In addition, driving style heavily influences the performance of both hybrid and conventional fuel vehicles. Therefore, this research aims to focus on urban PT in Palestine, particularly in Nablus city. It takes into account its topographic nature (mountainous), the driving style of public vehicle drivers (such as forced slow driving and frequent stop-and-go pattern, and the general reckless driving tendencies), and the specific characteristics of existing PT routes.

RESEARCH METHODOLOGY

Following the problem definition and a review of previous studies, the required data (quantitative and qualitative) was gathered to achieve the research objectives.

Information about the shared-taxi lines, including their operating and financial conditions, was gathered through interviews with both drivers and PT route managers at the main public transportation station. This stage utilized multiple data collection methods, with key approaches being in-person interviews with drivers, shared-taxi line supervisors, and station officials, along with the distribution of a survey form to drivers. The survey form was carefully designed with simple and straightforward questions to cater to drivers across various educational and cultural backgrounds. Additional data on shared-taxi routes in the city were collected from official sources and previous reports [20]. The details and interpretations of these data are presenting in the following sections.

Additionally, a representative sample of hybrid vehicle drivers participated in the survey, providing information through in-person and phone interviews as well as through a questionnaire. The collected data encompassed various aspects, including the characteristics of PT routes, operational features of hybrid vehicles, driving behaviors, and the revenues and expenses associated with both vehicle types for each route. The details of these data are presented in the following sections.

To estimate exhaust emissions, emission rates provided by manufacturers and pertinent agencies [21] were utilized for each engine type. Exhaust emissions were estimated based on fuel type and operating conditions for each route, as detailed in the following sections.

The collected data were then analyzed to compare conventional fuel and hybrid vehicles in terms of expenses, revenues, and environmental factors (exhaust emissions). The cost analysis included both fixed and operating costs, as well as revenues for each route. This analysis considered initial costs, depreciation, salvage value, vehicle lifetime, net cash flow, and interest rates to estimate the average monthly expenses and revenues for each route.

Various scenarios for transitioning shared-taxis to hybrid vehicles were examined to determine the most suitable option(s) for implementation based on expected revenues and emission reductions. These scenarios focused on a gradual switch of older model vehicles to hybrid. The analysis also considered the topography of each route. The scenario yielding higher revenues and lower fuel emission was recommended. Details of these analyses are provided in the following sections.

Data Collection and Existing Conditions of PT in Nablus City

Study Area

The study area is Nablus City, situated in the northern region of the WB, as shown in Figure 1. Nablus is the second most populous city and serves as one of the primary hubs for commercial activities, boasting significant development and dense urbanization. The city features a distinct topography, characterized by its predominantly mountainous terrain. Positioned amidst two mountain ranges to the north (Eibal Mount; the taller peak at 940 meters) and south (Jerzim Mount; 881 meters high), the city center lies in the interstice, with a linear road network traversing between the two mountainous regions [22], as shown in Figure 2. Moreover, Nablus is undergoing expansion, particularly into the surrounding mountainous areas; therefore, high grades are common on access roads to the hilly expanded areas.

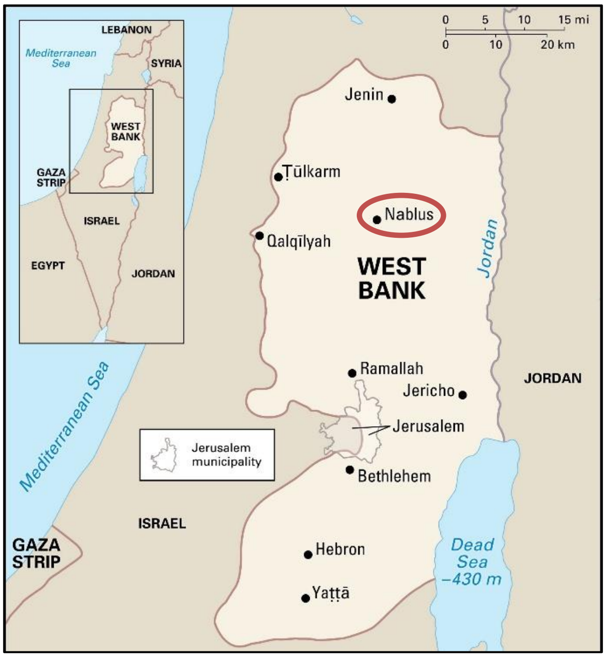

Figure (1): Location of Nablus in the West Bank.

The PT system in Nablus City also consists of taxis and buses, with taxis categorized into shared-taxis or office-taxis. Shared-taxis predominantly come in two sizes, four or seven seats, with the former being the more prevalent type [2]. PT routes within the city are divided into external (inter-city) connecting Nablus City with neighboring communities, and internal (intra-city), catering to the urban area.

Figure (2): A Photo for Nablus City Terrain.

Shared-Taxi Routes and Characteristics

Within Nablus City, there exist 9 shared-taxi routes, with variations in travelled distances, taxi types, and number of taxis for each. For the internal network, there exists a central terminal situated in the city center (denoted as **(T)** in Figure 3), serving as the departure point for all shared-taxi services. Each route is managed by a supervisor or manager responsible for organizing the service operations and collecting terminal fees.

