An-Najah National University

Faculty of Graduate Studies

Hybrid Vehicles for Nablus Intra-City Public Transportation: An Environmental and Economic Feasibility Study

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This Thesis is Submitted in Partial Fulfillment of the Requirements for the Degree of Master Degree of Clean Energy Conservation Engineering, Faculty of Graduate Studies, An-Najah National University, Nablus, Palestine.

2022

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Dedication

To My Beloved Family with

Respect and Love

Acknowledgment

First of all, I am thankful to the almighty God for granting me good health, strength and peace throughout the research period.

I would like to express my sincere gratitude to my academic advisor Dr. Khaled Al-Sahili. I am grateful for his continuous support, patience, motivation, enthusiasm, and knowledge. His guidance helped me all the time of the research, and writing of this thesis that I would never reach on my own.

Last but not least, I would like to thank my family especially my parents for supporting me spiritually through my life, and I offer my gratitude for my precious friends who helped me in this research.

Declaration

I, the undersigned, declare that I submitted the thesis entitled:

Hybrid Vehicles for Nablus Intra-City Public Transportation: An Environmental and Economic Feasibility Study

The work provided in this thesis, unless otherwise referenced, is the Researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

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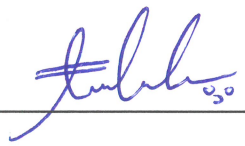
Signature: 

Date: 21/9/2022

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HYBRID VEHICLES FOR NABLUS INTRA-CITY PUBLIC TRANSPORTATION: AN ENVIRONMENTAL AND ECONOMIC FEASIBILITY STUDY

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Abstract

Background: There is a worldwide concern about the serious increase in exhaust emissions from vehicles that use traditional fuels, such as diesel, and the rise in fuel prices. Palestine is no exception. Nablus, the second largest city after East Jerusalem, has several types of topography, and suffers from traffic congestion. Within its urban area, traffic flows at low speeds, and drivers are normally forced to stop-and-go operation. This increases fuel consumption and the emission of exhaust gases of the diesel - operated public transport (PT) vehicles.

Objective: Against this background, this thesis explores the possibility of introducing alternative fuel vehicles (hybrid vehicles) particularly to Nablus urban public transportation.

Methodology: Interviews were conducted and a questionnaire was administered to a randomly chosen sample of PT drivers and route managers to obtain the operational characteristics of PT route and its associated costs and expenses. The existing financial aspects and environmental impacts of diesel vehicles were also analyzed.

Results: Three scenarios were developed. The first scenario is replacing old cars (2009 or older) with hybrid vehicles. This scenario would provide 17.5% to 31% saving of fuel on an average of 20.9% for all PT routes, and reduction of exhausts CO by 33%, CH+NO by 88%, and PM by 93%. The second scenario is replacing all vehicles produced between 2009-2014. This scenario would save 15% of fuel and reduce exhaust gases by 35%. This gives this scenario an importance in the long run, and there is no urgency for implementation at present. Finally, the third scenario is replacing old diesel vehicles with 7-passenger vans. This would save 31% of fuel on the economic side, and lead to a 33% reduction in exhaust gases in general.

Conclusions: The comparison between the three scenarios shows preference for the first scenario at present, while implementing other scenarios gradually. The first scenario is simple and close to reality, as old vehicle should typically be replaced; therefore, the study concluded that it would achieve financial and environmental benefits if PT went hybrid.

The study recommends setting up national level policies to encourage the use of alternative fuels, with particular focus on public transportation. At the same time, such policies should also include the transportation sector, in general.

Keywords: Public transport (PT), Vehicles, Emission, Hybrid, Diesel.

Chapter One

Introduction

1.1 Background

The transportation sector is one of the most important sectors that concerns researchers, and the Ministry of Transport seeks to develop it and improve the quality of service provided to citizens.

There is no doubt that hybrid cars have proven to save fuel and reduce exhaust emission. 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.

Hybrid cars actually started in Palestine in limited numbers; they are present in very few percentages. This makes collecting information about them somewhat challenging. However, based on data collected through interviews with hybrid car owners, the economic savings of these cars is approximately one third compared to diesel cars. Of course, this percentage is approximate and not based on a stable scientific basis. Nevertheless, it is considered a preliminary indicator and logical for fuel consumption and reducing exhaust gases.

In a recently published study on hybrid vehicles in Indonesia, hybrid vehicles were divided into two parts (1). The first is hybrid vehicles that use a gasoline engine and an electric motor that are unable to be charged from the charging station (HEV), and the other is hybrid vehicles that consist of a gasoline engine and another that can be charged (plug-in hybrid vehicles PHEV). The fuel consumption for conventional hybrid vehicles is approaching 23 kilometers per liter and for hybrid vehicles approaching 30 kilometers per liter. These values are certainly more efficient than gasoline-burning vehicles that consume approximately one liter per 13 kilometers.

To ensure the continuity of providing services and achieving sustainable development, it is necessary to make optimal use of the available resources. One of the ways of exploitation is to provide the fuel used for public transport vehicles by managing the use

of this fuel in a way that ensures its durability for a longer period and providing good performance for the vehicles.

The transportation sector is one of the most important contributors to the exhaust gases released to the environment in Palestine. It constitutes more than 40% of energy consumption (2).

The number of vehicles in the West Bank reached nearly 300,000, of which public vehicles made up approximately 3.5%, or about 10,000 vehicles distributed among buses of various sizes: small 17 passengers, medium 25 passengers, and large 50 passengers. As for cars, they are two types, small cars of 4 passengers, used for intra city and 7-passenger cars typically used for inter-cities trips (3).

With the increase in the demand for traditional cars (internal combustion engines) in Palestine, the problems of environmental pollution will certainly increase. The percentage of vehicles that use traditional fuel in general reaches approximately 99%. As for public transportation vehicles, the percentage reaches 100% using traditional fuel, specifically diesel fuel (2).

Although there is no clear date for the depletion of conventional fuels from the world; however, many international reports talk about the approaching fuel economy, and at the same time countries are striving to facilitate accessibility to alternative fuels. This is related to thinking that it could become less expensive in the long run-in case it becomes easier to obtain, unlike conventional fuels, which are all close to depleting and becoming scarcer, and thus more expensive.

1.2 Public Transport in Palestine

Public transportation (PT) provides people with mobility and access to their jobs, schools and universities, community resources, medical stations, and more. It benefits those who choose to use the PT, as well as those who have no other choice. Here are the definitions of the two important terms of PT (3).

Public Transport: (also known as public transportation, public transit, or mass transit) is the transport of passengers by group travel systems available for use by the general

public, typically managed on a schedule, operated on established routes, and that charge a posted fee for each trip (3).

Transport modes: are the means by which passengers and freight achieve mobility. They are mobile transport assets and fall into one of three basic types; land (road, rail and pipelines), water (shipping), and air.

The Ministry of Transport (MOT) is the agency responsible for regulating and administering the services. MOT issues the bus companies and taxis permits designating what routes they can use. The licenses for drivers and vehicles are also issued by the MOT, in addition to the transport fare (tickets fees).

1.2.1 Public Transportation in Nablus City

Public transportation (PT) system in Nablus consists mainly of taxis and busses; taxis are either shared or private taxis with a capacity of four seats (which constitute the majority) or seven passengers. Busses, on the other hand, which are owned by private companies, are either small busses with a capacity of twenty seats or normal busses with fifty seats.

A shared taxi is usually owned by a person, who is usually the driver, or hiring someone to work on it, or both of them work by a shift system and the wages are a percentage of the income. For the private taxis, a group of taxis owned by one or more having an office in the city, hiring drivers to work on them with a fixed wage, and their terminal is the office's parking.

The PT routes in Nablus City are divided into external (inter-city), which connects Nablus City with its villages and the other cities, and internal (intra-city), which is inside the city itself. For the external network there are three terminals for stopping and loading. The Eastern Terminal is mainly for the eastern villages and the two Western Terminal secretor intercity transportation. For the internal network there is one terminal in the center of the city at "Nablus Municipality Commercial Center" (the basement floors) where it is the starting point for all the shared taxis to go to their destinations. For the busses that transport internally they take "Hamdi Kanaan Street" as a station for stopping and loading.

The responsible body for the PT system in the city is Nablus Municipality, which organizes the shared taxis in two floors at “Nablus Municipality Commercial Center”; Basement-1, which contains four routes mainly for east destinations and Basement-2 with five routes for west destinations.

Each route has a supervisor or a manager to organize taxis and passengers, for conflict resolution, and collecting the terminals’ fees every day from the drivers. The municipality is also responsible for the (urban) roads, signs, signals, or any other repairs related to PT system within its urban boundaries.

The commonly observed public transportation problems in the city include circulating empty; therefore, adds to congestion, high fuel consumption, fuel emissions, bad odors produced by the diesel fuel cars, poor management system, among others. Several of these are common in other Palestinian cities, and in many other cities in the developing countries.

The environmental problems of air pollution and high fuel consumption have opened the door to thinking about alternative solutions; some of which are hybrid cars and electric cars. Both alternatives are considered to achieving the Palestinian Environmental Authority's strategies to reduce exhaust gases and reduce fuel consumption, as they are considered energy-saving alternatives. At the same time, diesel fuel prices are relatively cheaper than electricity, and diesel fuel vehicles are cheaper than electric vehicles. On the other hand, maintenance requirements for both systems vary. Furthermore, these parameters will certainly vary from one region to another in the world. Therefore, what worked successfully in one country might not work the same in a different country.

