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كلية الهندسة و تكنولوجيا المعلومات

Graduation Project Report I I

{ Developing and Using Speed Humps for Power Generation in Nablus City}

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DEDICATION

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قال تعالى: { يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنْكُمْ وَ الَّذِينَ أُوتُوا الْعِلْمَ دَرَجَات}.

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DISCLAIMER

This report was written by students: Aya Abd Aljabbar, Aya Rahhal, Huda Alhait, Islam Koa and Wesam Rabaya at the Civil Engineering Department and Mechanical Engineering Department, Faculty of Engineering and Information Technology, An-Najah National University. It has not been altered or corrected, other than editorial corrections, as a result of assessment and it may contain language as well as content errors. The views expressed in it together with any outcomes and recommendations are solely those of the students. An-Najah National University accepts no responsibility or liability for the consequences of this report being used for a purpose other than the purpose for which it was commissioned.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATION

- AADT	Average Annual Daily Traffic
- AASHTO	American Association of State Highway and Transportation Officials
- AC	Alternating Current
- ADT	Average Daily Traffic
- AISI	American Iron and Steel Institute
- ASME	American Society of Mechanical Engineers
- ASTM	American Society for Testing and Materials
- DC	Direct Current
- DHV	Design Hour Volume
- DIP	Direct In-line Package
- DOD	Depth of Discharge
- FHWA	Federal Highway Administration
- GIS	Geographic Information System
- GPS	Global Positioning System
- HV	Hourly Volume
- HPS	High Pressure Sodium
- IEC	Israel Electricity Corporation
- ITE	Institute of Transportation Engineers
- LED	Light Emitting Diode
- LPS	Low Pressure Sodium lights
- MEF	Monthly Expansion Factor
- NO	Number
- PC	Passenger Car
- PHF	Peak Hour Factor
- PHV	Peak Hour Volume
- PETL	National Electricity Transmission Company
- PV	Photovoltaic Solar Panels
- UMT	United Motor Trade
- SH	Speed Hump

- SHGEP Speed Hump Generating Electrical Power
- SMD Surface Mounted Diode
- PV Photovoltaic systems

ABSTRACT

Nablus is one of the largest Palestinian cities, it has a unique location that plays an important role in making Nablus vital commercial. In the recent years, the city has witnessed expanded in the residential and commercial areas, significant increase in the amount of traffic population, and the demand for basic services such as electricity.

Electricity in one of the most important innovations that makes our life easier. It is used in our daily life. There are many sources that are used to generate the electricity, such as fossil fuel, solar energy, etc. Nablus city suffers from many problems in the electricity sector in light of the political issues especially as it gets a high percentage of its electricity needs from Israeli's occupation. In this project, the possibility of harvesting electric energy from the traffic of vehicle on speed humps will be studied for Nablus city. The study will introduce an eco-friendly speed hump.

The methodology in this project includes; collect traffic data such as the coordinates of speed humps in the city using GPS devices. Next, use these coordinates to create a GIS map using ArcGIS software. In addition, the traffic volume counts were conducted in the city streets in order to determine the amount of electricity that can be harvested through the speed humps. Then, an electric speed bump design was developed in order to determine the energy and environmental impacts of electrical speed bump in the future. For this purpose, an economic and environmental feasibility analysis was conducted.

The results have showed that this could save NIS 742073 of energy consumed costs in street lightening and traffic signals during one year. More specifically, this number is almost equal to 44.66% of energy consumed annually in Nablus city for street lighting. Moreover, the payback period and the number of profits within 20 years are 15.5 years and NIS 4 million, respectively. However, if the project can be implemented on streets on which the flow is high, which is 14.1% of the total humps and 38% of the required energy could be produced. Also, the payback period and the number of profits within 20 years are 3.1 years and NIS 5.4 million, respectively. Furthermore, significant amounts of greenhouse gas (GHG) emissions could be reduced, as a result of reduced electricity production from fuel.

1 INTRODUCTION

1.1 General Back Ground

Transportation is a non-separable part of any society. It exhibits a very close relation to the style of life, the range, location of activities, and the goods, and services which will be available for consumption. Advances in transportation has made possible changes in the way of living and the way in which societies are organized and therefore have a great influence in the development of civilizations.

Means of transportation have gone through great developments associated with technology development. Transportation uses a huge amount of energy, for example, powering our cars, boats and planes. The transportation sector consumes a lot of energy in order to serve passengers and goods within the transportation system. Most vehicles require fuels like gasoline or diesel in order to run smoothly and efficiently. These fuels are derived from primary fuels like crude oil or natural gas, which consider as a non-renewable resource.

Recently, the problem of high energy consumption has arisen. The rapidly growing world energy use has already raised concerns over supply difficulties, exhaustion of energy resources and heavy environmental impacts. Energy harvesting development has become the source of many innovations as hybrid cars, solar panels, wind turbines, etc.

Energy harvesting, which is the process of extracting energy from the environment or from surrounding system and converting it to useable electrical energy became a prominent research topic. Generating renewable energy from the roadway infrastructure, which is called roadway harvesting, is an innovative idea. In this graduation project, the feasibility of generating electricity from speed humps will be determined.

1.2 Speed Humps

Since 1953, a great invention came in the world of physics and solved many problems of car accidents. Speed humps were back in time and still one of the most innovative ways to reduce car speed and protect the driver and the pedestrians from many problems.

Speed hump is a common traffic calming device that uses vertical deflection to slow down vehicles in order to improve traffic safety (Ahmad et al., 2019).

Speed humps are sometimes referred to as “pavement undulations” or “sleeping policemen”. Geometrically, humps are an elevated profile on the road defined by its base length, height and width.

Speed humps are implemented using various materials. They can be made from asphalt, concretes or prefabricated elements (tiles), rubber or plastic components. Furthermore, they are typically found on specific place on roadways and parking lots and do not tend to exhibit consistent design parameters from one installation to another, depending on type and shape of humps.

Generally, many factors contribute to the road safety improvement. These factors include road design, vehicle design, driver education and enforcement. The right hump in the right place may improve safety but that doesn't mean all humps make the road safer wherever they're put. However, removing some of the humps from the center of cities could help improve traffic flow and reduce exhaust emissions.

1.2.1 Types of humps:

Speed humps can be implemented in one of the following four shapes:

1. **Speed Bumps:**

Speed bump is an area raised from the road surface in a transverse direction; it is a narrow width and sharply inclined profile as shown in Figure 1.1. According to Federal Highway Administration (FHWA), the height of which usually ranges between (7 -10 cm) and its travel length between (30 -100 cm), So that a car has to slow down to 10 km/hr. to navigate one without damage. This format is usually performed on sub-local roads, residential area and in parking lots.

2. **Speed Humps:**

Large humps that span the entire width of the road. They look more like a feature of the road itself than speed bumps do, as they're covered in asphalt. Also, it is an area raised from the road surface in a transverse direction with long width and lower angle of slope as shown in Figure 1.1. According to (FHWA) the height of which usually ranges between (7 -10cm), but they're usually not as tall as speed bumps, also it is length around (3.5-4.5m). So that a car has to slow down to 25 to 35 km /hr. to navigate one without damage. This format is usually performed on residential local road.

From an operational standpoint, speed humps and bumps have critically different impacts on vehicles. Within typical residential operational speed ranges, vehicles slow to about 25 to 35 km/h on streets with properly spaced speed humps. A speed bump, on the other hand, causes significant driver discomfort at typical residential operational speed ranges and generally results in vehicles slowing to 10 km/h or less at each bump.

3. **Speed Table**

Speed tables are midblock traffic calming devices that raise the entire wheelbase of a vehicle to reduce its traffic speed; as shown in Figure 1.1 Speed tables are longer than speed humps and flat-topped, with a height of (7.5–9cm) and a length of 6.5 m.

4. **Speed cushion**

A speed cushion consists of two or more raised areas placed laterally across a roadway. The primary difference with other bumps is that a speed cushion has gaps between the raised areas to enable a vehicle with a wide track. Furthermore, the cutouts in the speed cushions are positioned such that a passenger vehicle cannot pass it without traveling over a portion of the raised pavement.

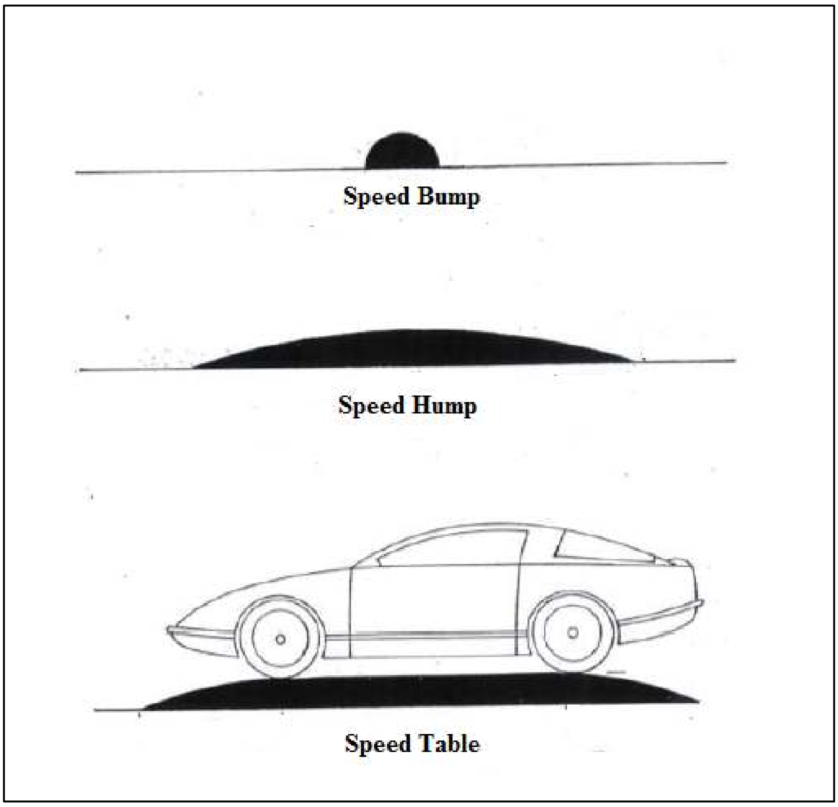


Figure 1.1 Different common type of humps

1.2.2 The future of speed humps in Palestine

Specific design standards and installation procedures for speed humps and related features such as signs and pavement markings shall be prepared and implemented by Transportation Ministry or other specification and standards related organizations.

Speed Bump Generating Electrical Power (SBGEP), transform kinetic energy and potential energy into electrical energy sorted in batteries and ready to be used for public lighting. This machine is very useful if it is used instead of widespread humps in Palestine since SBGEP is renewable energy generation system.

1.3 Solar Panel System

Light or visible light is electromagnetic radiation within the portion of the electromagnetic spectrum that can be perceived by the human eye Which consists of quanta (called photons).

Solar Photovoltaic systems (PV) absorb and convert sunlight into electrical energy by convert the energy-packed photons of natural sunlight into a usable energy form. This happened through Photons of light hitting the solar panel knock electrons in the substrate material into a higher level of activity, these electrons are then channeled off of the panel to create DC electricity. In most cases, an inverter will be used to convert the DC power into AC power, making it more directly usable to consumers as most modern electric appliances operate only on AC power.