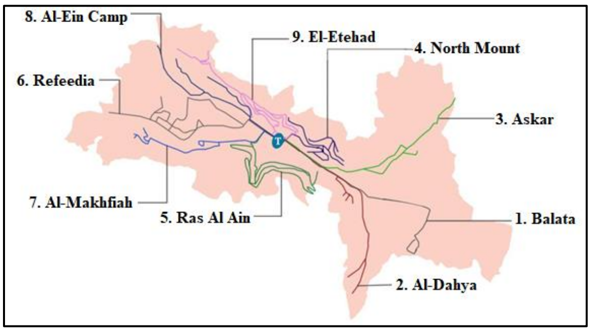

Figure (3): Shared-Taxi Routes in Nablus City.

The central station, which is located in a relatively flat area in the city center, is the origin-destination point for all internal routes in the city. Therefore, the internal routes would have to travel through the relatively flat terrain along the east-west central corridor, then certain routes would have to climb up the hilly terrain, particularly the northern and southern areas. As such, each route has to negotiate a different topography along its path. Here is a brief description of the general terrain of these routes.

Balata: Generally flat terrain

Al-Dahya: Flat along the east-west corridor, then mountainous terrain

Askar: Generally flat terrain

North Mountain: As the name indicates, mountainous

Ras Al Ain: Rolling to mountainous terrain

Rafeedia: Rolling terrain

Al-Makhfiah: Rolling to mountainous terrain

Al-Ein Camp: Flat to rolling

El-Etehad: Mountainous

A survey form was distributed for all routes to gather detailed information related to their operational and cost aspects. The survey encompassed 400 drivers, constituting 60% of the total drivers operating at the station, exceeding the minimum sample size required for a 95% significance level. The researchers distributed the survey forms and collected data manually at the main station, where the majority of drivers present were interviewed. The survey included all routes, and at least 30 drivers from each route were interviewed in groups. The interview involved 10 main questions pertaining to vehicle/route details, including vehicle type, production year, manufacturing company, monthly maintenance, number of daily trips, distance traveled, daily fuel consumption, station fees, number of main trips, and secondary trips, as well general comments. Responses were recorded manually on the survey forms, and average values were calculated, as presented in Table 1. Notably, the answers were generally consistent across drivers, suggesting a broad consensus on the operational and cost characteristics for each route.

Shared-taxi trips are classified into two types; main and secondary. A main trip occurs when the taxi departs from the main station with a full-load of passengers to the selected destination. Conversely, a secondary trip involves the taxi picking up passengers en-route.

Table (1): PT Routes' Operating Characteristics and Fuel Consumption Cost in Nablus City.

No.	Route Name	No. of Vehicles (4 seats)	No. of Vans (7 seats)	Route Length (Km)	Number of Trip/ Vehicle/ Day	Number of Passengers (One-Way)/ Vehicle/ Day	Number of Passengers (Round Trip)/ Vehicle/ Day	Car Fuel Consumption (₪)/Day(1)	Van Fuel Consumption (₪)/Day
1	Balata	80	-	2.5	20	80	120	45	63
2	Al-Dahya	40	-	3.4	20	80	120	61	86
3	Askar	101	-	7.0	17	68	102	107	150
4	North Mountain/Ebn Rushed	26	-	3.5	15	60	90	48	67
5	Ras Al Ain / Al Tawon	40	-	2.3	21	89	126	43	60
6	Rafeedia	175	5	4.4	28	112	168	110	154
7	Al-Makhfiah	104	16	2.5	24	106	159	54	76
8	Al-Ein Camp	60	-	3.2	28	112	168	81	114
9	El-Etehad	31	-	2.9	19	76	125	50	70

(1) Calculated based on average fuel consumption per kilometer travelled. ₪: Israeli Shekel (1 US$ = 3.5 ₪).

Table 2 presents the classification of PT vehicles according to their production years. The rate of fuel consumption expenses was obtained from drivers depending on the age of the vehicle; older vehicles exhibit marginally higher fuel consumption compared to newer models. The average fuel expenses were calculated for the consumed fuel per day. Additionally, fuel consumption was calculated based on the distance travelled for each route, providing more accurate assessment compared to information disclosed by drivers.

Given that the price of diesel in Palestine is approximately 5.0 Shekels for the year 2023(3), the cost per kilometer can be estimated at around 0.45 Shekels for fuel. For a van (7-seat), the average consumption rate is approximately 0.63 Shekels per liter. Table 1 presents the breakdown of fuel consumption costs per route.

As per the information gathered from drivers' interviews, the total maintenance cost for vehicles averaged around 6,000 Shekels annually. Additionally, drivers incur a daily station fee, totaling 2,592 Shekels per year, along with annual expenses for insurance and licensing, amounting to 6,900 Shekels. Consequently, when considering maintenance, station fees, insurance, and licensing collectively, the total annual cost sums up to 15,492 Shekels.

Table (2): Classification of Vehicles Based on the Production Year.

Production Year/Number	2002-2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Balata	10	7	6	9	11	12	6	8	6	5	0
Al-Dahya	0	3	1	4	10	5	4	2	5	1	5
Askar	2	5	7	7	17	16	9	11	10	6	4
North Mountain	0	6	0	1	3	7	3	4	0	2	0
Ras Al Ain	0	7	2	4	9	3	5	6	1	1	0
Rafeedia	17	13	8	21	22	29	25	18	10	12	5
Al-Makhfiah	3	9	5	12	31	22	15	9	4	3	4
Al-Ein Camp	4	3	1	7	8	9	7	5	8	1	2
El-Etehad	2	0	0	1	4	4	8	6	2	3	0
Total	38	53	30	66	115	107	82	69	46	34	20
Average Fuel Combustion/Day (₪)	130	125	125	120	120	115	115	110	110	105	105

(3) 1 US Dollar is equivalent to approximately 3.5 Shekels (at the time of the study)

Fixed Costs

The vehicle price was acquired from several car agencies/dealers. Subsequently, vehicles start depreciating annually after their use, which is meticulously controlled due to the multiplicity of vehicle types, depending on the company, manufacturer, and prevailing market conditions during the purchase and sale of the vehicle. Based on information provided by the car agencies and drivers, the average depreciation is approximately 10% of the vehicle's initial purchase price. An average value was taken based on the prices of new cars - called zero kilometers - sold in car dealerships and the prices of cars that have been sold for a year up to five years. By calculating the average, we found approximately a 10% decrease in the value of the car.