1.3 Problem Statement

More than 20,000 vehicles in general and more than 640vehicles in public transportation were newly registered during the year 2020 in the West Bank(3). This number constitutes an indication of the remarkable increase in the demand for conventional cars and thus will lead to an increase in emissions. In addition, the high fuel prices in Palestine are a burden on the shoulders of the citizens who are always looking to save money in fuel expenses and others.

Therefore, thinking of electric cars as an alternative solution to the problem of emissions and reducing consumption in economic terms opens the way of thinking. At the same time, the Israeli occupation controls electricity networks, specifically production, and sets quotas for Palestinian cities that are not sufficient to meet the citizen's electricity needs. And in the event that new electrical loads, such as the electric car, are added, this will weaken the electric network. Therefore, there is a need to strike a balance between the existing conventional system with all its limitations and the need for more developed, less expensive, and environmentally friendly one.

1.4 Research Scope and Objectives

This research discusses the economic and environmental feasibility and its reflection on public transportation in Palestine. The main objectives of this thesis are:

1. To conduct a feasibility study of replacing diesel vehicles with hybrid vehicles for public transportation services within the city of Nablus.
2. Compare between vehicles that use diesel fuel and hybrid vehicles.
3. Study the environmental and economic feasibility for switching from conventional to hybrid fuels.

1.5 Research Importance

The importance of the research lies in that it targets many aspects such as the economic, environmental, and social aspects; therefore, improving the service coverage.

The economic aspect is something that cannot be neglected in light of the economic crisis that the world in general and Palestine in particular are suffering from, as a result of the many political conflicts and the Covid-19 pandemic, which made the economic situation very difficult. Therefore, there is a need to explore alternatives for reducing economic burdens on the country and its citizens. One aspect is by reducing fuel consumption and raising the efficiency of public transport by using hybrid vehicles as an alternative to traditional fuel vehicles, specifically diesel. On the other hand, we have the environmental aspect, which is equally important in light of the escalating rates of emissions in the environment, which led to the problems of global warming and many environmental problems. This has reached alarming rates; therefore, the environmental

dimension cannot be neglected and proactive steps must be taken before the situation worsens.

Hybrid use is an alternative to traditional fuels. It is part of reducing emissions and achieving sustainable development goals that seek a better and safer environment. In the end, the research studies the possibility of opening new routes that serve citizens, and contribute to raising the quality of service in public transportation.

1.6 Study Area

The study area is Nablus City in the north of the West Bank. It is located at latitude 32.13 N and at longitude 35.16 E. Nablus is the second largest city in the West Bank after Hebron in terms of population. It is also considered as the one of the largest commercial centers, in turn joining the prosperity of economic conditions attracting commercial, shopping, and tourism activities. It has the largest university in the West Bank in terms of number of students.

Thus, Nablus City is considered as a large and dense development. In recent years, it has been observed the increase in urban expansion development of the city in general. The Planning Department of Nablus Municipality is working on a plan to expand the master plan of the city, especially from the western side to reach for new areas exceeding the current city boundaries. Therefore, the consideration of Nablus City as a case study is an appropriate and representative choice for the purpose of this research. Figure 1 shows location of Nablus Governorate with respect to the West Bank, where Nablus City is in the heart of the governorates.

Figure 1

Location of Nablus in the West Bank (4)

1.7 Thesis Structure

This thesis is composed of six chapters. Chapter One includes the background and importance of PT as a means of sustainable and social transportation, objectives, the research importance, study area, and thesis structure. Chapter Two presents a review of selected literature. Chapter Three outlines the research methodology while Chapter Four explores data collection and manipulation process in preparing for analysis. Chapter Five is the presentation of analysis of collected data and presents and discusses the results. Finally, Chapter six provides the conclusions and recommendations of this study.

Chapter Two

Literature Review

2.1 Overview

This chapter presents a review of the literature related to the challenges faced by the transportation sector and public transportation in the world in general, and in the State of Palestine in particular.

Emissions and fuel consumption of vehicles are among the most important challenges that will be reviewed in this chapter, especially since there is a group of international researches that discussed these two problems and presented some potential solutions and recommendations.

The research provides reviews on comparing vehicles that use conventional fuels, gasoline and diesel, and hybrid engines. It also explores the possibility of their service for the transportation sector and as a solution to the problem of emissions and fuel consumption.

Finally, the chapter presents a brief analysis of the Palestinian context, with a focus on public transportation internal routes in the city of Nablus in the West Bank.

2.2 Public Transport Sector

Infrastructure bottlenecks such as the lack of roads, railways, and aircraft are among the main factors that made the transport sector to begin to gradually move to the use of land vehicles (buses, cars).

In light of the models that are likely to grow 8% in passenger traffic annually and freight traffic by more than 5% in India, this will lead to an increase in energy consumption and carbon dioxide emissions(5).

The effects of different policy options aimed at reducing energy consumption and CO_2 emissions were analyzed using a scenario approach in India. Scenario analysis showed that efficiency improvements can reduce future energy consumption and CO_2 emissions by 26%. If the modal split was promoted in favor of public transport modes (rail and

general road transport), a 45% reduction in energy requirements and CO_2 emissions would be expected(5).

The close connection between the transport sector and the economy requires great attention in the transport sector to achieve rapid growth in the economy, especially in developing countries. There is no doubt that reducing fuel consumption and emissions is an essential component of sustainable development.

The adoption of the five-year system in development, 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, will reduce the rate of carbon dioxide emissions in Bangladesh to 110 percent between 1990 and 2017, as the results showed (6). Also, the aggregate effect of the economic activity factor, population factor, economic structure factor, and energy intensity factor are responsible for the increase in CO_2 emissions to 66.03%, 23.56%, 7.64%, and 6.25%, respectively.

Hybrid engines are a promising way to raise the overall fuel efficiency of passenger cars. The entry of hybrid vehicles to the car market is in increasing numbers. On the other hand, is it possible for hybrid vehicles to have regressive conditions that reduce their fuel efficiency? A survey of 367 second-generation Toyota Prius hybrid buyers in Switzerland in the first nine months after entering the market was conducted (response rate 82.6%). As a control group, questionnaires were also sent to 250 Toyota Corolla buyers (61% returned) and 250 Toyota Avensis (52%) 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. 6% of hybrid car purchases did not replace a previously owned car, the Swiss market average is 20%. Hence the rebound effects can be determined neither for the size of the vehicle nor for the ownership of the vehicle. As an energy policy measure, hybrid vehicles are eligible for tax deductions in parts of Switzerland. The research found that tax cuts helped increase the spread of hybrid vehicles. The economic aspect is a very important factor in encouraging the acquisition of these vehicles (7).

The current optimization strategy for a parallel hybrid requires much computational time and relies heavily on the drive cycle to accurately represent driving conditions in the future. With increasing application of the lithium-ion battery technology in the automotive industry, development processes and validation methods for the battery management system (BMS) have attracted attention (7). The paper proposed an algorithm to analyze charging characteristics and improve accuracy for determining state of charge, the equivalent of a fuel gauge for the battery pack, during the regenerative braking period of a Transmission-mounted electrical device-type parallel hybrid electric vehicle.

Ercan and Tatari (8) 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 causes significantly low CO_2, emissions than diesel and other alternative fuel options, while some of the driving cycles of the hybrid-powered transit bus cause 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 have less environmental emissions, the US's dependency on fossil fuel for electricity generation continues to yield significant lifetime impacts on BE transit bus operation.

2.3 Environmental Aspects of Hybrid Vehicles

The impact of hybrid vehicles on energy and the environment has been addressed in a study conducted in China. The promotion of hybrid and electric vehicles has been suggested as a promising solution to reduce transportation energy consumption and reduce vehicle emissions in China (9). The environmental impacts of hybrid (HEVs) and electric vehicles (EVs) during the period between 2010-2020 were focused on through a Life Cycle cost Analysis (LCA), energy consumption per kilometer of gasoline, and then converting gasoline into equivalent gas, coal, and oil. Gas (NG), oil, biomass, litter, and electricity were estimated for HEVs and EVs. It has been shown that EVs and HEVs can reduce the energy consumption of vehicles nationally, the average proportions were 17% -19% and 30% -33%, respectively. The study also calculated

detailed emission factors for sulfur dioxide, nitrogen oxides, volatile organic compounds, carbon dioxide, NH3, PM10, PM2.5, OC, EC, CO_2, N_2O, Methane, lead, and mercury. It is indicated that HEVs could lead to significant reductions in NOx Emissions of volatile organic compounds and carbon dioxide and less carbon dioxide and carbon dioxide emissions for a single vehicle. Electric vehicles can reduce many volatile organic compounds, NH_3, CO and carbon dioxide emissions, but would increase sulfur dioxide and nitrogen oxide and particles by 10.8 - 13.0, 2.7 - 2.9, and 3.6 - 11.5 times, respectively. The study concluded by recommending using of hybrid and electric vehicles in a wide range, especially in places that contain large concentrations of polluting gases (9).

A research on the potential of plug-in hybrid vehicles to reduce carbon dioxide emissions was conducted in Japan (10). The aim of the study was to evaluate the potential of plug-in hybrid electrical vehicles (PHEV) to reduce carbon dioxide emissions. The vehicle data was for 35 conventional HEVs from April to August in 2011. The results showed that the 43% travel distance was switched to EV mode, and that gasoline consumption had been reduced by 44%. Fully carbon dioxide emissions had been reduced by 17% taking into account electrical energy consumption. The amount of carbon dioxide reduction was in the range of 1-44%. The study recommended that the use of PHEV is more effective in reducing carbon dioxide(10).