The solar system works with two different systems, On-grid system and off-grid system.

How On-grid System works?

This system works in two-ways — the supply of electricity can flow from the grid to which it is connected to the user's home and from the user's home to the grid. This feature makes the on-grid solar system affordable and highly useful. The solar panels, installed on the user's home are 'tied' to the grid. The solar panels convert sunlight into electric energy, which is Direct Current (DC). This current is then sent to an inverter. The solar inverter then converts the DC to Alternating Current (AC), thus making it power the electrical items. This electricity is then routed to the grid where it is supplied for day-to-day use. The grid tied inverter additionally regulates the amount and voltage of electricity fed to the household since all the power generated is mostly much more than a home needs or can handle. An important feature is the net meter. It is a device that records the energy supplied to the grid and the energy consumed. At the end of each month, the outstanding is recorded and the consumer is provided with a bill. This ‘converted’ power supply is then used by homes through the main electricity distribution panel.

Figure 1.2 On grid system

<u>How Off-grid System works?</u>

An off-grid system is not connected to the electricity grid and therefore requires battery storage. Off-grid solar systems must be designed appropriately so that they will generate enough power throughout the year and have enough battery capacity to meet the home’s requirements, even in the depths of winter when there is generally much less sunlight. This description is for an AC coupled system, in a DC coupled system power is first sent to the battery bank, then sent to your appliances. To understand more about building and setting up an efficient off-grid home see our sister site go off-grid/hybrid.

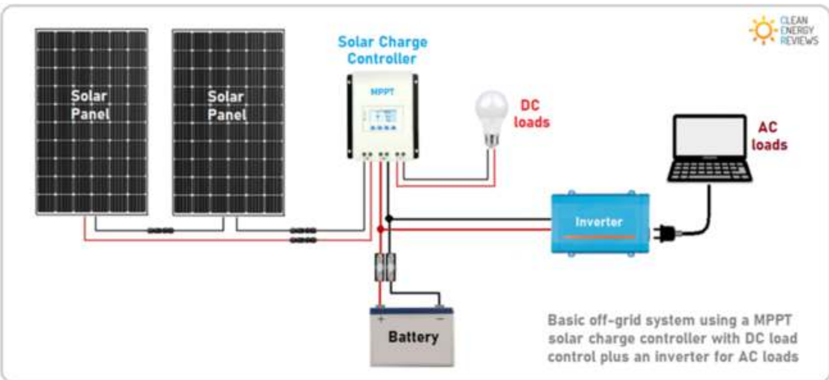


Figure 1.3 Off grid system

Understanding the components of a solar power system is the first step. The components of solar power system include:

1. **Solar inverter**

Inverters are the mechanisms that convert the direct current (DC) produced by the solar panels into the alternating current (AC) that homes require.

Inverters come in three types:

1. String or centralized inverters: They are the least expensive, but can be inefficient. This is because there is potential production loss if there is shading on the roof.
2. Micro inverters: These inverters are more expensive, and are attached to each solar panel, allowing for smooth operations even when some panels are shaded.
3. Power optimizers: Installed in each panel, they optimize the DC output of each PV module, which then goes on to a string inverter for conversion to AC power. They are less expensive than micro inverters, but slightly more expensive than string inverters.

2. **Solar storage**

Solar batteries can be installed to store energy for later or simply overnight. Essentially, storage batteries allow a PV system to operate when the electric grid is not available.

Alternatively, in some communities, net metering is available, which allows excess energy to be sent to the grid for credits. In essence, you will be using the grid as your excess storage option.

1.4 Objectives

The main objective of the project is to generate clean and cheap electricity as a result of traffic movement of vehicles on the speed humps in Nablus city and use them to operate the lighting poles and traffic lights. This would save energy and reduce the large amounts of money that is paid to Israeli occupation as a cost of the used electricity

Furthermore, the project suggested several different solutions to deal with the maintenance process. Additionally, this research will provide a GIS map for the locations and numbers of the speed humps in Nablus city, the volume of the vehicle on each hump, and to determine the expected traffic loads on these speed humps and as a result the expected amount of produced electricity. Finally, designing and fabricating a novel speed bump prototype.

1.5 Literature Review

Recently, electricity has become one of the main daily life problems that people face in Palestine. It is an essential part of nature and one of the most widely used forms of energy. Thus, creating methods for generating energy has become an important area for research due to the defects of traditional energy resources such as fossil fuels, coal, and natural gas that cause a lot of pollution and noise to the environment.

Despite the great importance of renewable energy and its abundance widely, some many problems and obstacles limit its spread and effective use. Including weather fluctuations, which reduce reliability of these resources, as in wind and solar energy, in addition to the fact that it requires large areas to exploit them effectively. As well as nuclear energy, which poses a threat to the environment and the human being, resulting in a lot of waste due to the consumption of radioactive materials and others.

Hence, traffic engineering is one of the areas in which energy harvesting attracts a lot of attention. With the continuous increase in the number of cars in a large way, we can take advantage of the humps that constitute an obstacle for drivers and benefit from them by producing clean and cheap energy. Moreover, this energy is used for road lighting and traffic system, and this energy can also be stored in batteries for later use. Also, this energy is used in the lighting of the roads and the traffic system, and this energy can also be stored in batteries for later use.

This topic is based on many research and studies; however, there are several innovative methods to generate energy from the speed hump, in this paper, some of these techniques are intended to be developed.

1.5.1 Piezoelectric:

Piere and Jecues. (1880) ,were the first who thought about harvesting energy from pressure, the study found that applying pressure on some materials created electricity this phenomenon known as the piezoelectric effect which is found in different crystals, bones and ceramics

Roshani et al. (2016), in USA, showed the results of testing several prototype systems. Each had different specifications but all works on the same concept which was piezoelectric effect. The prototypes were tested in a laboratory by applying a sinusoidal compressive load at a specific frequency. Each prototype showed a different result depends on its construction but in general this experiment confirmed that exploiting the traffic over highways can be dependable in powering many different applications.

Estyantiat et al. (2016) who're from Indonesia, suggested speed bumps with piezoelectric cantilever system as electrical harvester. They created a prototype with specific dimensions, which consisted of springs, electrical converter circuit and cantilever piezoelectric module. After testing the prototype in a laboratory the system generated energy was about 68.82 mJ.

Ennawaouil et al. (2019), designed roadway energy harvesting modules in a Korean local highway, which were based on piezoelectric polymers that can be a good alternative to piezoelectric ceramics. The modules output power was 16.5W/m^2. They noticed that there is a linear relation between the generated power and the speed and weight of the vehicle.

Rania Rushdi (2019), introduced a new expression in her research called "Piezo-bump" which inserted piezoelectric cells with speed bumps. This research consisted of two study method stages, the first one is designing a model with the maximum efficiency and the second stage consisted of applying this model in a case study then checked its designed efficiency. The study area was one of the most crowded streets in Egypt to get highest possible efficiency. However, the final results showed that the piezo-bumps generated 20 times over required consuming energy for lightning this road.

1.5.2 Thermoelectric:

According to Seebeck effect, electricity can be generated through a temperature difference. Shaban et al. (2019), studied the concept of applying thermoelectric generators in pavements, for producing electricity and using it in multi purposes. By exploiting the temperature difference between the surface of the pavement and it's underlying layers. The thermoelectric module made of a hot mix asphalt pavement order and a Portland cement concrete pavement order in a laboratory in USA. This experiment proved that thermoelectric effect has a very low efficiency almost about 300 W/lane-km.

Tahami (2019), Showed the development of thermoelectric pavement generators, by adding a cooling design to a prototype, in order to cool the underlying layers to increase the temperature difference, so higher efficiency. After this improvement the output power when the surface temperature is 65°C in a range of 19-46 MW by the 4 thermoelectric generators prototypes, which is fine but still not enough as an alternative competitor energy source.

1.5.3 Mechanical:

Sorma et al. (2014), introduced a mechanical method called in their article (Electro-Kinetic power generation). The Electro-Kinetic power generator is a process of producing electricity by harnessing the kinetic energy of automobiles that drive the track, the track is a number of designed roller. There was no prototype of this method, but the estimated calculated output power was 1.67W by one car. This main disadvantage of this process is the huge energy losses which estimated about 50-70%.

Ramadan et al. (2015), considered a mechanical system included many mechanisms connected to generator, in order to convert the kinetic and the potential energy into electricity. A small prototype was constructed than could handle 80kg, and the output power was 44.7W. After these experimentally results, the expectation output power of a speed bump breaker power generator of this type is 0.56KW per car. Which is an excellent estimation result if we consider this system in a traffic street?

Todaria et al. (2015), embodied a novel speed bump energy harvester in a special design that change the up and down movement into rotational one, so then rotate the generator. The advantages and disadvantages were known by using physical modeling and simulation. The electrical resultant power 200W.

A study by Zhang et al. (2016), described a method to convert the waste kinetic mechanical energy into useful electrical energy by using a mechanical system. This system consisted of main four elements, speed bump, suspension, generator and the power storage module. The average output voltage of this system experimentally was 55.2V, this number can be got when the vehicle is moving in speed of 40Km/h, which is acceptable for lightning road tunnels for example.

Iyen et al. (2017), performed in this project rack and pinion mechanism system which was connected to generator. The generated power was 1.9KW from this system, and to get that number this system must be put in heavy street traffic in order to get the required efficiency.

Gholikhani et al. (2019), studied two different mechanisms of electromagnetic energy harvesting technology to generate electricity: rotational mechanism and cantilever mechanism. The performance of these mechanisms was measured experimentally in a laboratory in USA, where the maximum output power the cantilever was 2.8W, while in the rotational mechanism 0.25W. After got these results, both mechanisms can be a certified alternative renewable energy.

1.5.4 Hydraulic:

A study by Gupta et al. (2013), showed an efficient model for generating electricity by using speed bumps. This method consisted of hydraulic press, crank lever mechanism that works as a beam engine and a dynamo plus electricity reservoir. The output power was about 3KW/100 vehicles, which is enough for lightning streets in rural areas in India as the article showed.

1.6 Significance of the project

Speed humps are mainly used as traffic calming devices in Palestinian cities, especially the city of Nablus, and as a result of the large traffic volume in the city of Nablus, the weight of moving cars on speed humps can be utilized to produce energy in safe and clean ways.

Transportation is an essential element in sustainable development because it maintains the flow of traffic continuously, reduces the consumption of renewable resources and limits the use of resources and energy production.