Hybrid System

The count of hybrid vehicles reached approximately 550 units in the West Bank by the year 2021, with a majority of them being Hyundai Ioniq models [4]. The focus of this study is on these vehicles, engaging in interviews with their respective owners. The study sample consisted of 250 drivers (45% of total hybrid vehicle owners), exceeding the minimum sample size required for a 95% significance level. The interviews were conducted through direct communication with the drivers or over the phone. The interview focused on the following questions: (a) have you calculated the fuel consumption of your hybrid car? (b) If the answer is yes, what is the average consumption? (c) What is the driving style followed (inside the city, outside it, between inside and outside the city)?

Respondents largely concurred that hybrid vehicles necessitated regular maintenance every five months, with an estimated cost of 200 Shekels. They also declared no significant issues with manufacturing defects or unusual maintenance requirements. Regarding fuel consumption, there was a considerable variation in responses among vehicle owners, which is normal and attributed to driving style and geographical location, among other factors.

Based on information from the auto company in Palestine, the price of a hybrid car (Hyundai Ionic) is 130,000 Shekels, and the price of the hybrid battery, which is assumed to be changed every 6 years, is 8,000 Shekels.

Approximately 40% of the interviewed drivers use their vehicles in the city with moderate driving style and an average vehicle consumption of 21 km/liter. In addition, approximately 40% of the interviewed drivers use their vehicles inside and outside the city for an average of 15 km/liter. Finally, 20% use their vehicles on external roads most of the time for an average of 14 km/liter.

It should be noted that "moderate driving style" refers to a technical term that describes how a driver operates a vehicle. It involves reducing fuel consumption by avoiding sudden acceleration, maintaining a moderate driving speed (less than 100 km/hr) and engine speed (less than 2000 rpm), and minimizing frequent stop-and-go driving, which can lead to inefficient driving [23]. During operation of a hybrid vehicle, the electric motor and internal combustion engine function either together or separately according to the speed conditions, driving conditions, and others. At smaller speeds, low acceleration-wherever possible-hybrid cars run on electric motors for maximum efficiency. When more power is required, the diesel engine may kick in all by itself or in conjunction with the electric motor during rapid acceleration or high-speed cruising. In situations that require more power, such as fast acceleration or hill climbing, both the electric motor and the diesel engine might work together to provide the required performance.

Results and Discussion

Analysis of Environmental Aspects

As discussed before, the efficiency of diesel-fueled vehicles decreases at low speeds, which correlates with increased exhaust gas emissions due to reduced combustion efficiency. Table 3 provides a comparison of standard gases emitted from diesel vehicles (complying with Euro 4, 5, and 6 standards, commonly used in Palestine) as well as hybrid cars, detailing their respective quantities based on the annual kilometers travelled multiplied by the emission rates per kilometer established under the Euro Exhaust Gas Laws [21]. The data in Table 3 underscores that the emission quantities from gasoline-powered vehicles are lower than those from diesel vehicles. Hybrid cars, equipped with both a gasoline engine and an electric motor, emit notably fewer exhaust gases. This reduced emission level is attributed to the fact that the gasoline engine in hybrid vehicles operates less frequently, leading to significantly lower emissions compared to diesel cars [24].

Table (3): Emission Standards for Passenger Cars [21].

Stage	Date	CO_2	HC	HC+NOx	NOx	PM
		g/km				
Positive Ignition (Gasoline)						
Euro 6	2014.09	1.0	0.10	-	0.06	0.005
Compression Ignition (Diesel)						
Euro 4	2005.01	0.50	-	0.30	0.25	0.025
Euro 5	2009.09	0.50	-	0.23	0.18	0.005
Euro 6	2014.09	0.50	-	0.17	0.08	0.005

Tables 4-6 present the amount of exhaust gases that come out of each route based on the following equation:

Total Emission = {No. of vehicles of production year (2005 - 2009) * (Euro 4 emission rate) + No. of vehicles of production year (2009 – 2014) * (Euro 5 emission rate) + No. vehicles of production year (2014 - 2017) * (Euro 6 emission rate)} * Annual Travelled Distance per Vehicle

Table (4): CO_2-equivalent Emission Quantity for Diesel Fuel and Hybrid per Route (kg/year).

No.	Route Name	CO_2–equ Diesel Emission Quantity - based on production year			Total CO_2-equ Emission for Diesel Fuel	Total CO_2-equ Emission for Hybrid
		2005-2009	2009-2014	2014-2017		
1	Balata	244.80	633.60	273.60	1,152.00	768.00
2	Al-Dahya	58.75	470.02	254.59	783.36	522.24
3	Askar	239.90	1919.23	1062.43	3221.57	2307.65
4	North Mountain	90.72	211.68	90.72	393.12	262.08
5	Ras Al Ain	97.37	319.94	111.28	528.60	370.94
6	Rafeedia	1064.45	3725.57	1596.67	6,386.69	4139.52
7	Al-Makhfiah	207.36	1468.80	345.60	2,021.76	1198.08
8	Al-Ein camp	180.63	825.75	412.88	1,419.26	1032.19
9	El-Etehad	31.74	269.77	174.56	476.06	327.96
	Total	**2,216.23**	**9,844.86**	**4,322.83**	**16,382.42**	**10,928.66**

Table (5): HC + NOx Emission Quantity for Diesel Fuel and Hybrid per Route (kg/year).