Although the use of electric vehicles (EVs) is an option to reduce emissions from internal combustion engines (ICEVs), the environmental impacts of electric vehicles cannot be neglected, and this is what the researcher discussed in a study in which the environmental impact of the increase in the proportion of electric vehicles in Brazil. The results of the research indicated that electric vehicles were better for abiotic depletion, global warming, ozone layer depletion, and fresh water aquatic ecotoxicity. In these categories, however, the lack of advance planning, leading to thermal electricity generation, could diminish EVs benefits or make them worse than ICEVs(11).

When talking about plug in hybrid vehicles, we find in front of us a lot of details that must be taken into account, and one of these important things is the electricity network and its ability to charge the batteries of vehicles.

This was discussed in a research sample of 37 million vehicles in the United States of America divided into several types of large, medium, and small vehicles so that the vehicles will travel average distances of 55 km per day. The research discussed the cost of electricity production in addition to the emissions resulting from the production of electricity. The results showed that charging during the day increases CO_2 emissions and costs compared to charging at night(12).

In order to know the environmental impact of a type of vehicle and compare it with another type to determine, which is less harmful to the environment, it is necessary to compare all existing types of vehicles. The researchers compared four types of vehicles in terms of the environmental impacts on a life cycle assessment (LCA) perspective: a conventional gasoline vehicle, a pure electric vehicle, a plug-in hybrid gasoline-electric vehicle, and a plug-in hybrid fuel cell-battery vehicle(13).

In order for the comparison to be logical and accurate, the researchers installed the power systems for all the previous types of vehicles so that the evaluation is done only on the basis of the type of fuel used in the engine. As for the rest of the parts, such as the power transmission systems and the chassis in the vehicle, are similar for all types, in addition to preparing a driving simulation system to assess the impact on fuel consumption. The results of the study indicated that the environmental impact of the four types of compounds was the least effective to the most effective lowest value corresponded to plug-in hybrid gasoline-electric vehicle, followed by the plug-in hybrid fuel cell-battery vehicle, the pure electric, and finally the conventional gasoline vehicle(13).

In light of the increasing demand for vehicles that use traditional fuels such as gasoline and diesel, which leads to financial pressures due to fluctuations in oil prices, and the vehicles that use traditional fuels pose a threat to the environment that cannot be ignored. In a study, which was conducted on a research sample in Canada, the researcher discussed the possibility of using hybrid vehicles as a step for effective sustainability in the transportation sector to become environmentally friendly(14).

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. The research 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 came as expected that the use of hybrid vehicles would reduce fuel consumption and pollutant emissions by 30% through the preparation of practical experiments for the impact of a type of vehicle, through which two vehicles from the same company were compared with the same specifications with different fuel used, one of them uses conventional fuel and the other uses a hybrid engine.

For example, the Honda Civic hybrid car provided savings in exhaust gases that amounted to 1450 kg of emissions throughout the year, which was31 percent less than the similar Honda Civic car in strength and speed, but it uses a gasoline engine. And when this was applied to the number of cars of this type in Canada, it was possible to reduce more than 100 kilotons of carbon dioxide per year. At the end of the study, the research made recommendations to the Canadian government to replace light vehicles with other vehicles that are similar in strength and shape, but use a hybrid engine so that the switch would be within a specific time range determined by the situation of each city during the next 30 years(14).

Studies indicate that the world population will increase from 7 billion in 2020 to 10 billion by 2050, which means that we will have from 700 million to 2.5 billion 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, so energy conservation and environmental protection are a global goal(15).

In a study conducted in 2007, it was shown that approximately 39% of emissions were emitted from vehicles, and this was a very high percentage. After that, governments in Europe and America decided to challenge it and try 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, which makes companies think of a less expensive alternative that the customer can buy.

Vehicle manufacturers had taken three directions, hybrid vehicles (use both fuel and electricity), fully electric vehicles, and vehicles based on fuel cells (hydrogen)(15).

The study presented results stating that the development on electric vehicles is more effective than working on hybrid cars, which were difficult to convince the customer due to their high initial price, and the expected danger of working on fuel cells is an important obstacle as well. This lead to the fact that the development of electric vehicles and raising its efficiency would bae successful investment(15).

2.4 Types of Vehicle Engines

We also know that there are many types of engines that vehicles can use, for example, engines that use diesel fuel, gasoline or gas, and it is possible to use hybrid engines that depend on two sources of energy, and finally, electric motors can be used in vehicles. This applies to most countries, the situation in Palestine is a little different. There is no law that limits the use of any type of vehicle, but the vast majority of drivers prefer to use diesel fuel because of its advantages, the most important of which is economic saving and its low price compared to gasoline, and possibly to other energy types.

2.4.1 Diesel Engine

Despite the efficiency of diesel fuel when used in vehicle engines, numerous researches explored finding alternatives to it and many countries issue laws to limit the spread of vehicles that use diesel fuel, which is a serious threat to the environment.

Research tries to find an alternative to diesel fuel, which is to use vegetable oils and compare the results of emissions by integrating vegetable oils (bio diesel) with diesel in certain proportions and measuring the number of emissions issued. It was found that it is possible to reduce 26% of emissions after merging 20% of vegetable oil with 80% of diesel. This study leads us, but it is possible to reduce diesel emissions and open the way for research in other ways, including what companies think of using hybrid engines(16).

2.4.2 Hybrid Engines

They are engines that are similar to traditional engines, but they depend on two sources of energy, usually a gasoline engine and an electric one (the most widespread) and it is

possible to adopt another type of fuel. The electric motor, which is fed by a lithium battery when the vehicle is lightly loaded, such as starting, low speeds, slopes, and easy roads, and it also operates the gasoline engine to charge the battery if necessary (17).

The idea of the spread of hybrid vehicles began as a solution that saves fuel consumption and reduces exhaust emissions, but it is not a magic solution that everyone expects (17).

2.5 The Environmental Aspects of the Transportation Sector in Palestine

An environmental impact assessment of using hybrid vehicles in public transportation in Palestine has been conducted. The study recognized that the environment is one the most important aspects of the sustainable development in the public transport sector in Palestine, as transportation is one of the most important contributors to the export of exhaust gases to the environment (18). Based on the data extracted from the prediction of future conditions, the researchers developed two scenarios. The first is to raise the percentage of hybrid vehicles to 10% and the second is to raise the percentage of hybrid vehicles to 20% of conventional internal combustion engine vehicles, which currently constitute 99%.

The results showed that the emissions of carbon dioxide, nitrous oxide, and methane estimated from the transportation sector in 2020 was 4,842,164.5, 213.8, and 445.8 tons, which are very high, and even much higher than the total national emissions for 2014. 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%. The research concluded that the second scenario would achieve a more sustainable transportation system (18).

Another research on assessing the impact of a hybrid vehicle engine type on the economic efficiency and environmental safety was conducted. The article provides a comparative assessment of the environmental and economic efficiency of vehicles with multiple engine types. It included the results of calculating emissions from the production and operation phases, a generalized assessment of the environmental impact

on the environment at all stages of the life cycle, and the results of the transportation cost calculation for comparison. The study concluded that the toxic emissions that contain carbon dioxide and nitrogen oxides that harm human health could be reduced to a large extent by using hybrid cars (19).

2.6 Hybrid Vehicles in Public Transport

There is no doubt that the exhaust emissions of cars that run on conventional fuels, gasoline or diesel, are one of the main causes of environmental problems in the atmosphere such as global warming and haze.

Replacing conventional fuel vehicles with electric vehicles is a new way to reduce urban air pollution in many countries such as America, Japan, European Union countries and China (20).

In 2011, Beijing launched a plan to replace electric vehicles (such as mid-range taxis) with gasoline vehicles (such as Hyundai taxis) with low-carbon conversions. The study used local data and life-cycle assessment-based analysis to compare the environmental impacts of switching from gasoline-powered Hyundai cars to electric midi cars. The researcher constructed a life cycle analysis (LCA) model using GaBi6 software and an integrated life cycle assessment model by CML2001 (problem oriented) and EI99 (damage oriented) models, which evaluated the comparative environmental impacts of the full life cycle, production phase, use phase and end of life. Finally, fog-induced major factors, major life cycle processes, and sensitivities of age and electrical power mix were analyzed (20).

The results indicated that in light of the whole life cycle assessment, electric vehicles can play an important role in reducing the possibility of global warming, and depleting the ozone layer; while EVs also showed the effects of increases in acidification potential, nutraceuticals, human toxicity, and environmental toxicity (marine and terrestrial aquatic). On the basis of analysis of inventory and electricity mix data in Beijing 2010, the comparative results of haze pollutant emissions showed that the full life-cycle emissions of VOCs from an average electric car were lower than that of a Hyundai gasoline car, but PM2 emissions, NOx, and SOx from a midi electric car were

higher than that of a gasoline-powered Hyundai car. These differences are mainly caused by different emissions during the phases of use.

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 and 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 (21).

Hybrid electric vehicles and electric vehicles are among the most promising ways to reduce fuel consumption and reduce emissions in automobiles. Based on published data from various sources, researchers made an economic and environmental comparison of a conventional, hybrid, and electric vehicle - currently available on the Greek market (21).