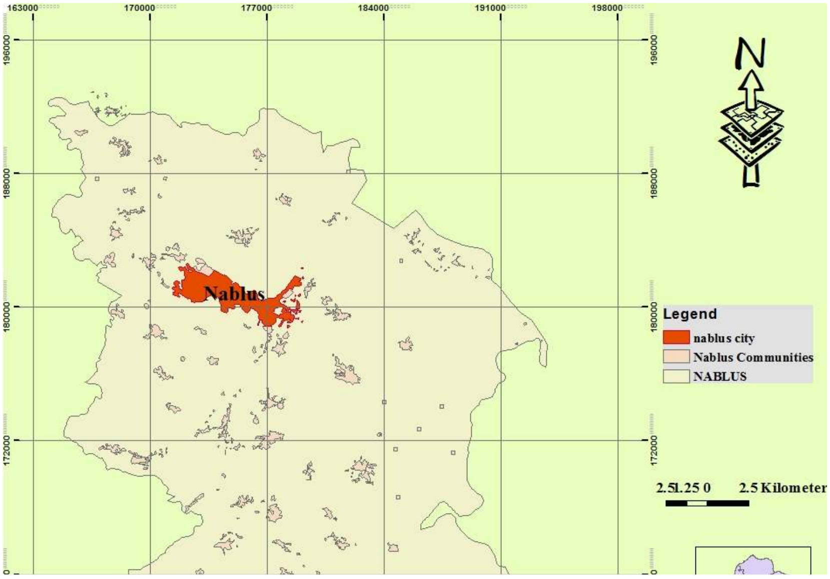
Adopting this method certainly does not substitute for other sources of electricity production, but its importance is formed by its reliance on clean energy and limiting the use of fossil fuels and their pollution and noise, also it has a continuous movement compared to most renewable and unpredictable sources such as wind ,solar, tidal and geothermal energy.

The project does not require special infrastructures or high financial costs. The developed speed bumps will be used to generate electricity that can contribute in lighting the streets.

1.7 Study area

The project was conducted in Nablus city, which is a Palestinian city that is located at the north of West Bank, also it is considered as a link between the Palestinian cities, it connects the northern and southern cities as well as eastern and western, located between Ebal and Jarzeem mountain with longitude 32.26667 and latitude 35.26667. Figure 1.4 and Figure 1.5 illustrate the location of Nablus city with respect to West Bank and Nablus governorate, respectively.

Figure 1 [illegible] West Bank



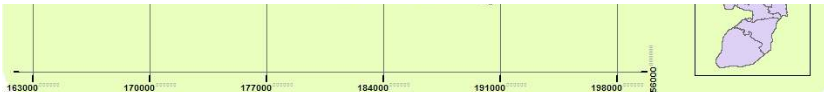


Figure 1. 3 The central location of Nablus city in Nablus governorate

1.8 Approach

When implementing any project, it’s necessary to collect relevant data and to conduct good planning and designing. The method of collecting data depends upon two main steps: use existing data from previous projects and collect required data from the project site.

The team began the work by an inventory study for the Nablus city, in order to collect the coordinates of speed humps, using two devices: Mobile and Handheld GPS device. The accuracy obtained through these two devices from 3-5 meters. This accuracy was found by taking a coordinate of a specific point from the Palestinian Land and Water Settlement Commission site and then form the Handheld GPS device, then comparing the two values. Moreover, the team visited relevant institutions to get the required data and devices. First, the department of Geography at An-Najah National University to get the map of Nablus city and use it to plan and drop the coordinates of the speed humps. Also, the department of Geometrics Engineering (Surveying Lab) to get the Handheld GPS device, and use it to work out the coordinates of speed humps. Second, the Municipality of Nablus, to get street centers and places of lamp posts plans.

Also, the team used previous studies in traffic volume analysis, to determine the design vehicle weight, then calculate peak hour (PH), peak hour volume (PHV), then to determine Average

Daily Traffic (ADT). Software programs were used such as ArcGIS, Excel sheet to analyze traffic volume data. Solid work program to design primary prototype of speed bump. Then calculate the feasibility study.

1.9 Report Structure

The graduation project consists of seven chapters: first chapter gives an introduction. The methodology of how the project is done presented in chapter two. Chapter three presents the way the data were collected. The analysis of data was illustrated in chapter four. The Speed hump design was illustrated in chapter five. In addition, Feasibility study illustrated in chapter sex. Finally, Conclusions and recommendation illustrated in chapter seven. Figure1.6 shows these chapters.

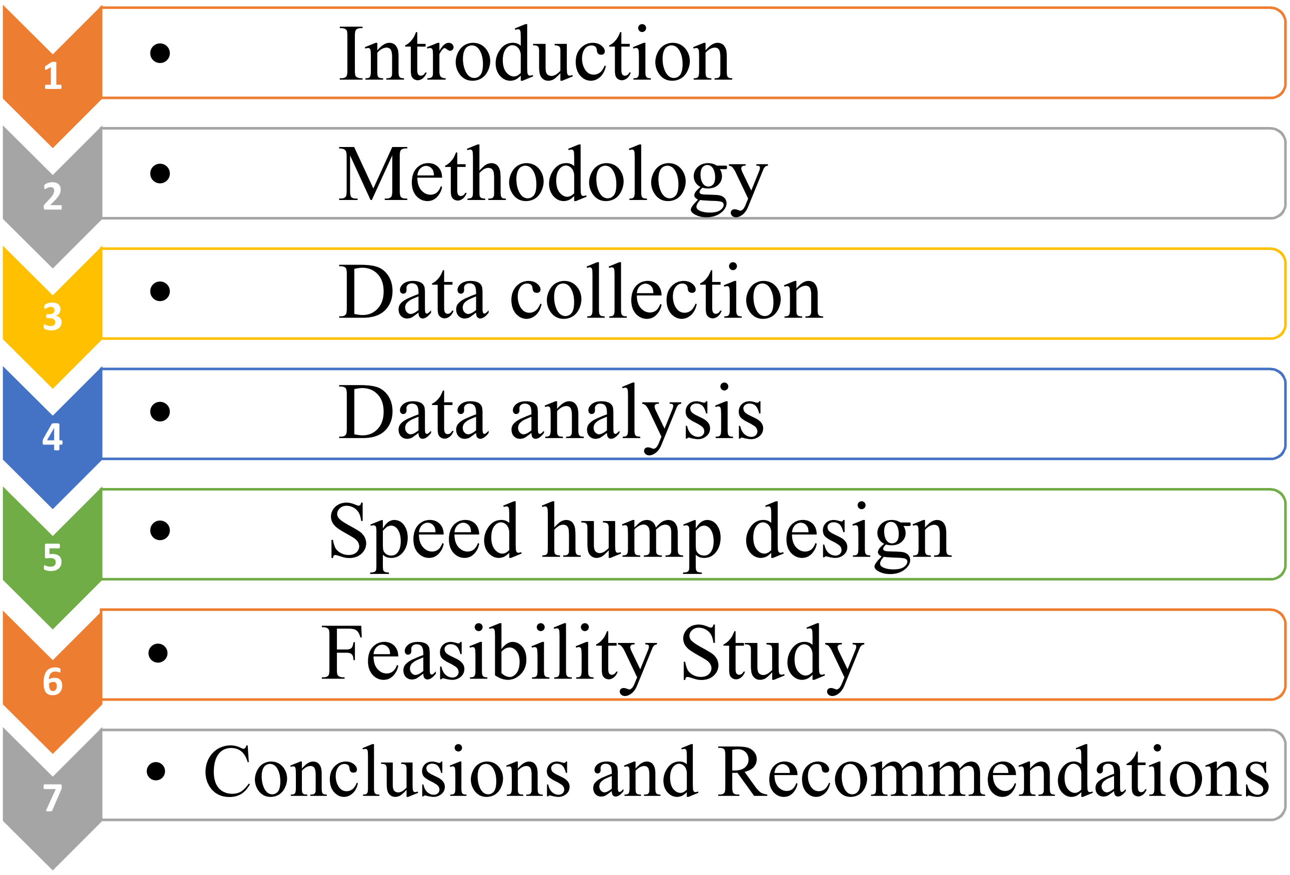


Figure 1.4 Report structure of the project

2 METHODOLOGY

This chapter will present the steps that the team followed to match the desired objectives stated previously in this report. It includes the methodology that was implemented in collecting data that are related to area of study, analyzing these data via computer software programs and economic feasibility study. In addition, GIS preparation, performing traffic volume study; furthermore, the methodology includes the set criteria and standards followed by the team. The speed hump design and constraints that were faced in this study.

2.1 Data collection

This stage considered to be one of the main stages of the project. In the beginning, the project team visited Nablus municipality, North Electricity Company, and Masader Company. Nablus municipality was visited to gather the required information, such as street AutoCAD drawing, lighting poles spots maps, also the cost of the speed hump per component (asphalt), excavation cost per speed hump and the monthly rate of electricity consumption by traffic signals and lighting of the streets of Nablus and the cost of electricity consumption demand. In addition, North Electricity Company was visited to obtain the number of lighting poles, the amount of energy loss in the network and the amount of consumption of the LED lamp compared to a regular lamp; furthermore, Masader Company was visited to obtain information about the solar panel, connecting cost with network, and how the system used to connect with the network.

After that the coordination of humps were collected for Nablus city, then data related to the number and classification of vehicles passed in each lane at each intersection and links were collected. Next, Excel sheets were used to determine the peak hour (PH), peak hour factor (PHF), peak hourly volume (PHV) and design hourly volume (DHV) for each lane.

2.2 GIS Map Preparation

A geographic information system (GIS) is a framework for gathering, managing, and analyzing data. Rooted in the science of geography, GIS integrates many types of data. It analyzes spatial location and organizes layers of information into visualizations using maps and Aerial photograph. (Esri, 2012).

In this project, an aerial photograph of Nablus city was analyzed by using the ArcGIS software as an important layer for many tasks. Firstly, the city was divided into different zones according to the spatial location of the city. Secondly, dropping the coordinates of the speed humps.

2.3 Performing Traffic Volume Study

Traffic volume studies are conducted to determine the volume of traffic moving on the roads at a particular section during a specified time period. Traffic volume studies are usually conducted when certain volume characteristics are needed such as Average Annual Daily Traffic (AADT), Average Daily Traffic (ADT) and Peak Hourly Volume (PHV).

Traffic volume study can be conducted in several ways depending on many factors such as the type of traffic data required, manpower available and available instrument. In this project, the manual method was used in recording the observed vehicle onto special sheet. This method is the least expensive. Vehicle classification, turning movement, the direction of travel, and vehicle occupancy were determined.

2.4 Setting Criteria and Standard

The criteria and standard that were used in this project are based on:

- ITE: The Institute of Transportation Engineers. ITE is an international membership association of transportation professionals who works to improve mobility and safety for all transportation system users and help build smart and livable communities. In 1997, the Institute of Transportation Engineers (ITE) published a Recommended Practice for the design and application of speed humps.

- FHWA: Federal Highway Administration. The Federal Highway Administration is an agency within the U.S. Department of Transportation that supports State and local governments in the design, construction, and maintenance of the Nation’s highway system. The Federal Highway Administration (FHWA) has responded by launching a national traffic calming technical assistance project in partnership with the Institute of Transportation Engineers (ITE). This report is one work product that includes a recommended practice for the design and application of speed humps.

- Palestinian 1923 / Palestinian Grid: The British Mandate Palestine grid was the geographic coordinate system used by the Palestine. The system was chosen by the Survey Department of the Government of Palestine in 1922. The projection used was the Cassini-Soldner projection.
- AASHTO (2011): American Association of State and Highway Transportation Officials. It includes standards set and specification, protocols, quality control, principles, and procedures that are used to design highways across the United States. Also, procedure that are used to calculate characteristics of traffic volume.
- ASME: The American Society of Mechanical Engineers. It is an American expert association that makes up the specifications and standards that must be followed in the foundations of mechanical engineering designs. In this project we use it in prototype design to determine the type of material used, modules of elasticity for spring (E), modules of rigidity (G) and elasticity of meshes.