No.	Route Name	HC & NOx Emission Quantity - based on production year –			Total HC & NOx Emission for Diesel Fuel	Total HC & NOx Emission for Hybrid
		2005-2009	2009-2014	2014-2017		
1	Balata	146.88	291.46	93.02	531.36	76.80
2	Al-Dahya	35.25	216.21	86.56	338.02	52.22
3	Askar	143.94	882.85	361.23	1388.02	230.76
4	North Mountain	54.43	97.37	30.84	182.65	26.21
5	Ras Al Ain	58.42	147.17	37.84	243.43	37.09
6	Rafeedia	638.67	1713.76	542.87	2895.30	413.95
7	Al-Makhfiah	124.42	675.65	117.50	917.57	119.81
8	Al-Ein camp	108.38	379.85	140.38	628.60	103.22
9	El-Etehad	19.04	124.09	59.35	202.49	32.80
	Total	1,329.74	4,528.63	1,469.76	7,327.43	1,092.87

Table (6): PM Emission Quantity for Diesel Fuel and Hybrid per Route (kg/year).

No.	Route Name	Emission Quantity (based on production year - kg/year)			Total PM Emission for Diesel Fuel	Total PM Emission Quantity for Hybrid
		2005-2009	2009-2014	2014-2017		
1	Balata	12.24	6.34	2.74	21.31	3.84
2	Al-Dahya	2.94	4.70	2.55	10.18	2.61
3	Askar	12.00	19.19	10.62	41.81	11.54
4	North Mountain	4.54	2.12	0.91	7.56	1.31
5	Ras Al Ain	4.87	3.20	1.11	9.18	1.85
6	Rafeedia	53.22	37.26	15.97	106.44	20.70
7	Al-Makhfiah	10.37	14.69	3.46	28.51	5.99
8	Al-Ein camp	9.03	8.26	4.13	21.42	5.16
9	El-Etehad	1.59	2.70	1.75	6.03	1.64
	Total	110.81	98.45	43.23	252.49	54.64

Kebriaei et al. [25] suggested that the gasoline combustion engine in hybrid vehicles operates at a third of its power. Reducing the power of a gasoline engine in a hybrid car to a third of its maximum can alter the composition of the exhaust gas, possibly increasing the amount of carbon monoxide and unburned hydrocarbons, decreasing nitrogen oxides, and increasing particulate matter. The efficiency of the car's emission control systems will also have an overall effect on emissions. Table 7 shows the difference in emissions between diesel and hybrid vehicles. This comparison is derived from the data presented in Tables 3-6, which account for the Euro standards (Table 3), vehicle age (including Euro type for each age group based on national usage), the number of vehicles per age group per route, distances traveled per route, and the emissions data (Tables 4-6).

Table (7): Comparison of Exhaust Gas Emissions between Hybrid and Diesel Vehicles (kg/year).

Emission	Diesel Fuel	Hybrid	Difference	% Difference
CO_2-equivalent	16,382.42	10,928.66	5,453.76	33.3%
HC & NOx	7,327.43	1,092.87	6,234.56	85.1%
PM	252.49	54.64	197.85	78.4%

Cost Analysis for Diesel and Hybrid Vehicles

This section focuses on analyzing the data for each of the nine routes in terms of economic aspects. The analysis is based on each individual PT route; the following is an example.

Sample Route: Balata Route

For Balata Route, there are 80 vehicles serving this line with 53% of the vehicles produced before year 2012. This means that there is a likelihood of replacing those vehicles because they are relatively old.

The average monthly cost was 2425 ₪. Then the total income per month per vehicle was calculated based on the following equation.

Total Monthly Income = Number of working days per month *Fare * Number of Passengers (Round Trip) = 9000 ₪

At the end, the profit per month per vehicle was calculated considering the depreciation of the vehicle, using the 'Net Cash Flow' (NCF) with its requirements: initial cost (P), salvage value (F), the expected life time of the vehicle (N), and interest rate (i%).

Based on interviews with route's official, the majority of shared taxis' initial cost is approximately 55,000 ₪, after 10 years it loses about 20% of its initial value, and will be sold in the market. A 3.5% interest rate was used based on information obtained from local banks.

To convert all the NCF to annual amounts 'A' (Profit), the following equation is used [26]:

A = -P (A/P, 3.5%, 10) + F (A/F, 3.5%, 10) + (Difference between income and expenses)

From the (NCF) tables, (A/P, 3.5%, 10) = 0.1202 and (A/F, 3.5%, 10) = 0.0852.

By substituting the values of P and F, the equation becomes:

-2862.2 + (Difference between income and expenses) = A = Profit/Year

Then to convert it to profit per month, the equation becomes:

{-2862.2 + (Difference between income and expenses) *12} / 12 = Profit/Month

For Balata route, Profit/Month = {-2862.2 + (6575*12)} / 12 = 6335 ₪

Hybrid Vehicle Costs

Expenses/Month = 2050 ₪. Then the total income per month per vehicle = 9000 ₪

The starting price of a "Hyundai Ioniq" hybrid vehicle is roughly 90,000 ₪, and over a span of 10 years, it depreciates by approximately 40% of its initial value, as per information gathered from interviews with drivers in the Palestinian vehicle market. The percentage decline in the price of hybrid vehicles is notably higher than that of diesel vehicles due to custom taxes. Specifically, the tax rate for hybrid vehicles stands at 30%, while for diesel vehicles, it amounts to 50%, according to the Palestinian customs system. However, PT vehicles are exempt from such taxes for the duration of their service, resulting in customs charges being set at zero.