Three different electricity generation scenarios - high, medium, and low carbon - were investigated. According to the comparison, hybrid and electric cars showed advantages over conventional cars. In the scenario of carbon-free electricity generation, the environmental benefits of electric vehicles were significant because 55.2% of the total greenhouse gas emissions and 61.4% of the total air pollution emissions originate from conventional cars; while 6.85% and 5.76% of the total generated air emissions were emitted by electric vehicles. It turned out that the environmental impact of using an electric vehicle depends on the source of the electricity. Moreover, three scenarios related to the penetration rate of alternative energy propulsion systems in the Greek market for the years 2012-2025 were investigated (22).

2.7Summary

Based on the reviewed literature, it is generally concluded that the use of hybrid vehicles rationalizes fuel consumption and reduces emissions. However, there is an important factor that is difficult to control in every country, which is the driving style and topographic nature, in addition to the fluctuating fuel prices in each country. Furthermore, there are limited published scientific articles about the use of hybrid vehicles in public transportation (buses and taxis). The majority of articles were in the form of project reports, articles in newspapers, or information published by

manufacturers (sounds like promotion material) and interested agencies, and the majority focused on hybrid buses. In addition, the driving style plays an important factor and has a great impact on the performance of hybrid and conventional fuel vehicles.

Therefore, this research will focus on urban public transportation in Palestine, specifically the city of Nablus, taking into account its topographic nature (mountainous), the driving style of public vehicle drivers (forced slow driving and frequent stop-and-go due to urban area congestion, as well as the general reckless driving behavior, when feasible), and the characteristics of existing public transport routes. Finally, the fixed costs and variable costs for public transport vehicles and services vary from one country to another.

Chapter Three

Research Methodology

3.1 Overview

This chapter describes the methodological approach adopted by the study to achieve the study objectives. This includes the research overall approach, methodology steps, sampling, data types, collection, and analysis.

3.2 Research Strategy

According to Creswell, the research approach “are plans and procedures for research that span the steps from broad assumptions to detailed methods of data collection, analysis, and interpretation”. The three research approaches are qualitative, quantitative, and mixed methods. Choosing any of the aforementioned approaches to address the research problem depends mainly on the research problem nature and the researcher experiences (23).

The qualitative approach aims to explore the meaning of peoples, experiences, cultures by collecting and analyzing qualitative data through observations and interviews. The quantitative approach aims to analyze the relationships between variables which can be measured by instrument such experiment and survey. After that, the data can be statistically analyzed. The mixed method approach integrates qualitative and quantitative data in the same study (23).

The main objective of the research is to study the economic and environmental feasibility of switching public transport vehicles in Nablus city internal routes to hybrid vehicles. This comes to achieve the goals of sustainable development in reducing emissions from diesel fuel. Reducing emissions leads to the preservation of the environment. The second goal is to manage resources in a better way by reducing fuel consumption.

The study approach combines conducting oral interviews with drivers, distributing questionnaires to them, taking random samples and studying them in a detailed manner.

3.3 Stages of the Methodology

Figure 2 illustrates the flow chart of the methodology adopted by the researcher in order to achieve the research objectives. The methodology comprises mainly of five steps. These steps are discussed in the following sub-sections.

A) Stage one: Defining the Problem

At this stage, the researcher identified the problem that all PT vehicles in Palestine including Nablus use diesel fuel, which is not an environmentally friendly fuel. Furthermore, the main station in Nablus City suffers from the high rate of vehicle emissions, which is indicated by the bad odor produced by diesel engines.

B) Stage two: Previous Research Study

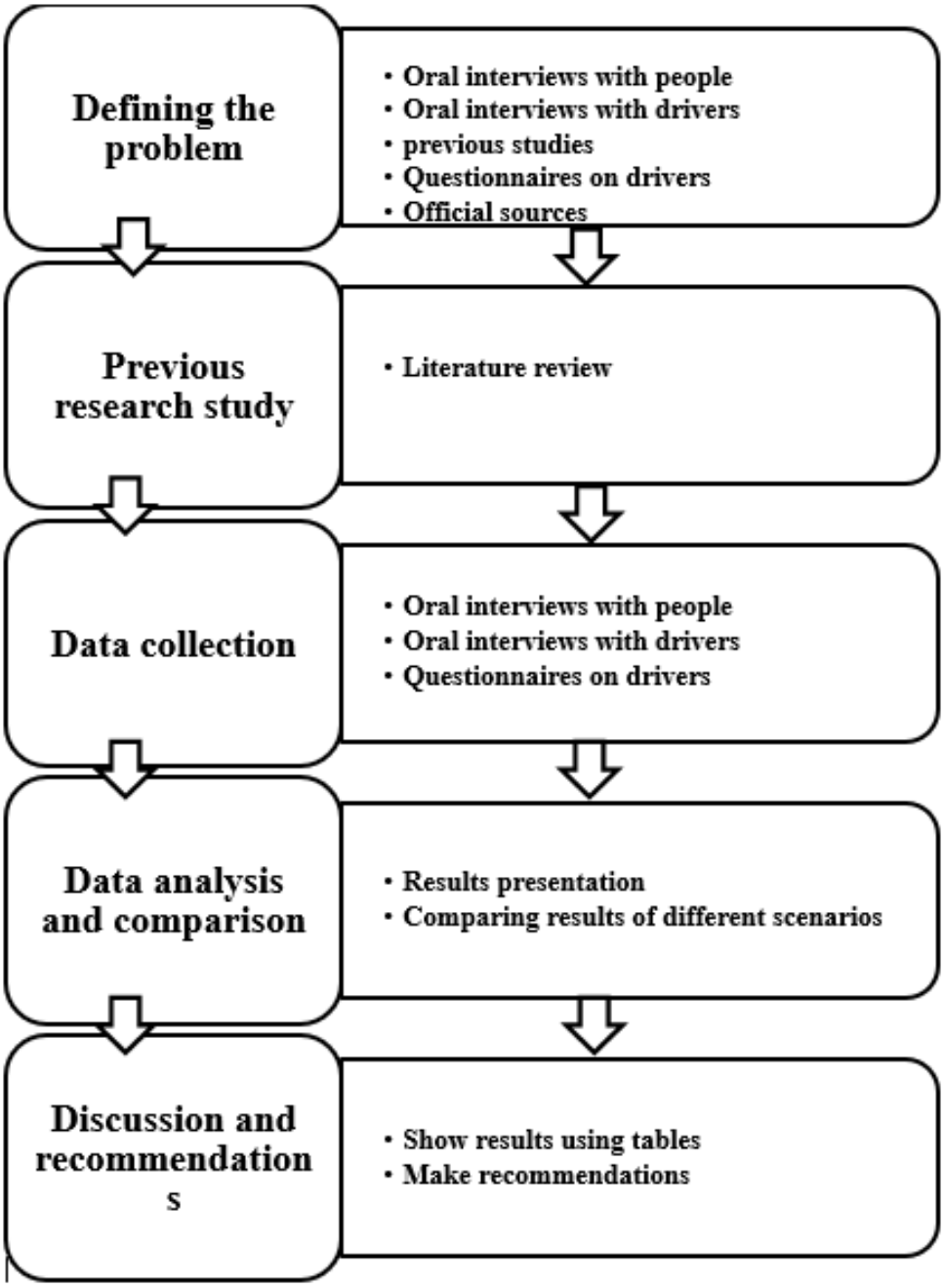
At this stage, several publications and research related to the scope of this research have been reviewed from various countries of the world. By reviewing these, more information has been obtained about the subject.

C) Stage three: Data Collection

In this study, many data types (quantitative and qualitative) were gathered to achieve the research objectives. The researcher collected data from the main public transportation station. This stage included more than one data collection tool; the most important of which was conducting in-person interviews with drivers, PT line supervisors, and station officials, in addition to distributing a survey form to drivers. The survey formwas prepared and questions were clear and direct so that the answers meet the need of the research, and it was made simple so as to target drivers with different educational and cultural attainments. Additional data about PT routes in the city was also collected from official sources and previous reports. Details of these data and their interpretations are presenting in the following chapters.

Figure 2

Research methodology stages



D) Stage four: Data Analysis and Comparison

At this stage, the data was analyzed, categorized in tables, and compared in order to obtain the best solutions that meet the economic and environmental aspects.

E) Stage five: Discussion of Results and Making Recommendations

In the fifth and final stage, the results become clearer, through which the researcher presented the proposed recommendations.

Chapter Four

Data Collection and Existing Conditions of PT in Nablus City

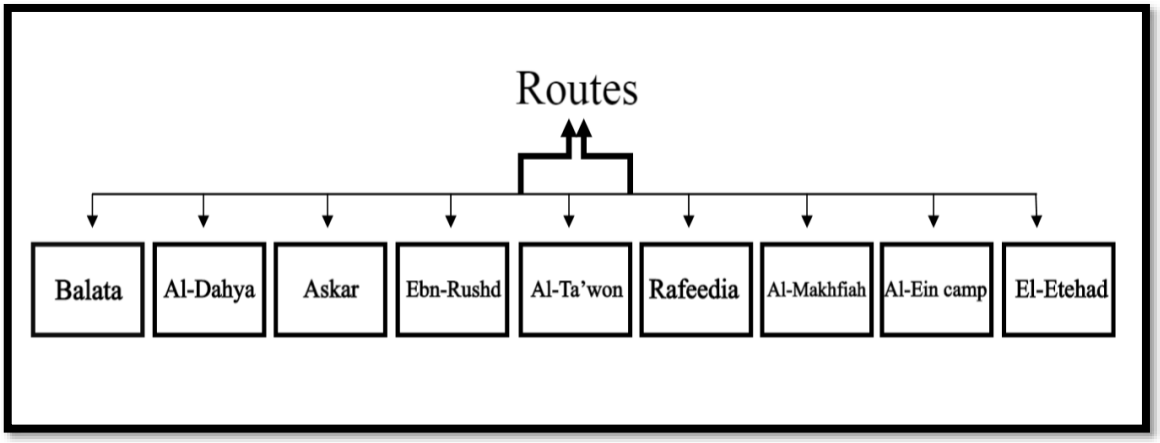
In this chapter, data about public transportation (PT) within the city of Nablus a represented for each PT route. This includes the number and type of vehicles, bus or car, transfers in each route, repair costs, and fuel consumption and emissions for each.