2.5 Speed Humps Design

Mechanical speed hump energy harvesting system was used. The applied system consists of two sections; the first section is a mechanical section which includes different gears, a flywheel, pulleys and a belt. The second section is electrical one, which includes a generator, an inverter, a charger controller and a buttery. The use of the mechanical parts is transforming the up and down motions that result from the passing of vehicles over the speed hump into rotational regular motion. The rotational motion shifted directly to the first part of the electrical system which is the generator. The golden star in our system is given to the generator which is the essential part in the system that turns the mechanical energy to electrical energy.

2.6 Analysis of Economic Feasibility Study

The economic feasibility study is carried out by analyzing the cost of manufacturing, periodic maintenance, and the annual revenue resulting from covering the electricity to the network, and this in turn depends on Cost Benefit Analysis (CBA). CBA starts from the premise that a project should only be commissioned if all the benefits exceed the aggregate costs.

Accordingly, the economic feasibility was analyzed using Excel and Matlab. The Matlab program was used in order to find out the number of batteries suitable for their type for each electrical speed bump,calculate Internal Rate of Retain (IRR), Pay Back Period (PBP), and classify the electrical speed bumps according to Flow, and calculate the number of batteries suitable for their type for each classification. Furthermore, excel program was used to calculate the Net Cash flow.

In the field of electrical speed bumps, an economically feasible electrical speed bump means that all the benefits arising from this process exceed its total costs and, therefore, it is shown that electrical from speed bump is a positive process not only from an economically point of view, but also environmentally. This is the golden point in this project, that the project is environmental and economic, it is rarely available.

2.7 Design Alternative

When a product is available in different cases where all the cases share the same components. However, adding or applying other parts to a specific place, these are referred to as alternatives. Design alternatives for the facilities at a particular site can readily be considered in the decision analysis framework for siting. Here, design alternatives means two distinct but similar facilities at the same site, for the same ultimate purpose.

In this project several alternatives have been proposed, and these alternatives depend on the percentage of energy produced from the consumed energy.

These alternatives as follow:

- Bumps are divided according to traffic volume into three categories:
  1. Maximum Flow: The speed humps represent the traffic volume on them of more than 10,000 vehicles. And their number was 57 speed humps.
  2. Average Flow: The bumps represent the traffic volume on them that ranges between 1000 and 10,000 vehicles. And their number was 276 speed humps.
  3. Minimum Flow: The bumps represent the traffic volume on them of less than 1000 vehicles. And their number was 72 speed humps.

The results of each category of output energy, cost their economic feasibility were analyzed in the following chapters.

- Adding solar panels to the lighting poles near the SBGEP because the storage system is available, and this addition can improve the amount of electrical energy produced from the SBEP.

2.8 Project Constraints

Project constraints are restrictions that define project's limitation, such as time, resources and quality. They have an impact on how the project is accomplished and its results. Thus, these constrains must be well defined and the impact of each one of them on the project should be determined.

The main constraints that were faced in this project, are as the following:

- Time: The project final due date, with the state of emergency to face the coronavirus in the country and worldwide. The biggest challenge was to continue the volume studies and prepare a prototype for the speed bump within the specified date. Thus, the project's final delivery date was delayed.
- Resources: This constraint is associated directly to the project cost. The required amount of money for achieving the work. Such as problem was faced in obtaining the expensive GPS devices to find the speed hump coordinates. As an alternative, the handheld GPS devices and Mobile were used. Then the accuracy obtained through these two devices from 3-5 meters. This accuracy was found by taking coordinates of a specific point from the Palestinian Land and Water Settlement Commission site and then form the Handheld GPS device, then comparing the two values in order to determine the adjustment factor and as a result to increase the accuracy of the data.
- Lake of available data: At the beginning of the project, the Geo-MoLG site was disable, so no aerial photo 2019 for Nablus city is available. To overcome such as lake in data, Geography Department helped with giving a photo for 2018. In addition, the lack of data in previous graduation project and difficult to get it.

3 DATA COLLECTION

Data collection is the process of gathering and measuring information about various fields and it is an important aspect of any type of research study.

Collecting traffic data is a basic requirement for transportation systems for several functions:

1. Transportation Operation.
2. Planning and Design of the roads networks.
3. Traffic Control and Management.

4. Maintenance.

There are several sources of data collection in this project, which include reconnaissance visits, collection maps and information from the municipalities and companies. Coordinates and dimensions of speed humps were recorded using the handheld GPS device and the mobile phone. Traffic survey was conducted on many intersections and streets in the city during the morning and evening peak hours. The detailed traffic volume data with vehicle classifications were filled in the sheet at the given time interval in the data sheet. Further, the filled data sheet was used to analyze the data for the required result. The traffic volume counts were conducted using coverage method of manual counting for short duration counts, ranging from six hours to seven days, distributed throughout the system to provide point-specific information.

3.1 Type of Collected Data

The team collected various types of data, including

3.1.1 Reconnaissance Visit

Reconnaissance visits are the basis for field studies, which is used in the early stages of any scientific research or graduation project, aiming to collect the necessary data within the circumstances in which this research is conducted

This project based mainly on reconnaissance visits. In order to model the system, it was necessary to divide the study area into traffic zones. According to the municipal divisions, Nablus City was divided into 43 neighborhoods as shown in Figure 3.1 then include each group of neighboring neighborhoods to form one zone. As a result, Nablus city was divided into 6 main zones as shown in Figure 3.2, these zones are:

a. Rafidia / Al makhfia zone (A).
b. Central zone (B).
c. Gerizim zone (C).
d. Ebal zone (D).
e. Eastern zone (E).
f. Industrial zone (F).

After that, every zone has given a letter as shown in Figure 3.3, also they were visited by the team to investigate the study area more accurately and collect the coordinates of the speed humps over two consecutive weeks, which made it easy to create a map that contains all the speed humps, thus determining the appropriate places to calculate the traffic volume. Through reconnaissance visits, many things were identified, including clarifying the mechanism of work and determining the dimensions of the existing speed humps, and if they satisfy the standards or do not.