When a driver intends to convert a PT vehicle into a private vehicle, an annual vehicle tax is levied on it. Consequently, PT vehicles experience a depreciation equivalent to the amount of tax exemption granted. For instance, if a vehicle is priced at 100,000 Shekels without tax and 150,000 Shekels with tax, it depreciates by 10%. Upon the driver's decision to sell it as a regular vehicle after a decade, assuming its market equivalent is approximately 100,000 Shekels, the driver does not incur any loss.

In the case of hybrid vehicles, despite their lower tax rate, they have higher purchase prices. PT drivers, however, do not benefit from tax deduction since they do not pay it in the first place. Initially, hybrid vehicles are priced lower than diesel vehicles. Initially, hybrid vehicles are priced lower than diesel counterparts. Over the vehicle's operating years, the expenses incurred are associated with customs taxes, resulting in a decline in the vehicle's value. Additionally, there's a necessity to replace the battery approximately every 6-7 years, with an estimated cost of around 8,000 Shekels, based on prevailing prices in the local Palestinian market.

By applying these values, Profit/Month = 6500 ₪, a difference of 6500 – 6335 = 165 ₪/month; the saving for changing vehicles from diesel to hybrid is 165 Shekels per month.

Upon analyzing the economic savings of converting all diesel vehicles to hybrids, it indicates that this conversion might not be highly viable for this line. The modest monthly saving doesn't justify the switch and doesn't provide ample incentive for drivers to alter their driving style. Despite the various disadvantages associated with diesel vehicles, the economic justification for transitioning to hybrid does not appear to compelling enough.

Ultimately, the current status is deemed suitable for this particular route, as well as for certain other routes. The recommendation for this route is to keep it as is. Therefore, there is no strong argument to persuade any party to switch the vehicles on this route to hybrid, especially considering the economic feasibility aspect. However, as the vehicles aging and need replacement, there will be generally no environmental harm, in terms of gas emissions, of switching new vehicles to hybrid and gain even modest benefit. However, the delay in switching new cars to hybrid cars is in the economic interest, as this switch does not achieve the economic benefit as in old cars. On the other hand, it might be difficult to convince drivers to replace their cars that were purchased less than 3 years ago. A summary of income and profit for each route is presented in Table 8.

Scenarios for Switching from Diesel to Hybrid

The shift from diesel vehicles to hybrid is anticipated to occur gradually. Consequently, two alternative scenarios are proposed and applied to each route separately. In addition, a prerequisite is established, mandating that any newly introduced vehicle into the service must be a hybrid vehicle.Replacing all vehicles with a production date earlier than 2009

2. Replacing all vehicles with production dates from 2009-2014 (added to scenario 1)

Table (8): Profit Summaries of PT Routes for Diesel and Hybrid Cars.

No.	Route Name	Average Monthly Profit for Diesel (₪)	Average Monthly Profit for Hybrid (₪)	Difference ₪/month
1	Balata	6335	6500	165
2	Al-Dahya	5951	6250	299
3	Askar	4847	5532	685
4	North Mountain	4103	4293	190
5	Ras Al Ain	6815	6963	148
6	Rafeedia	8231	8942	711
7	Al-Makhfiah	8927	9167	240
8	Al-Ein Camp	8927	9394	467
9	El-Etehad	6575	6782	207
	Total	60,711	63,823	3112

First Scenario

Vehicles manufactured between 2005 and 2009 tend to have higher fuel consumption compared to newer models. To estimate their fuel usage, fixed percentage factors are applied to the general fuel consumption rate. For instance, vehicles produced before 2009 have their consumption rate multiplied by a factor of 1.15 in comparison to more recent models (manufactured between 2014-2017). Similarly, vehicles from the period of 2009-2014 have their consumption rate multiplied by a factor of 1.10. It's important to note that while these factors may not provide pinpoint accuracy, they offer a reasonable approach to calculate consumption rates. These factors are derived from average consumption rates reported by drivers of the respective vehicles and serve as an aggregate representation for estimation purposes.

Table 9 outlines the summarized results. When comparing Table 8 to Table 9, a substantial difference in savings is observed between the current conditions and Scenario 1, ranging from 17.5% to 31.3%. This accounts for a total monthly saving of approximately 125,000 Shekel across all routes; an average of 1,372 Shekel per vehicle per month. This difference in savings is quite significant.

The evident recommendation derived from this comparison highlights the replacement of outgoing old vehicles with hybrid vehicles. This transition would yield an average financial saving of about 20.9%, in addition to a substantial 33% reduction in exhaust emissions. It is also observed that specific routes exhibit higher potential for fuel cost savings compared to others. Among these, Rafeedia, followed by Balata, and Al-Makhfiah routes, demonstrate higher potential for savings due to a considerable number of older vehicles, as these routes have the highest number of older vehicles (older than 2009) among all routes. For example, Rafeedia route has 30 vehicles older than 2009 that should be replaced with hybrid (under Scenario 1). Therefore, the amount of fuel cost saving per vehicle is high, averaging around 1785 shekels and totaling 53,550 Shekels for the entire route. In terms of average savings per vehicle, the order of routes with the highest potential savings are ranked as follows: Rafeedia, Al-Ein Camp, Al-Makhfiah, and Askar. These differences are attributed mainly to the number of older vehicles and the distinct characteristics of each route.