4.1 PT Routes

In Nablus City, there are 9 public transportation routes or paths that citizens take to reach their destinations (see Figure 3). The traveled distances and the type and number of taxis vary. A survey form has been prepared for each route to obtain detailed information related to its operation and cost.

Figure 3

PT Routes in Nablus City



4.2 PT Data

The data collection methodology was based on the survey form, shown in Figure 4 which was collected through field visits of the stations and conducting group interviews with drivers and managers. The sample included approximately 10 drivers in each group, with a total of 400 drivers, which constitutes approximately 60% of the total drivers working at the station. The interview included 10 main questions related to the vehicles, costs and expenses, daily trip characteristics, fuel consumption, etc., as shown in Figure 4.

Figure 4

Survey Form for Shared-Taxi Drivers

Survey

transportation line _____

1	Vehicle type	Car, bus, mini bus
2	Vehicle production year	
3	The manufacture company	
4	Monthly maintenance	
5	Number of moves per day	
6	Daily distance traveled km	
7	Daily fuel consumption	
8	Daily station fee	
9	Number of main moves	
10	Number of sub moves	

4.2.1 Number of Vehicles for PT Routes

The following table (Table 1A) shows the distribution of vehicles on the entire routes and their division based on a 4-passenger or 7-passenger vehicle.

Table 1A

Number and Type of Vehicles for Each Route

No.	Route Name	Number of Vehicles (4 seats)	Number of Vans (7 seats)
1	Balata	80	-
2	Al-Dahya	40	-
3	Askar	101	-
4	North Mountain	26	-
5	Ras Al Ain	40	-
6	Rafeedia	175	5
7	Al-Makhfiah	104	16
8	Al-Ein Camp	60	-
9	El-Etehad	31	-
	Total	657	21

4.2.2 Daily Distance Traveled

The trips that a shared-taxi do are classified into two types; main and secondary. These are described as follows.

1- The main trip, which is when the driver loads passengers from the main station to the selected destination. The vehicle is full when 4 passengers board, and the driver does not take off before the number is complete.
2- Secondary-trip, which is when the taxi returns to the main station and picks passengers along the road, transferring them at the same price; the vehicle might be completely full.

The existing income and expense analysis was estimated by considering the number of vehicles, number of trips, and number of passengers. Table 1B shows the length of the routes, number of trips, and number of passengers (daily) per route per vehicle. The lengths of routes were obtained from Nablus Municipality, while numbers of trips were obtained by asking several drivers and taking the average, then by multiplying number of trips by 4 (the average capacity of the vehicles). For the number of passengers in a return trip, it is approximately half full, on average; therefore, the number of trips is multiplied by 6 passengers (1.5 round trip) based on estimates from the drivers.

Table 1B

Length of Routes, Number of Trips, and Number of Passengers for the PT Internal Routes in Nablus City

No.	Route Name	Length (Km)	Number of Trip/Vehicle / Day	Number of Passengers (One-Way) /Vehicle/Day	Number of Passengers (Round Trip)/Vehicle/Day
1	Balata	2.5	20	80	120
2	Al-Dahya	3.4	20	80	120
3	Askar	7.0	17	68	102
4	North Mountain	3.5	15	60	90
5	Ras Al Ain	2.3	21	89	126
6	Rafeedia	4.4	28	112	168
7	Al-Makhfiah	2.5	24	106	159
8	Al-Ein Camp	3.2	28	112	168
9	El-Etehad	2.9	19	76	125

4.2.3 Car Production Year

The classification of vehicles inside the station based on the vehicle production year and their numbers are presented in Table 2A.

Table 2A

Classification of Vehicles Based on Vehicle's 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

4.2.4 PT Vehicles' Expenses

Based on what was collected from drivers, the main expenses were based on fixed costs such as insurance, annual licensing, and maintenance, in addition to variable costs such as fuel consumption, as detailed in the following sub-sections.

4.2.4.1 Fuel Expenses

The rate of fuel consumption expenses based on random samples of drivers depending on the age of the vehicle; older vehicles consume more fuel than modern vehicles by a small percentage. The samples were at least four drivers from each year of production, and an average of the answers was calculated for the cost of fuel consumed per day.

Fuel consumption was also calculated based on the distance traveled for each route, which is more accurate than information disclosed by drivers. Table 2B shows the average fuel consumption cost per vehicle per route. This table is based on measuring the consumption rate for the distance traveled and taking the average fuel consumption expenses of all vehicles. Table 2B shows the data collected on the fuel costs from drivers, and Table 5 shows the fuel consumption per route.

Table 2B

Rate of fuel consumption depending on the age of the vehicle

Production Date	2002-2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Fuel combustion/day (NIS) (₪)	130	125	125	120	120	115	115	110	110	105	105

Table 2C

Fuel Consumption Rate per Route

No.	Route Name	Length (Km)	Number of Trips/Vehicle /Day	Distance Traveled/Day (km)	Car Fuel Consumption (₪)/Day[1]	Van Fuel Consumption (₪)/Day	Cost Difference (₪)/Day
1	Balata	2.5	20	100	45	63.00	18
2	Al-Dahya	3.4	20	136	61	86.00	25
3	Askar	7	17	238	107	150.00	43
4	North Mountain	3.5	15	105	48	67.00	19
5	Ras Al Ain	2.3	21	96.6	43	60.00	17
6	Rafeedia	4.4	28	246.4	110	154.00	44
7	Al-Makhfiah	2.5	24	120	54	76.00	22
8	Al-Ein camp	3.2	28	179.2	81	114.00	33
9	El-Etehad	2.9	19	110.2	50	70.00	20

(1) Calculated based on the average fuel consumption per kilometer traveled.

The rate of fuel consumption in kilometers per lite becomes possible to calculate, which is approximately 11 kilometers per liter of diesel as an average throughout the year. Since the price of diesel in Palestine can be fixed at around five Shekels (for year 2021); therefore, one-kilometer costs approximately 0.45 Shekels for fuel. As for a van, its average consumption rate is 0.63 Shekels per liter.

4.2.4.2 Maintenance, Insurance, and Licensing Costs

Through interviews with drivers about the maintenance of their vehicles, most of them agreed that the total paid would be approximately 6,000 Shekels per year, including the periodic maintenance of the vehicle three times a year, in addition to changing the brakes twice a year and replacing the consumable parts, when needed.

Also, the driver is obliged to pay a daily fee for the station, which ranges from 8 to 10 Shekels; an average of 9. Therefore, the annual station fee is (9Shekel on average * 288 working day) approximately 2,592 Shekels.

When talking about costs, one cannot forget the depreciation of the vehicle, which constitutes an important factor. The vehicle's price was obtained from the car agency/dealer for "zero kilometers"; meaning that it is a brand new. Then a vehicle begins depreciating annually after use, and this is precisely controlled due to the

multiplicity of vehicle types based on the company, and the manufacturer and the market situation at the time of buying and selling the vehicle. However, it is possible to take an approximate value of up to 10% of the initial vehicle's price, and this is an approximate number used in the market as a "rule of thumb."

As for licensing and insurance of the car, it pays annually a total of 6,900 Shekel distributed between the insurance company for insuring the vehicle, driver, and passengers in cases of accidents, and part goes to licensing the car at the competent department in the Ministry of Transport. Table 3A shows the cost details.

Table 3A

Maintenance, Insurance, and Licensing Annual Costs

	Fixed Period Costs	Total
Annual Maintenance	6,000 Shekel	6,000 Shekel
Annual Station Fee	2,592 Shekel	2,592 Shekel
Annual Insurance - License	6,900 Shekel	6,900 Shekel
Total		15,492 Shekel

4.3 Hybrid System

The number of hybrid vehicles in Palestine reached approximately 550 vehicles until the beginning of the year 2021 (Palestinian Central Bureau of Statistics, 2021); most of them are produced by Hyundai Ioniq. The focus here is on these vehicles by conducting interviews with vehicle owners using the following survey form (Figure5).

The study sample included 250 drivers (45% of total hybrid vehicle owners) who agreed that hybrid vehicles only needed regular periodic maintenance every five months, for an estimated cost of 200 Shekels, and they did not appear to have problems with the manufacturing or requiring abnormal maintenance.

With regard to fuel consumption, there was a large variation in the responses of vehicles' owners, and this is normal since it depends on the driving style and location, to a large extent.