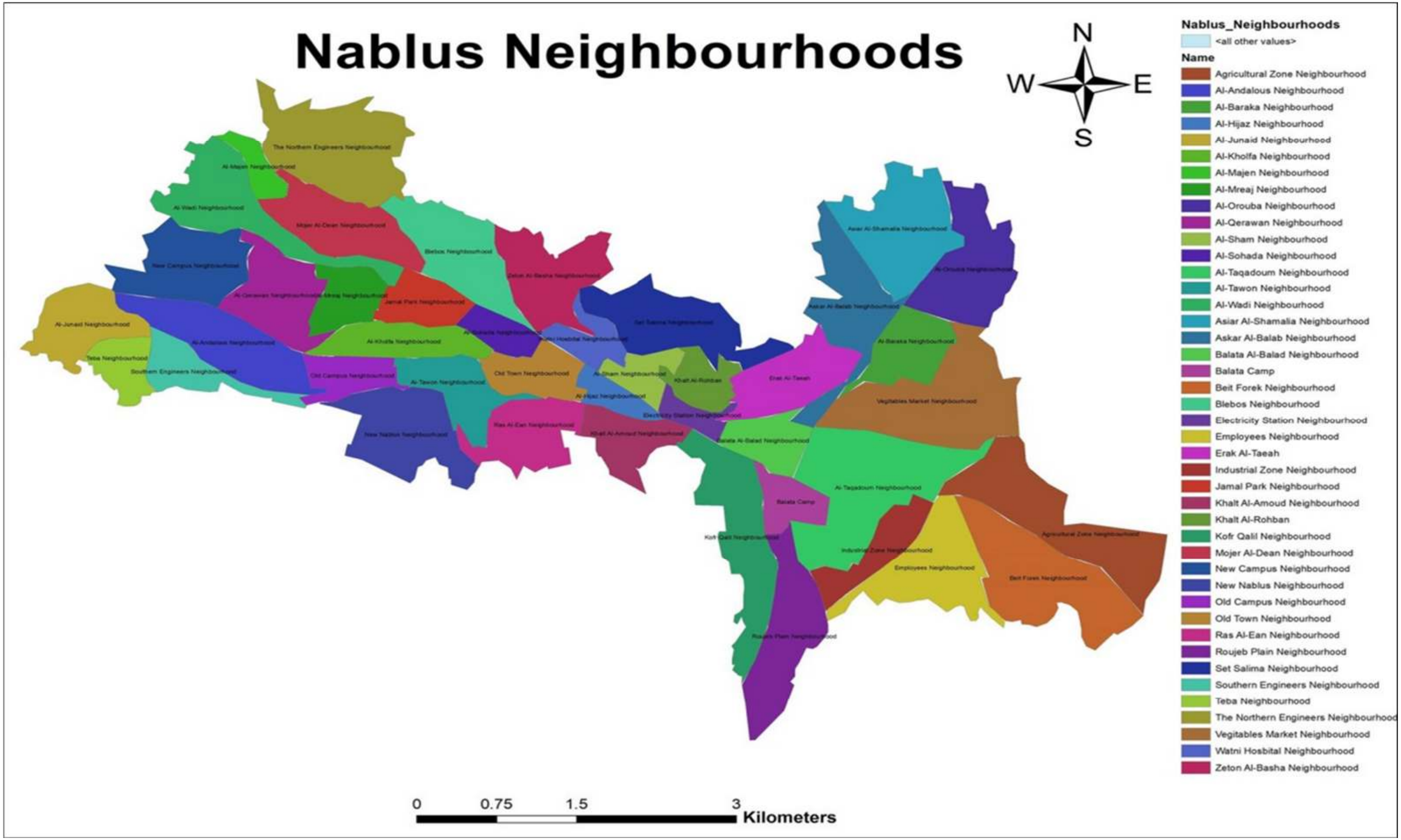


Figure 3.1 Nablus city neighborhoods

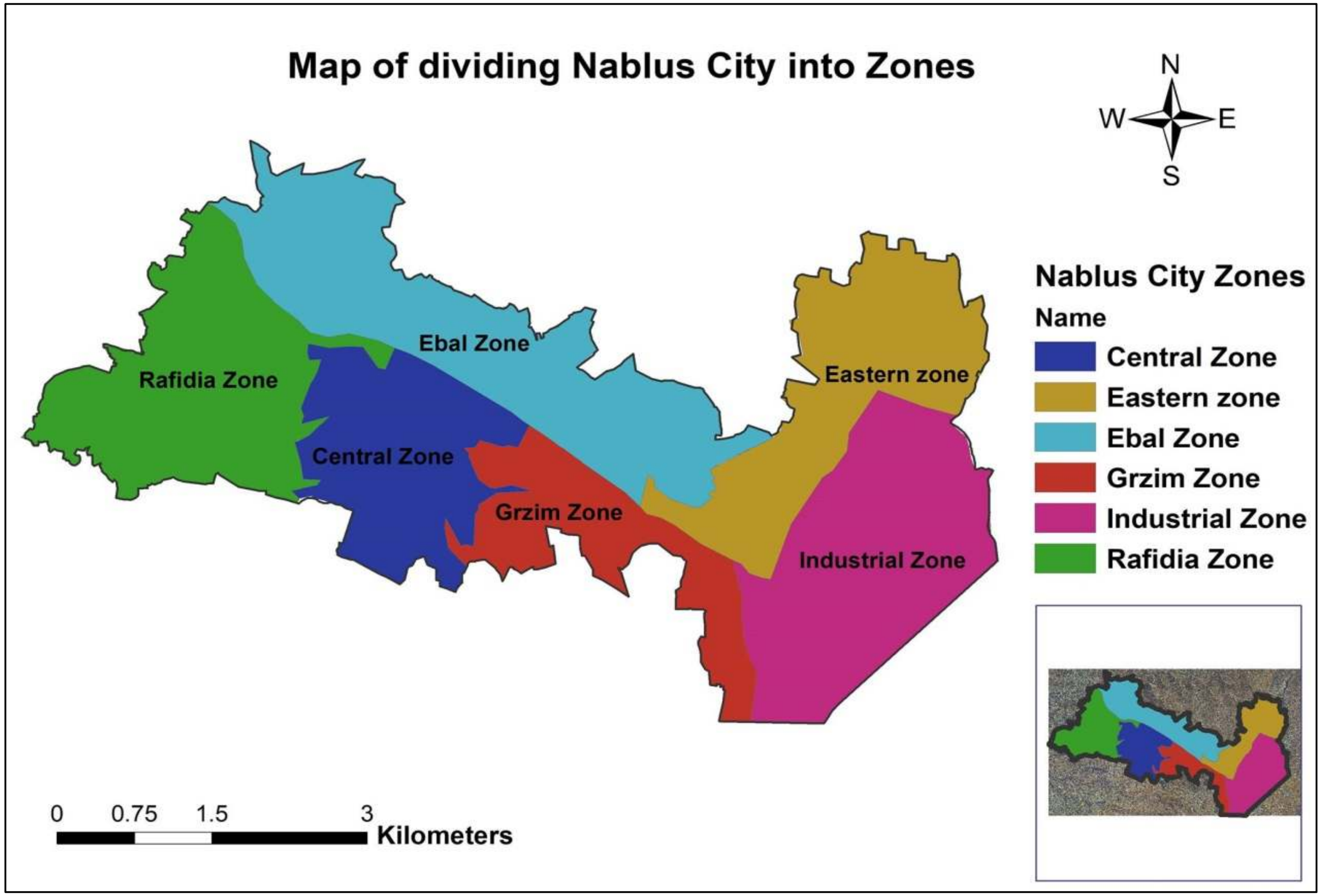


Figure 3.2 Nablus city zones

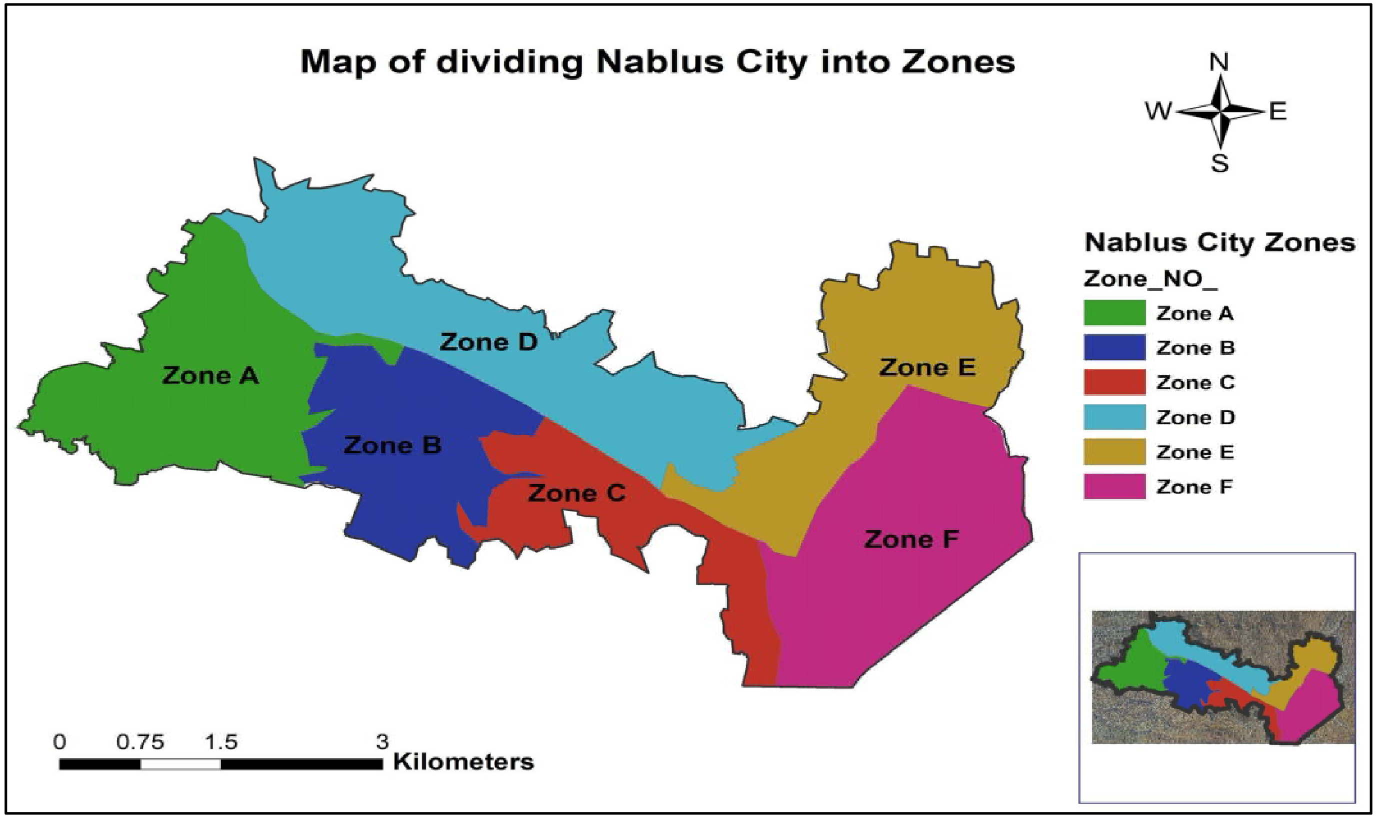


Figure 3.3 Nablus city zones

3.1.2 Collection Maps and Information

The map is the primary element to clarify everything in every location in addition to the aerial photograph that shows all parts of the city like streets, buildings, etc., for this reason the need for an aerial photograph in this project is one of the important elements to accomplish this project in an organized and accurate manner.

Therefore, the Department of Geography at An-Najah National University was visited to obtain the aerial photo of Nablus (for the year 2018) and to use it in many important matters. First, to divide the city into parts, for easy handling of all speed humps. Secondly, using the aerial photo to drop the coordinates of speed humps, lighting poles and street centers on it.

Furthermore, some required data were collected from local institutions and authorities, for instance, Nablus municipality, Northern Electricity Company and Masader Company. Nablus municipality was visited to gather AutoCAD files that contain street centers and lighting poles; in order to know the number of lighting poles and the number of traffic signals in every street that can be supplied with electricity from speed bumps. Also, the cost of constructing a speed hump and electrical speed bump as asphalt material, site work, installation work, and cost of running a speed bump and connecting it to the network .

In addition, the data about electricity within the city of Nablus, like the cost of 1 kilowatt (kW) which is approximately 0.5531 NIS, and therefore the average consumption of electricity per household is about 330 kilowatts per month, as well as, the average consumption of electricity which is about 29,393 kW per day, 894,037 kW per month, and 10,728,439 KW annually, the electricity used by traffic signals only costs the municipality approximately 100,000 NIS per month and lighting poles costs about 469,603 NIS per month; This is to compare the rate of consumption of electricity with the rate of electricity production from the speed bump.

Moreover, The Northern Electricity Company has also been visited to search for the prices paid to the occupying power for the electricity supplied to the city of Nablus, which is estimated about 18 million NIS per month. Also, the prices paid to National Electricity Transmission Company PETL about 7 million NIS. Where PETL is the first Palestinian governmental company to supervise the construction and operation of the national electric energy transmission system and its transportation to the Palestinian market. Moreover, information on the type of lamp used and the volume of its consumption were taken daily.

Furthermore, Masader Company was visited to obtain information about the solar panel, connecting cost with network, and how the system used to connect with the network.

3.1.3 Speed Humps Coordination

Global Positioning System (GPS) is a system of 30+ navigation satellites circling Earth. Their location is known because they constantly send out signals. Moreover, it is considered one of the most important systems used to locate objects on the ground.

The coordinates are values by which specific locations are determined on the surface of the Earth or map. The coordinate systems vary according to the difference in reference surface on which the locations are represented. In this project world 1983 and Palestinian Grid 1923 were used to determine the coordinates.

The coordinates of the speed humps were obtained through the following steps:

Firstly, the city of Nablus was divided into 6 zones: A, B, C, D, E and F in order to facilitate coordinate setting process.

Secondly, every zone was visited in order to record the coordinates and dimensions of speed humps using the handheld GPS device and the mobile phone and filled in data sheet as shown in Figure 3.4. Then the coordinates were transformed from the international system to the Palestinian system through GIS program. Also, they were verified through the website of the Palestinian Land and Water Settlement Commission. This site is a system that divides the concerned area into basins and neighborhoods with names that are known in the region for the purpose of inference and guidance on land borders and others.

Finally, these speed humps with their characteristics were entered on the Excel program, each speed hump was given a symbol according to the zone in which it was located, and then these coordinates were projected on the city's aerial photograph using the GIS program.

Zone name: -----------　　　　　　　　**Date:** ---/---/2020

Street name: ----------　　　　　　　　**Day:** ------------

No. of bump	Street characteristics					Notes
	Dimensions			Coordinates		

Figure 3.4 The form of monitor coordination humps

3.1.4 Traffic Volume

In traffic volume count, the number of vehicles passing through a road or intersection over a period of time is counted. Traffic data collection is very important part in transportation for planning, also traffic volumes are the major factor in determining design criteria and it's an integral part of many transport studies for example, determine level of service of a road, finding annual average daily traffic, design a signal at intersection. Although manual counting is one of the most used methods, other techniques have recently emerged.

Manual count: is the most common way to collect traffic volume data which include a group of people who collect data that cannot be obtained efficiently by automated methods such as vehicle occupancy rate, pedestrian and vehicles classification during a specific time period in a specific location by marking counting papers, then the data is organized for compilation and analysis by marking counting papers, then the data is organized for compilation and analysis.

Automatic count: this method is based on a roadside device and sensor that records the number of passing vehicles and the most important ones are pneumatic road tubes, piezoelectric sensors and magnetic loops. It is used in cases where manual count is not possible to be conducted.

In this project we used manual counting by filling counting forms as shown in Figure 3.6 and Figure 3.7.