Table (9): Financial Savings for Scenario 1.

No.	Route Name	Number of Cars	Diesel Profit ₪/month	Hybrid Profit ₪/month	Average Saving per Car ₪/month	% Average Saving per Car	Total Saving by Route ₪/month
1	Balata	17	5508	6500	992	18.0%	16,864
2	Al-Dahya	3	5174	6250	1,076	20.8%	3,228
3	Askar	7	4214	5532	1,318	31.3%	9,226
4	North Mountain	6	3567	4293	726	20.4%	4,356
5	Ras Al Ain	7	5926	6963	1,037	17.5%	7,259
6	Rafeedia	30	7157	8942	1,785	24.9%	53,550
7	Al-Makhfiah	12	7762	9167	1,405	18.1%	16,860
8	Al-Ein Camp	7	7762	9394	1,632	21.0%	11,424
9	El-Etehad	2	5717	6782	1,065	18.6%	2,130
	Total	91	52,787	63,823	11,036	20.9%	124,897

For instance, Rafeedia has the highest number of vehicles older than 2009 (30 vehicles) and the largest total number of vehicles on the route (180 vehicles), with the route being relatively flat, which contributes to its highest average savings per car. Al-Ein Camp, with 7 out of 55 vehicles older than 2009 and a route that ranges from flat to rolling, ranks second in average savings due to the combination of older vehicles and route topography. Similarly, Al-Makhfiah and Askar also show considerable average savings. Al-Makhfiah features a high number of older vehicles and a hilly topography, while Askar has 6 out of 26 vehicles older than 2009 on a flat route.

It was also mentioned that old vehicles (older than 2009) emit higher exhaust gases than newer models; this is illustrated Table 10. It is noted that rates of exhaust gases reduction are high; they are close and consistent across different routes. This indicates a high potential for switching, and provides encouraging incentive for transitioning to hybrid vehicles.

Table (10): Difference in Exhaust Emissions between Diesel and Hybrid Vehicles per Route.

No.	Route Name	No. of Cars to be Replaced	Emission Quantity (kg/year) Diesel Fuel			Emission Quantity for Hybrid (kg/year)			Emission Reduction (kg/ year)		
			CO_2-equ	HC + NOx	PM	CO_2-equ	HC + NOx	PM	CO_2-equ	HC + Nox	PM
1	Balata	17	244.80	146.88	12.24	163.20	16.32	0.82	81.6	130.56	11.42
2	Al-Dahya	3	58.75	35.25	2.94	39.17	3.92	0.20	19.58	31.33	2.74
3	Askar	7	239.90	143.94	12.00	159.94	15.99	0.80	79.96	127.95	11.2
4	North Mountain	6	90.72	54.43	4.54	60.48	6.05	0.30	30.24	48.38	4.24
5	Ras Al Ain	7	97.37	58.42	4.87	64.92	6.49	0.32	32.45	51.93	4.55
6	Rafeedia	30	1064.45	638.67	53.22	709.63	70.96	3.55	354.82	567.71	49.67
7	Al-Makhfiah	12	207.36	124.42	10.37	138.24	13.82	0.69	69.12	110.6	9.68
8	Al-Ein camp	7	180.63	108.38	9.03	120.42	12.04	0.60	60.21	96.34	8.43
9	El-Etehad	2	31.74	19.04	1.59	21.16	2.12	0.11	10.58	16.92	1.48
Total		91	2,216.23	1,329.74	110.81	1,477.15	147.72	7.39	739.08	1,182.02	103.42

Second Scenario

Following a similar calculation procedure, Table 11 illustrates the summarized savings for vehicles produced between 2009 and 2014. The savings range from 11.9% for Ras Al-Ain to 25.0% for Askar routes, resulting in a cumulative monthly saving of 523,334 Shekel across all routes. These percentages mainly arise from the relatively high operational costs associated with these routes and their topographical features, as previously mentioned. For instance, the Ras Al Ain route is hillier compared to the Askar route, resulting in higher diesel fuel consumption due to the more demanding driving conditions compared to hybrid electric vehicles. Therefore, the varying levels of savings per route are attributed to the combination of number of old cars (those older than 2014) and topographic nature of each route. The highest savings are observed on the Rafeedia, Al-Makhfiah, Askar, Al-Ein Camp, and Balata routes.

Furthermore, a closer examination of savings per route reveals their considerable amounts. Therefore, this calls for a serious consideration of implementing the second scenario.

Table (11): Financial Savings for Scenario 2

No.	Route Name	Number of Cars	Diesel Profit ₪/month	Hybrid Profit ₪/month	Saving per Car ₪/month	%Saving per Car ₪/month	Saving by Route ₪/month
1	Balata	61	5783	6500	717	12.4%	43,713
2	Al-Dahya	27	5433	6250	817	15.0%	22,067
3	Askar	63	4425	5532	1107	25.0%	69,760
4	North Mountain	20	3745	4293	548	14.6%	10,953
5	Ras Al Ain	30	6222	6963	741	11.9%	22,221
6	Rafeedia	135	7515	8942	1427	19.0%	192,665
7	Al-Makhfiah	97	8150	9167	1017	12.5%	98,639
8	Al-Ein Camp	39	8150	9394	1244	15.3%	48,512
9	El-Etehad	19	6003	6782	779	13.0%	14,804
Total (%Avg)		491	55,426	63,823	8,397	15.1%	523,334

Comparison with Other Studies

Different studies in the literature have reported varying results concerning the conversion of fossil fuel to hybrids, each addressing specific conditions, scenarios, and outcomes. Despite these differences, it can be concluded that the findings of this study align with some of the literature while diverging from others. Here is a comparison with selected studies.