Figure 5
Survey Form for Hybrid Vehicles

Car type	Plug in Hybrid - Hybrid
Gasoline engine capacity (cc; cm^3)	
Electric motor capacity - horse power (hp)	
Battery capacity - Ampere hour (Ah)	
The manufacturing company	
Production Date	
Driving modes	• Inside the city • On external roads • Internal and external roads
Average fuel consumption in km/liter	
Regular maintenance cost (Shekel)	
Driving style -- **Using sudden pedals and accelerating constantly**	• Rarely • Sometimes • Always Notes:
Facing problems that need to visit the repair shop **(Does not include regular maintenance)**	• Rarely • Sometimes • Always Notes:

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

Approximately 40% of the interviewed drivers use their vehicles in the city with moderate driving style with an average vehicle consumption of approximately 21 kilometers per liter. In addition, approximately 40% of the interviewed drivers use their vehicles inside and outside the city for an average of 15 kilometers per liter. Finally, 20% use their vehicles on external roads most of the time for an average of approximately 14 kilometers per liter, as summarized in Table 3B.

Table 3B

Gasoline Consumption for Hybrid Vehicles Based on Usage

	Inside the City	On the Outside Roads	In & Out of the City
Gasoline consumption km/l	21 km/l	14 km/l	15 km/l

4.4 Environmental Aspects

As mentioned before, the efficiency of cars with diesel fuel decreases at low speeds and this applies to exhaust gas emissions; they increase because the combustion efficiency is lower. Table 4 shows the standard gases emitted from the diesel (for Euros 4, 5 and 6, which are the types used in Palestine) and hybrid cars and their quantities based on the annual number of kilometers traveled multiplied by the number of gases emitted by vehicles per kilometer, as authorized globally in the Euro Exhaust Gas Laws (Emission Standards, 2021). Table 4 shows clearly that the hybrid vehicles emit much lower gases than diesel cars (24).

Table 4

Emission Standards for Passenger Cars (24).

Stage	Date	CO	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

In order to calculate the quantities of exhaust gas from diesel vehicles, Table 2A shows the number of cars for the year of production, and Table 8shows the standard exhaust gases coming out of the cars based on Euro 4, 5 and 6 classifications. Tables5A-5B are prepared showing the amount of exhaust gases that come out of each route based on the following equation:

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

Since there are no Euro-standard determinants for hybrid vehicles, we can calculate the rate of exhaust gas production by dividing the production of gasoline by three, based on the study referred to earlier indicating that the gasoline combustion engine in the hybrid operates at a third of its power, and thus produces a third of the amount of exhaust gases.

Table 5A

CO Emission Quantity for Diesel Fuel and Hybrid per Route (kg/year)

No.	Route Name	CO Diesel Emission Quantity (based on production year - kg /year)			Total CO Emission for Diesel Fuel	Total CO 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

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

Table 5B

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

No.	Route Name	HC & NOx Emission Quantity (based on production year – kg/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 5C

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

As for calculating the quantities of exhaust gases emitted from hybrid vehicles, based on the data collected in Table 3B, hybrid vehicles consume one third of the fuel for the same vehicle from gasoline. Therefore, we can consider that one third of the amount of exhaust gases are emitted by gasoline vehicles according to Euro 6 as shown in Table 4.

For Balata Route, as an example, the CO emission quantity for diesel fuel is calculated as follows:

$$\{17\ (\text{cars } 2005-2009) * 0.5\ (\text{emission rate of Euro 4}) + 44\ (\text{cars of newer than } 2009-2014) * 0.5\ (\text{emission rate of Euro 5}) + 10\ (\text{cars of } 2014-2017) * 0.5\ (\text{emission rate of Euro 6})\} * 288\ (\text{days per year}) * 100\ (\text{km traveled per day})/1000\ \text{g/kg} = (1{,}152\ \text{kg/year})$$

The CO emission quantity for hybrid vehicles

$$= \text{number of cars} * \text{Traveled Distance} * 1/3 * \text{Euro 6}$$

$$= 768\ \text{kg/year}$$

After calculating the exhaust gas emissions from diesel and hybrid vehicles in the previous tables, Table6 shows the difference in emissions between diesel and hybrid vehicles.

Table 6

Comparison of Exhaust Gas Emissions between Hybrid and Diesel Vehicles (kg/year)

Emission	Diesel Fuel	Hybrid	Difference	% Difference
CO	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%

Chapter Five

Cost Analysis for Diesel and Hybrid Vehicles

After collecting the data shown in Chapter Four, this chapter focuses on analyzing the data for each of the nine routes so that the economic and environmental aspects are taken into consideration. Therefore, the results will highlight the possibility of switching vehicles from diesel to hybrid and the economic feasibility of this step. The analysis is based on each individual PT route.

5.1 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. As shown before, the fixed costs include insurance, licensing, station fees, and maintenance costs. Therefore, the main criteria for switching are the cost of fuel and the road topography.

5.1.1 Diesel Vehicle Costs

Based on the annual total costs of a diesel vehicle shown in the data collection chapter, we find the following

Monthly Expenses =License and Insurance + (Fuel costs per kilometer * Daily Mileage*Number of Working Days) + Terminal Fees + Maintenance = 2425₪

Then the total income per month per vehicle was calculated as shown in 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 interviewing route's official, most of shared taxis' initial cost is approximately 55,000 ₪, and after 10 years it loses about 20% of its initial value, and will be sold to

the market. A 3.5% interest rate was used based on information obtained from local banks. The cost summary is:

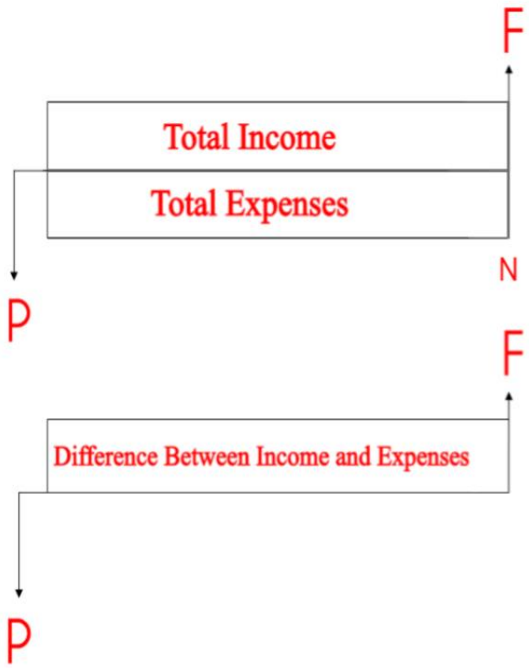
P = 55,000₪

F = 44,000₪

N= 10 years

i% = 3.5%

Using NCF:



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

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

(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 ₪

5.1.2 Hybrid Vehicle Costs

Expenses/Month =License and Insurance + (Fuel costs per kilometer * daily mileage*Number of working days Total) + Terminal Fees + Maintenance = 1300 + 750 = 2050₪

Then the total income per month per vehicle was calculated.

Total Income/Month = Number of working days * Fare * Number of Passengers (Round Trip) = 25 * 3 * 120 = 9000 ₪

The initial cost of a hybrid vehicle "Hyundai Ionic" is approximately 90,000 ₪, and after 10 years it loses about 40% of its initial investment, as it is known in the Palestinian market for vehicles and obtained from the drivers' interviews, and will be sold to the market. The percentage loss of hybrid vehicles' price is more than diesel vehicles due to customs taxes. As the tax on hybrid vehicles is 30%, while for diesel vehicles it is 50%, according to the Palestinian Customs Authority, and public vehicles are exempt from tax throughout their work as a public vehicle, on which customs are equal to zero.

If the driver wants to sell the public vehicle and turn it into a private vehicle, the vehicle tax is deducted from it every year. Therefore, public vehicles are depreciated by the amount of tax exempted from it, where the vehicle price is 100,000 Shekels without tax and 150,000 Shekel with tax; it decreases by 10%. When the driver intends to sell it as a normal vehicle after ten years, for example, the price of its counterpart in the market is approximately 100,000; therefore, the driver does not lose anything.

In the case of hybrid vehicles, their tax is low, but the price is high. The public driver does not benefit from the tax deduction, as he/she does not pay it in the first place. At the beginning of purchase, hybrid vehicles are less than diesel vehicles. The years in which the vehicle operates, the consumption is from customs taxes, so the decrease is in price. In addition, for the hybrid vehicle there is a need to replace the battery every five years, with an approximate price of 15,000 Shekels, according to the local Palestinian market price.

The summary is:

P = 90,000₪

F = 54,000₪

F1 = -15,000₪ **(5 years)**

F = -15,000₪ **(10 years)**

N = 10 years

i% = 3.5%

Using NCF, and converting all the NCF to 'A' equal quantities per years (Profit), using the economic equation:

A= -P (A/P, 3.5%, 10) + F (A/F, 3.5%, 10) - F (F/P, 3.5%, 5) - F (F/P, 3.5%, 5) + (Difference between income and expenses)

Based on the Engineering Economy tables:

(A/P, 3.5%, 10) = 0.1202

(A/F, 3.5%, 10) = 0.0852

By Compensating the values of P and F, the equation becomes**:**

Profit/Month = 6500 ₪

Difference = 6500 – 6335 = 165 ₪/month

The saving for changing vehicles from diesel to hybrid is 165 Shekels per month.

When analyzing this economic savings, it is concluded that it is not highly feasible to make changes on this line; saving this modest amount per month is not worth making the switch and changing the driving style for drivers. Despite all the disadvantages that surround diesel vehicles, but it is still economically not that worthwhile to switch to hybrid vehicles.

Finally, the status quo is seen as appropriate for this line. The recommendation for this route is to keep it as is. Therefore, there is no strong argument to persuade any party to switch vehicles on this line to hybrid vehicles, based on the economic feasibility aspect. On the other hand, as vehicles are becoming old and need replacement, then there will be no harm of switching new vehicles to be hybrid and gain even additional modest benefit, at the same time benefiting the environment.