In this project a traffic volume survey was conducted, which is the determination of the number, movement and classification of roadway vehicles at a given location. As mentioned before, the main objective of the project is to measure the potential amount of electricity generated from the speed humps in Nablus city, to achieve this goal adequate information about the volume of vehicles passing through the speed humps should be collected.

Volume survey was performed over Nablus city, in order to achieve the survey; the city was divided into 6 areas as mentioned before. To make the process easier, each area was given a letter, then every counting location in that area was named by the letter and a number.

Counting locations were chosen based on the location and number of speed humps as shown in figure 3.5 Where the red color represents the places that were counted by the team and their percentage was 97%, while the green color represents the readings taken from previous studies and their percentage was 3%. Furthermore approximately 10% of these areas were counted after the emergency period. The locations varied between T-intersection, four intersections, multi-intersection, two-lane two-way road and four lane road. The traffic count was performed during the expected peak hour. That is, during the morning period (7.00-9.00AM) and during the evening period (12.00-3.00PM) for four days per week of the same sight for the uniformity of data.

The vehicles were classified into five categories according to American Association of State Highway and Transportation Officials (AASHTO): passenger car, mini bus, buses, trucks and others.

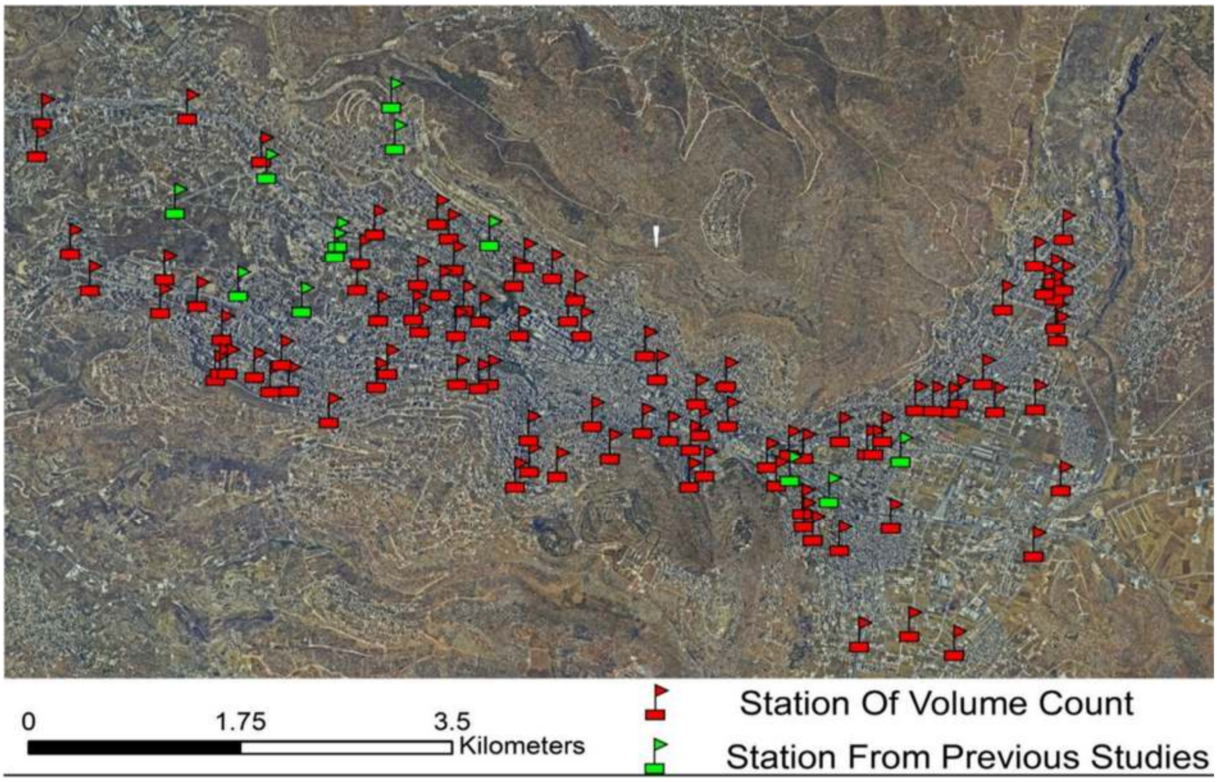


Figure 3.5 Counting location in Nablus city .

Day	MONDAY OR	TUESDAY	
Date	19 OR 18	/08/2019	
Time (from - to)			

NOTES:

Count Station	
Weather	
Observer Number/Name	

Approach:				1. NORTH			2. SOUTH			3. EAST			4.WEST				
Right						Through						Left					
PC	TAXI	MINI BUS	BUS	TRUCK	OTHERS	PC	TAXI	MINI BUS	BUS	TRUCK	OTHERS	PC	TAXI	MINI BUS	BUS	TRUCK	OTHERS

Approach:				1. NORTH			2. SOUTH			3. EAST			4.WEST				
Right						Through						Left					
PC	TAXI	MINI BUS	BUS	TRUCK	OTHERS	PC	TAXI	MINI BUS	BUS	TRUCK	OTHERS	PC	TAXI	MINI BUS	BUS	TRUCK	OTHERS

Figure 3.6 The form of traffic volume count at intersection.

Name of street :			day:				date :	
Time	In				Out			
	pc	mini bus	bus	truck	pc	mini bus	bus	truck

Figure 3.7 The form of traffic volume count at a link.

3.1.4.1 Previous studies

Previous studies are one of the most important pillars that must be considered when planning to conduct a study to implement any project in any field. Previous Studies must be reviewed and analyzed in order to present a new scientifically contribution.

At some locations, the traffic volumes were determined based on the previous graduations' projects. The volume at 12 main intersections was taken from the (Rabee et al, 2016) and 2 other intersections from (Salman et al, 2019). Using the appropriate growth rate, the traffic volume at these intersections was calculated. These intersections are:

1. Al-Gawi Intersection
2. Al-Quds – Balata Intersection.
3. Asira Intersection.
4. An-Najah Hospital intersection.
5. Tell- AL-Makhfia Intersection.
6. Nablus Aljadeedah Intersection.
7. Tunis- Abda-lRaheem Mahmoud Intersection.
8. Tunis-Yaffa Intersection.
9. Tunis-Hiafa Intersection.
10. Al-Shilla Villas Intersection.
11. Ring Road Intersection.
12. Korean Institute intersection (Almaktoom Intersection).
13. AL-Amria Intersection.
14. Rafedia-AL-Molouk Halls Intersection.

The growth rate refers to the change in population size as a factor of time, both for the human and non-human populations. In this project, the growth rate for traffic volume is calculated using the Growth Equation:

$$Pt = Po \times (1 + r)^n \tag{3.1}$$

Where:

Po: Current volume

Pt: Volume at time t.

r: Growth rate.

n: Number of years.

To find the growth rate that reflects volume changes of vehicles in Nablus, the number of licensed vehicles in the city was taken from the Transportation Ministry from 2012 to 2018.

Sample of calculations:

- The growth rate for 2013-2014:

$$26139 = 24079(1 + \mathrm{r})^1 \rightarrow \mathrm{r} = 8.57\ \%$$

- The growth rate for 2015-2016

$30870 = 270582 \times (1 + r)^1 \rightarrow r = 11.92\ \%$

- The growth rate for 2016-2017

$34013 = 30870\ (1 + r)^1 \rightarrow r = 10.18\ \%$

As can be observed from the graph shown in Figure 3.8, there is a large variation in the growth rate over the years, and the value starts decreasing from the year 2016 to 2018. The reason for this reduction because the value is affected by several factors, the main factors are the economic satiation in the country and the taxes imposed by the government.

Another way to find the growthrate value is from previous studies. Back to previous graduation projects, the value was taken 4%, which could be representative for many reasons. The value is in continues decreasing since 2016, and 4% is close to the normal population growth rate in the city (3-4%).

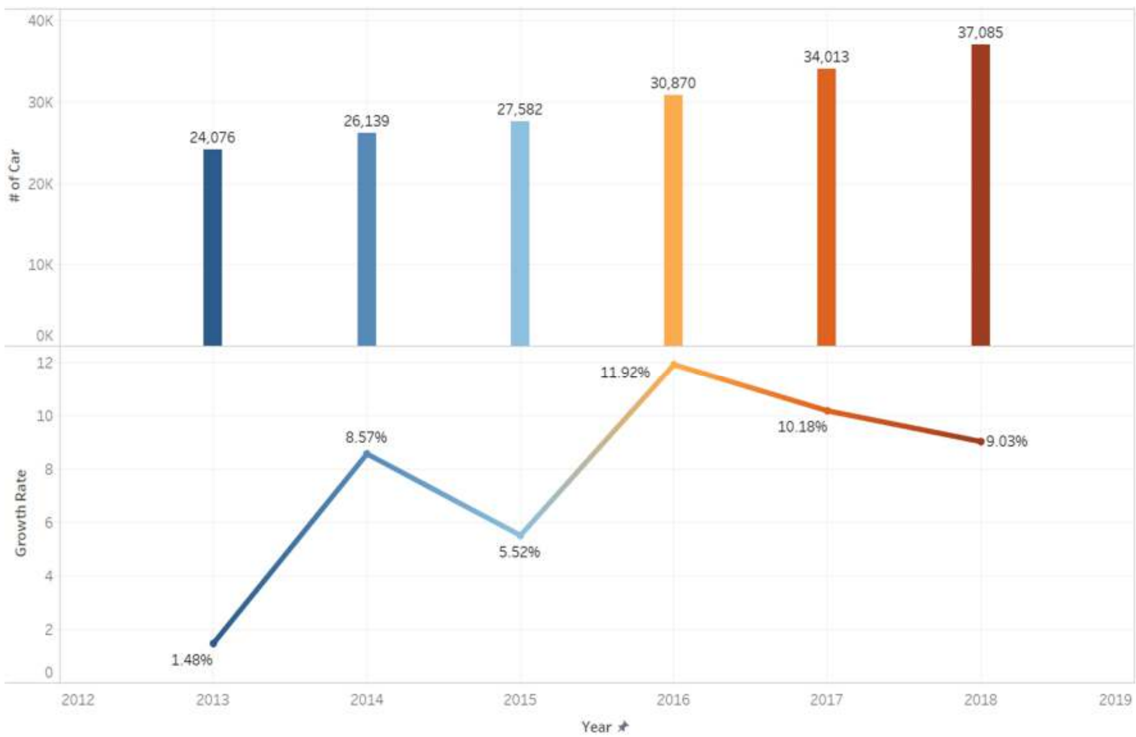


Figure 5 Graph Shows The Number Of Vehicle And Growth Rate

Figure 3.8 Graph shows the number of vehicle and growth rate.

4 DATA ANALYSIS

4.1 Volume Studies

4.1.1 Introduction

Traffic volume is defined as the number of vehicles that pass through a point on transportation facility during a specified time period. Volume studies are conducted to determine the number, movements and classification of roadway vehicles at given location. The data collected can be used to identify critical flow time periods, determine the influence of large vehicles or pedestrians on traffic flow. The length of counting period depends on the type of count being taken and intended use of the data recorded. The information on traffic volume is an important required for planning, analysis, design and operation of roadway systems.