Hassouna and Asaad (16) estimated that converting 50% of all PT vehicles in Palestine to hybrids could reduce CO_2 by 28%. While this result is somewhat comparable to our study, their national level study would not address for the specific characteristics of routes and their topography and considered all PT vehicles, whereas our study particularly focused on shared-taxis.

Similarly, Khan and Kar [16] found that hybrid vehicles would reduce fuel consumption and pollutant emissions by 30%, and Singh [7] reported that hybrid cars would, on average, emit 25-30% less carbon dioxide. On the other hand, Bozo et al. [8] estimated that introducing 5% hybrid vehicles at the 21 Dhjetori" intersection in Albania could reduce pollution by over 22% and CO_2 by 12%. The difference here is that their study focussed on a specific intersection with a small proportion of hybrid vehicles.

The impact of hybrid vehicles on energy and the environment was also addressed in a study conducted in China [12] from 2010 to 2020. The study estimated a 30%-33% reduction in energy consumption and pollution. Although this study is somewhat dated, its results are consistent with our findings.

Regarding cost, Tang, et al. [27] reported varying life cycle cost savings of 5% to 18% across different European countries, including the cost of battery replacement, which is considerable. These findings align with the savings reported in Scenario 2 of our study, after taking into consideration the cost of battery replacement, which was not included in the cost analysis.

In conclusions, the study results are generally consistent with other studies in the literature, with some variation attributed differences in topography and operating cost of public transport routes, among others.

CONCLUSIONS AND RECOMMENDATIONS

The world is striving to reduce fuel consumption and emissions for all sectors including transportation, as it is a major consumer of conventional fuels. Therefore, there is a global interest of exploring alternative fuels for vehicles, including hybrid system. The public transportation (PT) is one of the major consumers of fuel within the transport sector. Therefore, this study aimed to assess the viability of transitioning Nablus intra-city PT shared-taxis from diesel vehicles to hybrids, emphasizing a comparative analysis between the two systems. The significance of this study is that it takes into account the topographic nature of route (such as the city of Nablus in Palestine), in addition to the driving style of shared-taxi drivers.

Based on the current conditions (PT routes' characteristics and economic aspects), while acknowledging potential environmental benefits in terms of reduced exhaust emissions, it was found that the financial gains (revenue-expenses) from converting all shared-taxi vehicles to hybrids might not justify the switch and driver adaptations due to modest monthly savings.

Based on two investigated scenarios, it became evident that replacing old vehicles (pre- 2009) with hybrid (scenario 1) yielded substantial cost reduction (17.5% to 31%) and emission decrease (CO_2-equivalent by 33%, NOx by 88%, and PM by 93%). Similarly, scenario 2, involving additional older models (2009-2014), resulted in considerable financial savings (15% on average), in addition to reduced emissions.

In conclusion, this study has determined that transitioning Nablus's intra-city shared-taxi vehicles from diesel vehicles to hybrids is a feasible option. However, several critical factors must be taken into account before making a final decision. The topography of Nablus, with its hilly and challenging routes, plays a significant role in fuel efficiency, making hybrid vehicles a suitable choice for improving fuel economy on these demanding routes.

The overall conclusion is to immediately adopt the policy of replacing old shared-taxi vehicles (2009 or older) with hybrid since these vehicles are to be replaced anyways; at the same time financial and environmental benefits will be achieved. Then, gradually replace other shared-taxi vehicles with hybrid, particularly older models since they consume higher fuel and produce higher emission rates, in addition to all newly introduced vehicles in the PT sector.

Nonetheless, the study highlights that the environmental impact and cost of hybrid vehicle batteries were not fully considered in the calculations. Given that EV batteries are more expensive than those for hybrid vehicles, careful consideration of these costs, along with the environmental challenges posed by improper battery waste management, is essential before finalizing any transition strategy.

To facilitate citizens' acquisition of hybrid vehicles, government support through financial incentives and supportive legislation is recommended. Future research avenues should explore the potential introduction of electric vehicles in PT and delve into the comprehensive life cycle emissions of hybrid cars, encompassing battery production and disposal impacts. Additionally, research should consider the comfort of drivers/passengers when determining vehicle choices.

Despite the economic savings and the reduction of exhaust gases of hybrid vehicles, two important things cannot be ignored. The first is the emissions that a hybrid car causes over its entire life cycle from battery production and its damage when disposed, and the other is the driving comfort for the drivers or passengers; these must be taken into account in future research.

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REFERENCES

1] Sabri M, Danapalasingam K, Rahmat F. A review on hybrid electric vehicles architecture and energy management strategies. Renew and Sustainable Energy Review. 2016;53:1433-42. doi: 10.1016/j.rser.2015.09.036.

2] Palestinian Central Bureau of Statistics – PCBS. (2024). Transportation and Communication Statistics – Annual Report 2023. Palestinian Central Bureau of Statistics, Ramallah, Palestine.

3] Palestinian Central Bureau of Statistics – PCBS. Transportation and Communication Statistics – Annual Report 2022. Ramallah, Palestine: Palestinian Central Bureau of Statistics; 2023.