The summary of income and profit for each route is presented in Table 7.

Table 7

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

5.1.3 Scenarios for Switching from Diesel to Hybrid

The transition from using diesel vehicles to hybrid vehicles will not happen quickly, as it must be a gradual shift, and accordingly several scenarios are proposed and will be applied to each route separately. The explored three scenarios are:

First: Replacing all vehicles with a production date less than 2009

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

Third: It is a requirement for any vehicle that will enter the service to be hybrid

The First Scenario

Both economic and environmental aspects will be discussed to convert all cars with a production date less than year 2009.

According to the interviews with drivers, we can safely assume that vehicles from the production date of 2005-2009 consume more fuel than vehicles produced from 2009-2014 or more recent than 2014 (up to 2017). Therefore, we could estimate fixed percentages applied to the general rate of fuel consumption. As such, for the vehicles produced before 2009, their consumption rate will be multiplied by a factor of 1.15 (as compared to the recent models (2014-2017)), and for vehicles produced in 2009-2014 the rate will be multiplied by a factor of 1.15 These factors might not be highly accurate; however, they are relatively accurate and reasonable in terms of calculating consumption rates as there is no clear factors that can be used with 100% accuracy. Furthermore, they represent the aggregate average consumption rates obtained for drivers of the respective vehicles.

When calculating the income for old vehicles with production less than 2009 separately and taking into account the high fuel consumption by a factor of 1.15 more than new vehicles, the equation is as follows

P = 55,000₪

F = 44,000₪

N = 10 years

i% = 3.5%

Using NCF and converting all the NCF to annual amounts 'A' (Profit), the following equation is used:

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

(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:

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

For Balata route:

Profit/Month = 5508 ₪

The summary of savings for each route is presented in Table 8A.

Table 8A

Financial Savings for Scenario 1

No.	Route Name	Number of Cars	Diesel Profit ₪/month	Hybrid Profit ₪/month	Saving per Car ₪/month	% 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

As noted in Table 7 when compared with Table 8A, there is a considerable difference in savings between the current conditions and Scenario 1; ranging from 17.5 to 31.3% for a total saving of approximately 125,000 Shekel for all routes. When vehicles of older age are replaced with hybrid, the fuel consumption rate saving is high as those consume the highest rate. When the consumption rate and cost was calculated on the aggregate level for each route, the differences were not high. On the other hand, when the difference in consumption rate for each production date group is considered, Table 8A shows considerable differences.

The obvious recommendation that should come out of this comparison is that the old vehicle that is to be out of service should be replaced by a hybrid vehicle. This would achieve a financial saving of approximately 20.9% on average, in addition to 33% reduction in exhaust gases, as shown in the Chapter 4.

It is also observed that there are some routes that could save on fuel cost higher than others such as Rafeedia, followed by Balata, and Al-Makhfiah routes. The main reason here is that those routes have considerable number of old vehicles. 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 is high, approximately

1785 shekels per vehicle on average and 53,550 Shekels for the entire route. In terms of savings per vehicle, Rafeedia, Al-Ein Camp, Al-Makhfiah, and Askar routes would have the highest savings, in this order. The reasons for these variations are mainly due to the number of old vehicles and the characteristics of each route.

Emissions Difference

It was also mentioned that old cars (older than 2009) emit more exhaust gases than newer cars, and this is illustrated Table 8B.

Table 8B

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					
			CO	HC + NOx	PM	CO	HC + NOx	PM	CO		HC + Nox		PM	
									(kg/ year)	%	(kg/ year)	%	(kg/ year)	%
1	Balata	17	244.80	146.88	12.24	163.20	16.32	0.82	81.6	33.3%	130.56	88.9%	11.42	93.3%
2	Al-Dahya	3	58.75	35.25	2.94	39.17	3.92	0.20	19.58	33.3%	31.33	88.9%	2.74	93.2%
3	Askar	7	239.90	143.94	12.00	159.94	15.99	0.80	79.96	33.3%	127.95	88.9%	11.2	93.3%
4	North Mountain	6	90.72	54.43	4.54	60.48	6.05	0.30	30.24	33.3%	48.38	88.9%	4.24	93.4%
5	Ras Al Ain	7	97.37	58.42	4.87	64.92	6.49	0.32	32.45	33.3%	51.93	88.9%	4.55	93.4%
6	Rafeedia	30	1064.45	638.67	53.22	709.63	70.96	3.55	354.82	33.3%	567.71	88.9%	49.67	93.3%
7	Al-Makhfiah	12	207.36	124.42	10.37	138.24	13.82	0.69	69.12	33.3%	110.6	88.9%	9.68	93.3%
8	Al-Ein camp	7	180.63	108.38	9.03	120.42	12.04	0.60	60.21	33.3%	96.34	88.9%	8.43	93.4%
9	El-Etehad	2	31.74	19.04	1.59	21.16	2.12	0.11	10.58	33.3%	16.92	88.9%	1.48	93.1%
	Total	91	2,216.2	1,329.7	110.8	1,477.1	147.7	7.39	739.08	33.3%	1,182.0	88.9%	103.4	93.3%

It is noted from Table 8B the high rates of exhaust gases reduction, as they are close and similar ratios for the different routes. Therefore, this makes the potential for switching high and encouraging.

The Second Scenario

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

When calculating the income for vehicles with their production year from 2009 -2014 separately and taking into account the high fuel consumption by a factor of 1.1 as compared to new vehicles, the equation becomes as follows:

P = 55,000₪

F = 44,000₪

N = 10 years

i% = 3.5%

Using NCF, and converting all the NCF to annual amounts 'A' (Profit), the following equation is used:

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

(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:

Profit permonth =

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

For Balata Line:

Profit/Month = 5783 ₪

The summary of savings for Scenario 2 is shown in Table 9.

Table 9

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

The table shows the savings results for the second scenario, with savings ranging from 11.9% for Ras Al-Ain to 25.0% for Askar routes, for a total saving amount of 523,334 Shekel for the entire routes. These percentages are due to the high costs of these two routes. However, if we look at the amount of savings per route, we notice, for example, 1427 Shekel for Rafeedia, 1244 Shekels for Al-Ein Camp, 1017 Shekel for Al-Makhfiah, and1107 Shekel for Askar routes; the least is 548 Shekel for North Mount route, these all are not little savings. Therefore, this calls for a serious consideration of applying the second scenario.

5.1.4 Switching from Diesel Cars to Diesel Vans

In this section, the possibility of replacing old cars (4-passenger seats) with production years of 2005-2009 with newer vans (7-passenger seats). Proportional to the size, the engines for the van consume 1.25 more than the small cars and produce more exhaust gases in the same proportion.

The number of transported passengers by these cars to be replaced is calculated by multiplying the number of vehicles by the number of daily passengers, as reported in Chapter Four. Then for the same number of passengers, the equivalent number of van trips needed is calculated, as shown in Table 10A. The financial comparison for both cases is shown in Table 10B.

Based on the number of trips the 4-passenger cars make and the number of trips the vans make, the daily cost for both is calculated, while keeping all other variables the same (maintenance, insurance, and station costs; the prices of the van and the car are close to each other). The daily distance traveled by each mode (cars and vans) is also calculated. The cost of diesel in Palestine is fixed at around five Shekels per liter. Therefore, one-kilometer costs approximately 0.45 for cars produced from 2005-2009, while its 0.63 Shekels per liter for vans.

Furthermore, based on the number of kilometers traveled by 4-passenger car and 7-passenger vans, the amount of exhaust emissions and the difference between them are calculated. The passenger ratio of a 4-passenger car to a 7-passenger van is 0.57; meaning that every 100 cars can be replaced with 57 vans. Accordingly, the amount of exhaust gas emissions for both vehicle types is calculated (see Table 10B).

Table 10A

Equivalent Number of Van Trips to Replace the 2005-2009 Cars and Associated Costs

No.	Route Name	Route Length (Km)	Number of Passengers (Round Trip) /Vehicle/Day	Number of Cars to be Replaced (2005-2009)	Number of 4-Passenger Car Trips	Equivalent Number of Van Trips	Cost for 4-Passenger Cars ₪/month	Cost for Vans ₪/month	Difference ₪/month	%
1	Balata	2.5	120	17	510	291	17,901	11,934	5,967	0.33
2	Al-Dahya	3.4	120	3	90	51	4,296	2,864	1,432	0.33
3	Askar	7	102	7	178	102	17,543	11,695	5,848	0.33
4	North Mountain	3.5	90	6	135	77	6,634	4,423	2,211	0.33
5	Ras Al Ain	2.3	126	7	220	126	7,120	4,747	2,373	0.33
6	Rafeedia	4.4	168	30	1260	720	77,838	51,892	25,946	0.33
7	Al-Makhfiah	2.5	159	12	477	272	16,743	11,162	5,581	0.33
8	Al-Ein Camp	3.2	168	7	294	168	13,209	8,806	4,403	0.33
9	El-Etehad	2.9	125	2	62	35	2,545	1,697	848	0.33
	Total	31.7	1178	91	3226	1842	163,829	109,220	54,609	0.33

Table 10B

Equivalent Number of Van Trips to Replace the 2005-2009 Cars and Associated Emissions