4.1.2 Purpose of Traffic Volume Study

General Objective of Traffic Volume Study:

1. Design purpose.
2. Dynamic Traffic Management.
3. Estimation of highway usage.
4. Measurement of current demand of a facility.
5. Economic feasibility evaluation.

Specific Objective of Traffic Volume Study:

The main objectives of traffic volume study in addition to counting the number of vehicles for the studied road network in this project, identifies the most traffic volume street that contains speed humps in order to generate the maximum amount of electricity. As a result of the study, the frequency of the vehicles that pass through the speed hump can be determined, this is very important for measuring the amount of generated electricity. By knowing the predominant type of vehicle that passes over these speed humps, design vehicle can be selected in order to estimate the expected amount of produced electricity.

4.1.3 Study location and Methods

The study was conduct in Nablus city. The method used in manual count method. The reasons that this method is used are:

1. Easy, simple and direct.
2. Not expensive.
3. Easy to collect data.
4. The vehicle count can be classified.
5. No need for special equipment.
6. The data collected can be used immediately after collection.

4.1.4 Duration of Counting

The study was conducted from 15 February to 6 March 2020, then stopped because of the emergency state (Coronavirus lockdown) and continued from 12 to 18 June 2020. The time chosen in the study was 7am to 9am which includes morning peak hour and 12pm to 3pm which includes afternoon peak hour.

For this project, the data collected from traffic count are used to determine certain volume characteristics:

- ❖ Average Annual Daily Traffic (AADT)

Average Annual Daily Traffic is one of the most important parameters used in the transportation engineering. AADT is the total volume collected every day of a year, divided by 365. It's an important traffic measure used in any transportation related project, also it is an important parameter used in Safety Analysis software and the Highway Safety Manual (Harwood, 2004). AADTs are used in several traffic and transportation analyses for:

a. Estimation of highway user revenues.
b. Computation of crash rates in terms of number of crashes per 100 million vehicle miles.
c. Establishment of traffic volume trends
d. Evaluation of the economic feasibility of highway projects.
e. Development of freeway and major arterial street systems.
f. Determining funding for highway maintenance and improvement.

g. Analyzing the environmental hazards of pollution related to road transport

❖ Average Daily Traffic (ADT)

The Average daily traffic is defined as the total volume during a given time period, greater than 24 hour and less than one year, divided by the number of days in that time period. The current ADT volume can be determined when continuous traffic counts are available. When only periodic counts are taken, the ADT volume can be estimated by adjusting the periodic counts according to such factors as the season, month, or days of week.

ADTs may be used for:

a. Planning of highway activities.
b. Measurement of current demand.
c. Evaluation of existing traffic flow.

Another method to find AADT, other than counting, is from ADT. The AADT for a given year can be obtained by estimating the average daily traffic (ADT) for a month and multiple this volume by monthly expansion factor (MEF).

Because of the lake of information, and the difficulty to find the AADT by counting, also because limited duration for the project. The ADT is used as an alternative for the AADT in the project, which won't make much difference.

To find the ADT, the following equation is used

$$DHV = ADT \ x \ K \rightarrow ADT = \frac{DHV}{K} \tag{4.1}$$

Where:

ADT: Average Daily Traffic (veh/day).

DHV: Design Hourly Volume (veh/hr.)

K: Proration of ADT occurring in the peak hour

- K – Factor

K – Factor is important in traffic engineering statistics used throughout highway engineering, capacity and design purpose, there are several oscillating values of K – Factor such as K 30, K50 and K100 the most common one is typically referred to as the K-30.

Based on the Figure 4.1 which shows the relationship between the highest hourly volumes and ADT on rural arterials that produced from an analysis of traffic count data covering a wide range of volumes and geographic conditions, it is recommended that the hourly traffic volume that should generally be used in the design is the 30th highest hourly volume of the year, abbreviated as 30 HV or K30,because it is forming a control element in the design through the changes that result from the choice of size higher or somewhat less and also K30 is the most frequent in each year.

K – Factor is typically derived from continuous count station on the same routes with similar traffic characteristics in the same area. On a typical rural arterial that having unusually high or low fluctuation in traffic flow the value ok K – Factor is in the range of (12 - 18) % of the ADT, as well the range in maximum hourly volumes for the same groups of roads varies approximately from (16- 32) % of the ADT. However, in an urban area, the value of K – Factor is in the range of (8 – 12) % of the ADT.

In this project, Nablus City was the study area which considered as urban classes, so the value of 10 % is considered as an ideal value because it represents the average of the range.

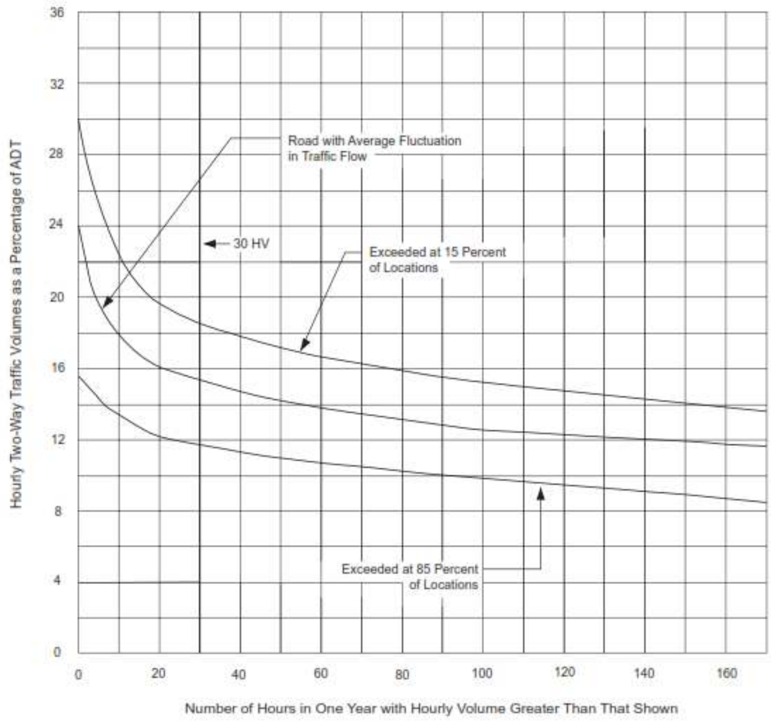


Figure 4.1 Relation between ph and adt on rural arterials

- ❖ Peak Hour Factor (PHF)

The accepted unit of time for expressing flow rate is a one-hour period so in traffic volume studies, the focus is placed on the peak – hour traffic volume and considered as the acceptable unit for describing traffic flow, which used in evaluating capacity and other parameters. Because the flow is not uniform during one hour there are periods during the hour where congestion is worse than other times, so the hour was divided into four quarters of 15 minutes. Accordingly, the total hourly volume that can be served without exceeding a specified degree of congestion is equal to or less than four times the maximum 15-minute count. In this project depending on the traffic count at each speed hump for a period of four hours, it was found that the peak hour at most speed humps is between (7-9) Am.

Peak Hour Factor (PHF) can be described as the ratio of the peak hour volume to the number of vehicles during the highest 15-minute period multiplied by 4, this factor used to convert the rate of flow during the highest 15-minute period to the total hourly, it reflects the stability of volume distribution in an hour.

PHF has a significant impact on the traffic analysis result, for example, capacity and Level of Service (LOS) analysis. PHF is never greater than 1 it is normally within the range of 0.75 to 0.95.

$$PHF = \frac{\varepsilon\, volume\ of\ the\ four\ quarters\ in\ PH}{4\times maximum\ quarter\ volume\ in\ PH} \qquad (4.2)$$

❖ Peak Hour Volume (PHV)

Peak Hour Volume (PHV) used to reflect fluctuation of traffic volume in a day; it is defined as the maximum number of the vehicle that passes a point on a highway during 60 consecutive minutes. Highways should be designed to adequately accommodate peak hour volume traffic.

To find peak hour volume we should find the volume count of traffic in Nablus City this can be estimated in a deferent method such as manual and automatic. Usually, the peak hour volume is in the term of passenger car units. Table 4.1 represents the peak hour volume **(PHV)** for both directions at each bump.

PHV is used for:

1. Functional classification of highways,
2. Analysis of capacity and Level of Service
3. Developing program related to traffic operation,
4. Planning and design highways facility such as the number of lanes, intersection signalization.

After applying manual count at each street contains speed humps, the following results of PHV, DHV, and ADT were summarized in Table 4.1 for each Speed hump in Nablus.

Table 4.1 PHV , DHV & ADT for each speed hump

Pump Name	PHV	DHV	ADT	Pump Name	PHV	DHV	ADT
A1	337	337	3370	**A42**	856	856	8560
A2	1174	1174	11740	**A43**	36	36	360
A3	863	863	8630	**A44**	542	542	5420
A4	1174	1174	11740	**A45**	542	542	5420
A5	863	863	8630	**A46**	542	542	5420
A6	865	865	8650	**A47**	26	26	260
A7	516	516	5160	**A48**	21	21	210
A8	1214	1214	12140	**A49**	364	364	3640
A9	1271	1271	12710	**A50**	360	360	3600

A10	212	212	2120	**A51**	2	2	20
A11	1338	1338	13380	**A52**	537	537	5370
A12	996	996	9960	**A53**	4	4	40
A13	172	172	1720	**A54**	537	537	5370
A14	999	999	9990	**A55**	537	537	5370
A15	999	999	9990	**A56**	537	537	5370
A16	445	445	4450	**B1**	962	962	9620
A17	445	445	4450	**B2**	962	962	9620
A18	163	163	1630	**B3**	983	983	9830
A19	181	181	1810	**B4**	838	838	8380
A20	960	960	9600	**B5**	247	247	2470
A21	1177	1177	11770	**B6**	247	247	2470
A22	960	960	9600	**B7**	247	247	2470
A23	1922	1922	19220	**B8 or G**	0	0	0
A24	2032	2032	20320	**B9**	235	235	2350
A25	1177	1177	11770	**B10**	114	114	1140
A26	0	0	0	**B11**	2337	2337	23370
A27	960	960	9600	**B12**	1055	1055	10550
A28	1337	1337	13370	**B13**	1009	1009	10090
A29	1448	1448	14480	**B14**	1009	1009	10090
A30	1337	1337	13370	**B15**	247	247	2470
A31	1337	1337	13370	**B16**	178	178	1780
A32	1337	1337	13370	**B17**	53	53	530
A33	29	29	290	**B18**	327	327	3270
A34	386	386	3860	**B19**	630	630	6300
A35	323	323	3230	**B20**	685	685	6850
A36	323	323	3230	**B21**	685	685	6850
A37	402	402	4020	**B22**	1521	1521	15210
A38	537	537	5370	**B23**	964	964	9640
A39	537	537	5370	**B24**	1988	1988	19880
A40	321	321	3210	**B25**	1988	1988	19880
A41	321	321	3210	**B26**	950	950	9500
B27	950	950	9500	**C5**	1521	1521	15210
B28	420	420	4200	**C6**	720	720	7200
B29	184	184	1840	**C7**	536	536	5360
B30	184	184	1840	**C8**	103	103	1030
B31	184	184	1840	**C9**	223	223	2230
B32	856	856	8560	**C10**	184	184	1840
B33	539	539	5390	**C11**	120	120	1200
B34	539	539	5390	**C12**	138	138	1380