4] Palestinian Central Bureau of Statistics – PCBS. Transportation and Communication Statistics – Annual Report 2021. Ramallah, Palestine: Palestinian Central Bureau of Statistics; 2021.

5] United Nations. World Population Projected to Reach 9.8 Billion in 2050, and 11.2 Billion in 2100. United Nations, Department of Economic and Social Affairs. Retrieved 15 Dec 2021. https://www.un.org/development/desa/en/news/population/world-population-prospects-2017.html

6] Khan M, Kar N. Hybrid electric vehicles for sustainable transportation: A Canadian perspective. World Electric Vehicle Journal. 2009;3(1):551-62. doi: 10.3390/wevj3030551.

7] Singh S. Environmental impact analysis: carbon emission reductions in hybrid cars. International Journal of Research Publication and Reviews. 2023;4(11):2950-4. https://doi.org/10.55248/gengpi.4.1123.113207

8] Bozo L, Hajderi A, Basholli F. The impact of hybrid cars on reducing urban pollution and global warming. In: Proceedings of the 6th Advanced Engineering Days (AED) Conference; 2023 Mar 5; Mersin, Türkiye.

9] de Haan P, Peters A, Scholz RW. Reducing energy consumption in road transport through hybrid vehicles:

investigation of rebound effects, and possible effects of tax rebates. Journal of Clean Production. 2007;15(11-12):1076-84. doi: 10.1016/j.jclepro.2006.05.025.

10] Meireles M, Robaina M, Magueta D. The effectiveness of environmental taxes in reducing CO2 emissions in passenger vehicles: the case of Mediterranean countries. International Journal of Environmental Research and Public Health. 2021;18(10):5442. doi: 10.3390/ijerph18105442.

11] Hossain MA, Chen S, Khan AG. Decomposition study of energy-related CO2 emissions from Bangladesh's transport sector development. Environmental Science and Pollution Research. 2020;28:4676-90. doi: 10.1007/s11356-020-10846-5.

12] Lang J, Cheng S, Zhou Y, Zhao B, Wang H, Zhang S. Energy and environmental implications of hybrid and electric vehicles in China. Energies. 2013;6(5):2663-83. doi: 10.3390/en6052663.

13] Ercan T, Tatari O. A hybrid life cycle assessment of public transportation buses with alternative fuel options. International Journal of Life Cycle Assessment. 2015;20:1213-31. doi: 10.1007/s11367-015-0927-2.

14] Hassouna FM, Al-Sahili K. Environmental impact assessment of the transportation sector and hybrid vehicle implications in Palestine. Sustainability. 2020;12(19):7878. doi: 10.3390/su12197878.

15] Hassouna F. Sustainability assessment of public bus transportation sector in West Bank, Palestine. Environmental Research Communications. 2023;5. doi: 10.1088/2515-7620/acb03f.

16] Hassouna F, Assad M. Towards a sustainable public transportation: replacing the conventional taxis by a hybrid taxi fleet in the West Bank, Palestine. International Journal of Environmental Research and Public Health. 2020;17(23):8940. doi: 10.3390/ijerph17238940.

17] Salameh M, Khatib T, Al Sahili K. A novel design of photovoltaic-based charging station for battery vehicles with dynamic demand: a case of short runs. International Journal of Photoenergy. 2021;2021:6641548. doi: 10.1155/2021/6641548.

18] Shi X, Wang X, Yang J, Sun Z. Electric vehicle transformation in Beijing and the comparative eco-environmental impacts: a case study of electric and gasoline powered taxis. Journal of Clean Production. 2016;137:449-60. doi: 10.1016/j.jclepro.2016.07.096.

19] Gabsalikhova L, Sadygova G, Almetova Z. Activities to convert the public transport fleet to electric buses. Transportation Research Procedia. 2018;36:669-75. doi: 10.1016/j.trpro.2018.12.127.

20] Al-Sahili K, Qaisi K. A methodology for measuring a local index of public transport accessibility. Proceedings of the Institution of Civil Engineers - Transport. 2023;176(6):337-48. doi: 10.1680/jtran.20.00029

21] EU Climate Action. CO_2 emission performance standards for cars and vans. 2019 [cited 2021 Dec 15]. Available from: https://climate.ec.europa.eu/eu-action/transport-emissions/road-transport-reducing-co2-emissions-vehicles/co2-emission-performance-standards-cars-and-vans_en

22] Wikipedia. Nablus. Accessed on September 2, 2024. https://en.wikipedia.org/wiki/Nablus#Geography

23] Qin D, Zhan S, Zeng Y, Su L. Management strategy of hybrid electrical vehicle based on driving style recognition. Journal of Mechanical Engineering. 2016;52(8):162-9.

24] Huang Y, Zheng J, Yu S, et al. Fuel consumption and emissions performance under real driving: comparison between hybrid and conventional vehicles. Science of the Total Environment. 2019;659:275-82. https://doi.org/10.1016/j.scitotenv.2018.12.349

25] Kebriaei M, Niasar AH, Asaei B. Hybrid electric vehicles: an overview. 2015 International Conference on Connected Vehicles and Expo (ICCVE); 2015. p. 299-305. doi: 10.1109/ICCVE.2015.84.

26] Blank, L. and Tarquin, A. Engineering Economy, 9th Edition. New York: McGraw-Hill; 2024.

27] Tang C, Ge Y-E, Xue H, Ceder A, Wang X. Optimal selection of vehicle types for an electric bus route with shifting departure times. International Journal of Sustainable Transportation. 2023;17(11):1217-35. https://doi.org/10.1080/15568318.2022.2079445