No.	Route Name	No. of Cars to be Replaced	Number of Vans	Emission Quantity (kg/year) Diesel Fuel			Emission Quantity for Hybrid (kg/year)			Emission Reduction					
				CO	HC + NOx	PM	CO	HC + NOx	PM	CO		HC + Nox		PM	
										(kg/ year)	%	(kg/ year)	%	(kg/ year)	%
1	Balata	17	10	244.80	146.88	12.24	167.44	100.47	8.37	77.36	31.6%	46.41	31.6%	3.87	31.6%
2	Al-Dahya	3	2	58.75	35.25	2.94	40.19	24.11	2.01	18.57	31.6%	11.14	31.6%	0.93	31.6%
3	Askar	7	4	239.90	143.94	12.00	164.09	98.45	8.21	75.81	31.6%	45.49	31.6%	3.79	31.6%
4	North Mountain	6	3	90.72	54.43	4.54	62.05	37.23	3.11	28.67	31.6%	17.20	31.6%	1.43	31.6%
5	Ras Al Ain	7	4	97.37	58.42	4.87	66.60	39.96	3.33	30.77	31.6%	18.46	31.6%	1.54	31.6%
6	Rafeedia	30	17	1064.45	638.67	53.22	728.08	436.85	36.40	336.37	31.6%	201.82	31.6%	16.82	31.6%
7	Al-Makhfiah	12	7	207.36	124.42	10.37	141.83	85.10	7.09	65.53	31.6%	39.32	31.6%	3.28	31.6%
8	Al-Ein camp	7	4	180.63	108.38	9.03	123.55	74.13	6.18	57.08	31.6%	34.25	31.6%	2.85	31.6%
9	El-Etehad	2	1	31.74	19.04	1.59	21.71	13.02	1.09	10.03	31.6%	6.02	31.6%	0.50	31.6%
	Total (%avg)	91	52	2,216.23	1,329.74	110.81	1515.55	909.33	75.79	700.17	31.6%	420.10	31.6%	35.01	31.6%

Based on the previous three scenarios, they are all applicable; however, each differs according to the payback period, as well as for the sake of the environment. The simplest one is the first scenario that is closest to reality by virtue of the ease of changing old cars and convincing vehicle owners to change them. In addition, when the station's management decides to create a new line, it is clearly better to start with hybrid vehicles; it saves some money and produces less air pollution.

Chapter Six

Conclusions and Recommendations

Although there is no clear time for the depletion of conventional fuels from the world, many international reports talk about the approaching fuel economy, and at the same time countries are striving to facilitate access to alternative fuels. This is linked to the belief that it could become less expensive in the long run if it becomes easier to obtain, unlike conventional fuels, which are nearing depletion and becoming scarcer, and therefore more expensive.

Public transportation (PT) provides people with mobility and access to their jobs, schools, universities, community resources, medical stations, and more. It benefits those who choose to use a PT, as well as those who have no other choice.

The objective of this thesis is conducting a feasibility study for replacing public diesel vehicles with hybrid vehicles for Nablus intra-city public transportation, and comparing between the two systems.

Data were obtained from the field through interviews and questionnaires for public transportation drivers and line managers, as well as hybrid vehicle users. Vehicles' various costs and expenses were obtained from the official sources, drivers, and auto dealers. The environmental impacts were estimated using the typical emission rates for both vehicles. Three different scenarios were investigated, and solutions to reduce exhaust gas emissions and rationalize fuel consumption by introducing hybrid vehicles to public transport were also presented.

6.2 Conclusions

Based on results obtained in this study, the following conclusions are drawn.

- The importance of this study is that it among few that takes into account the topographic nature of route (such as the city of Nablus in Palestine), in addition to the driving style of public vehicle drivers.
- Based on the current conditions (PT routes' characteristics and economic aspects), and despite the potential environmental benefits, it is not highly financially feasible to switch all PT vehicles to hybrid; saving modest amount

per month is not worth making the switch and changing the driving style for drivers. Therefore, three scenarios were investigated.

- The first scenario (replacing old cars from the production date of 2009 and older with hybrid vehicles) showed better results, with a cost reduction ranging from 17.5% to 31%, with a significant reduction in emissions (carbon monoxide by 33%, nitrogen oxides by 88%, and particlesby 93%).
- The scenario of replacing additional old cars (vehicles with production dates from 2009-2014; scenario 2) showed also significant financial savings (15% on average), in addition to lower gas emissions.
- On the other hand, replacing old diesel vehicles with 7-passenger vans (scenario 3) showed generally lower reduction in costs and emissions than scenarios 1 and 2.
- The overall conclusion is to immediately adopt the policy of replacing old PT 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 PT vehicles with hybrid, particularly older models since they consume higher fuel and produce higher emission rates.

6.3 Recommendations and Future Research

The study offers the following recommendations:

- It is recommended to implement the first scenario - replacing old vehicles with hybrids as soon as possible, move gradually to the entire fleet.
- The government should facilitate for citizens to acquire hybrid vehicles in various ways. This could be achieved by providing financial incentives, and enactment of laws to encourage vehicle owners to purchase hybrid vehicles.
- For future researchers, it is recommended to conduct similar studies for all Palestinian cities, taking into account the particular nature of each city and its PT characteristics.
- Study the possibility of introducing electric vehicles to public transport or as personal vehicles.
- Finally, it is recommended studying the possibility of replacing vehicles with electric buses for public transport, as it saves energy and the environment, as well as reducing traffic congestion.

- Despite the economic savings and the reduction of exhaust gases for hybrid cars, 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. In addition, the use of 7-seat vans instead of 4-seat cars will reduce the number of drivers, and this would negatively affect the social and economical aspects at the community level; therefore, proper mitigation measures should be proposed before deciding to such switching.

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جـامعـــة النجاح الوطنية

كليـــة الدراســـات العليـــا

دراسة جدوى بيئية واقتصادية لاستخدام المركبات الهجينة في المواصلات العامة في مدينة نابلس

اعداد

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قدمت هذه الرسالة استكمالا لمتطلبات الحصول على درجة الماجستير في برنامج هندسة الطاقة المتجددة وترشيد الاستهلاك، من كلية الدراسات العليا، في جامعة النجاح الوطنية، نابلس– فلسطين.

2022

دراسة جدوى بيئية واقتصادية لاستخدام المركبات الهجينة في المواصلات العامة في مدينة نابلس

إعداد
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الملخص

خلفية الدراسة : هناك اهتمام عالمي بشأن الزيادة العامة في انبعاثات العادم من المركبات التي تستخدم الوقود التقليدي، مثل الديزل، وارتفاع أسعار الوقود، بما في ذلك فلسطين.

مدينة نابلس، وهي مدينة رئيسية في الضفة الغربية، تحمل خصوصية التضاريس المختلفة، وتعاني من الازدحام المروري. في داخل المنطقة الحضرية في نابلس، تسير حركة المرور بسرعات منخفضة، ويضطر السائقون عادةً إلى التوقف والسير بشكل مستمر. يؤدي هذا إلى زيادة استهلاك الوقود وانبعاث غازات العادم لمركبات النقل العام التي تعمل بالديزل.

الاهداف: تهدف هذه الأطروحة إلى دراسة إمكانية إدخال مركبات الوقود البديل (المركبات الهجينة) خاصة في وسائل النقل العام في المناطق الحضرية لمدينة نابلس، فلسطين.

منهجية الدراسة: تم إجراء المقابلات وتوزيع الاستبيانات على سائقي مركبات النقل العام ومدراء الخطوط، تم من خلالها الحصول على الخصائص التشغيلية لخطوط النقل العام والتكاليف والنفقات المرتبطة به.

نتائج الدراسة: تم تطوير ثلاثة سيناريوهات تمثل الأول في استبدال السيارات القديمة (2009 أو أقدم) بالمركبات الهجينة. أظهرت نتائج تحليل هذا السيناريو توفيرًا ماليا يتراوح من 17.5٪ إلى 31٪، وبمتوسط 20.9٪ لجميع مسارات النقل العام في المدينة، بينما كان الانخفاض في عوادم ثاني أكسيد الكربون بنسبة 33٪، و CH + NO بنسبة 88٪، و PM بنسبة 93٪.

أما بالنسبة للسيناريو الثاني (استبدال جميع المركبات بتاريخ الإنتاج من 2009–2014)، فقد تم تحقيق متوسط توفير اقتصادي بنسبة 15٪ وخفض غازات العادم بنسبة 35٪. وهذا يعطي هذا السيناريو أهمية على المدى الطويل، بحيث توجد ضرورة ملحة لتطبيقه في الوقت الحالي. وأخيرًا، أظهر السيناريو الثالث، وهو استبدال سيارات الديزل القديمة بمركبات "الفان" التي تتسع لـ7 ركاب، توفيرًا بنسبة 31٪ في الجانب الاقتصادي، وانخفاضًا بنسبة 33٪ في غازات العادم بشكل عام.

الإستنتاجات: المقارنة بين السيناريوهات تفضيل السيناريو الأول في الوقت الحالي، مع تنفيذ السيناريوهات الأخرى بشكل تدريجي. السيناريو الأول بسيط وقريب من الواقع، حيث أنه يجب استبدال السيارة القديمة بأية حال؛ لذلك خلصت الدراسة إلى أنها تحقق فائدة مالية وبيئية لتحويلها إلى هجين.

توصي الدراسة بوضع سياسات على المستوى الوطني لتشجيع استخدام أنواع الوقود البديلة، مع التركيز بشكل خاص على النقل العام. في الوقت نفسه، يجب أن تشمل هذه السياسات أيضًا قطاع النقل بشكل عام.

الكلمات المفتاحية: نقل عام، مركبات، انبعاث، هجين، ديزل.