B35	539	539	5390	**C13**	2120	2120	21200
B36	64	64	640	**C14**	182	182	1820
B37	64	64	640	**C15**	182	182	1820
B38	305	305	3050	**C16**	182	182	1820
B39	305	305	3050	**C17**	182	182	1820
B40	7	7	70	**C18**	182	182	1820
B41	1337	1337	13370	**C19**	182	182	1820
B42	1337	1337	13370	**C20**	342	342	3420
B43	837	837	8370	**C21**	89	89	890
B44	837	837	8370	**C22**	8	8	80
B45	810	810	8100	**C23**	386	386	3860
B46	146	146	1460	**C24**	386	386	3860
B47	146	146	1460	**C25**	2198	2198	21980
B48	146	146	1460	**C26**	1700	1700	17000
B49	146	146	1460	**C27**	164	164	1640
B50	826	826	8260	**C28**	236	236	2360
B51	865	865	8650	**C29**	251	251	2510
B52	140	140	1400	**C30**	170	170	1700
B53	140	140	1400	**C31**	170	170	1700
B54	140	140	1400	**C32**	170	170	1700
B55	340	340	3400	**C33**	183	183	1830
B56	497	497	4970	**C34**	183	183	1830
B57	299	299	2990	**C35**	151	151	1510
B58	299	299	2990	**C36**	151	151	1510
B59	1254	1254	12540	**C37**	151	151	1510
B60	1254	1254	12540	**C38**	823	823	8230
B61	1254	1254	12540	**C39**	900	900	9000
B62	299	299	2990	**C40**	838	838	8380
B63	299	299	2990	**C41**	838	838	8380
B64	299	299	2990	**C42**	838	838	8380
C1	754	754	7540	**C43**	838	838	8380
C2	754	754	7540	**C44**	851	851	8510
C3	1521	1521	15210	**C45**	851	851	8510
C4	1521	1521	15210	**D1**	337	337	3370
D2	212	212	2120	**D44**	838	838	8380
D3	1045	1045	10450	**D45**	405	405	4050
D4	549	549	5490	**D46**	299	299	2990
D5	1214	1214	12140	**D47**	1448	1448	14480
D6	848	848	8480	**D48**	359	359	3590
D7	848	848	8480	**D49**	359	359	3590

D8	200	200	2000	**D50**	359	359	3590
D9	200	200	2000	**D51**	359	359	3590
D10	200	200	2000	**D52**	909	909	9090
D11	200	200	2000	**D53**	259	259	2590
D12	200	200	2000	**D54**	151	151	1510
D13	1282	1282	12820	**D55**	151	151	1510
D14	1282	1282	12820	**D56**	151	151	1510
D15	1282	1282	12820	**D57**	151	151	1510
D16	1282	1282	12820	**D58**	693	693	6930
D17	963	963	9630	**D59**	582	582	5820
D18	963	963	9630	**D60**	582	582	5820
D19	482	482	4820	**D61**	471	471	4710
D20	482	482	4820	**D62**	471	471	4710
D21	482	482	4820	**D63**	96	96	960
D22	482	482	4820	**D64**	96	96	960
D23	482	482	4820	**D65**	761	761	7610
D24	534	534	5340	**D66**	1045	1045	10450
D25	534	534	5340	**D67**	1045	1045	10450
D26	534	534	5340	**D68**	1045	1045	10450
D27	183	183	1830	**D69**	1045	1045	10450
D28	183	183	1830	**D70**	37	37	370
D29	653	653	6530	**D71**	37	37	370
D30	653	653	6530	**D72**	37	37	370
D31	653	653	6530	**D73**	631	631	6310
D32	350	350	3500	**D74**	633	633	6330
D33	350	350	3500	**D75**	219	219	2190
D34	350	350	3500	**D76**	219	219	2190
D35	350	350	3500	**D77**	219	219	2190
D36	195	195	1950	**D78**	219	219	2190
D37	298	298	2980	**D79**	219	219	2190
D38	238	238	2380	**D80**	219	219	2190
D39	739	739	7390	**D81**	376	376	3760
D40	739	739	7390	**E1**	284	284	2840
D41	1443	1443	14430	**E2**	2052	2052	20520
D42	1679	1679	16790	**E3**	1642	1642	16420
D43	936	936	9360	**E4**	103	103	1030
E5	150	150	1500	**E47**	308	308	3080
E6	150	150	1500	**E48**	308	308	3080
E7	150	150	1500	**E49**	20	20	200
E8	150	150	1500	**E50**	20	20	200

E9	150	150	1500	**E51**	229	229	2290
E10	1576	1576	15760	**E52**	229	229	2290
E11	43	43	430	**E53**	152	152	1520
E12	103	103	1030	**E54**	152	152	1520
E13	103	103	1030	**E55**	152	152	1520
E14	103	103	1030	**E56**	152	152	1520
E15	389	389	3890	**E57**	2102	2102	21020
E16	389	389	3890	**E58**	1864	1864	18640
E17	389	389	3890	**E59**	19	19	190
E18	389	389	3890	**E60**	19	19	190
E19	389	389	3890	**E61**	19	19	190
E20	389	389	3890	**E62**	19	19	190
E21	389	389	3890	**E63**	45	45	450
E22	389	389	3890	**E64**	854	854	8540
E23	308	308	3080	**F1**	1069	1069	10690
E24	327	327	3270	**F2**	579	579	5790
E25	327	327	3270	**F3**	579	579	5790
E26	342	342	3420	**F4**	579	579	5790
E27	25	25	250	**F5**	520	520	5200
E28	14	14	140	**F6**	520	520	5200
E29	60	60	600	**F7**	144	144	1440
E30	50	50	500	**F8**	144	144	1440
E31	50	50	500	**F9**	144	144	1440
E32	53	53	530	**F10**	30	30	300
E33	53	53	530	**F11**	30	30	300
E34	52	52	520	**F12**	30	30	300
E35	100	100	1000	**F13**	9	9	90
E36	97	97	970	**F14**	36	36	360
E37	43	43	430	**F15**	36	36	360
E38	122	122	1220	**F16**	36	36	360
E39	60	60	600	**F17**	36	36	360
E40	75	75	750	**F18**	7	7	70
E41	104	104	1040	**F19**	7	7	70
E42	15	15	150	**F20**	7	7	70
E43	14	14	140	**F21**	7	7	70
E44	61	61	610	**F22**	7	7	70
E45	1035	1035	10350	**F23**	7	7	70
E46	308	308	3080	**F24**	180	180	1800
F25	180	180	1800	**F48**	923	923	9230
F26	433	433	4330	**F49**	923	923	9230

F27	422	422	4220	**F50**	1021	1021	10210
F28	422	422	4220	**F51**	905	905	9050
F29	246	246	2460	**F52**	900	900	9000
F30	246	246	2460	**F53**	823	823	8230
F31	277	277	2770	**F54**	823	823	8230
F32	277	277	2770				
F33	277	277	2770				
F34	1149	1149	11490				
F35	333	333	3330				
F36	333	333	3330				
F37	579	579	5790				
F38	579	579	5790				
F39	653	653	6530				
F40	1108	1108	11080				
F41	192	192	1920				
F42	624	624	6240				
F43	624	624	6240				
F44	524	524	5240				
F45	1118	1118	11180				
F46	957	957	9570				
F47	48	48	480				

4.2 Illustrative Example

In this study, in order to determine the traffic condition, traffic volume was counted at speed humps as mentioned previously.

The traffic analysis is performed based on the data collected and presented in appendix (A).

The following illustrative example shows the process and steps that were implemented in order to determine the ADT:

Speed Hump Number: A29

This speed hump is located in zone A which is called Rafidia, specifically in **Yasser Arafat Street** which is a two-way undivided street that allows vehicles to travel in both directions where the speed hump is 8 meters long, 4 meters wide and 7 cm high.

- **For the westbound:**
  - ✓ **PHV and PHF:**

The PHV is the maximum summation of four consequential intervals of 15 minutes**.** The maximum value represents the peak hour.

Table 4.2 PHV for speed hump A29 in Westbound

In							
Time	PC	Mini-Bus	Bus	Truck	Other	Total	PHV
7:00-7:15	61	0	0	2	0	63	
7:15-7:30	48	0	3	5	0	56	
7:30-7:45	167	1	0	2	3	174	
7:45-8:00	174	2	4	0	0	**180**	473
8:00-8:15	107	1	0	2	0	110	520
8:15-8:30	95	0	2	3	2	102	**566**
8:30-8:45	96	1	0	3	0	100	392
8:45-9:00	76	0	0	3	0	80	392
Total	824	5	9	20	5	865	7.30-8.30
1:00-1:15	71	0	0	2	2	75	
1.15-1.30	91	2	2	3	0	98	
1.30-1.45	115	0	2	0	3	120	
1.45-2.00	130	2	2	2	0	136	429
2.00-2.15	144	3	0	2	4	153	507
2.15-2.30	178	0	4	0	0	182	591
2.30-2.45	150	0	2	2	2	156	627
2.45-3.00	177	0	7	0	2	**186**	677
Total	1056	7	19	11	13	1106	**2.00-3.00**

Table 4.2 shows that the maximum value is **677** vehicles in the period **(2.00 to 3.00)** and therefore the value of the PHV equals **677** vehicles per hour.

To calculate the value of PHF we apply the following formula:

$$PHF = \frac{PHV}{4 \times V15}$$

- PHV = 677 vehicles

- V_{15}: Maximum number of vehicles in 15 minutes within the maximum hour
- V_{15} = 186 vehicles (from table 4.2).

$$\rightarrow PHF = \frac{677}{4 \times 186} = 0.909$$

✓ **Calculate DHV:**

The design flow rate can be calculated by dividing the peak hour volume by the PHF, but in this project needed a minimum number of vehicles so:

$$DHV = PHV$$

$$\rightarrow DHV = 677\ Vehicles/hour$$

✓ **Calculate ADT:**

The volume was found during the peak hour then used the k-factor to convert the peak hour volume to the equivalent ADT. Typical k-factor can be obtained from variety of sources, AASHTO, etc.

As a result of the lack of sufficient and detailed data, peak hour traffic in an urban environment is typically taken to be 8–12% of average daily traffic, so we took K value equal to 10%.

$$ADT = \frac{DHV}{K}$$

$$\rightarrow ADT = \frac{677}{0.1} = 6770\ Vehicles/day$$

For the eastbound:

Table 4.3 PHV for speed hump A29 in Eestbound

Out							
Time	PC	Mini-Bus	Bus	Truck	Other	Total	PHV
7:00-7:15	109	0	3	0	0	112	
7:15-7:30	153	0	6	0	0	159	

7:30-7:45	195	2	8	0	3	208	
7:45-8:00	247	3	15	3	0	**268**	747
8:00-8:15	128	2	2	4	0	136	771
8:15-8:30	112	0	0	2	2	116	728
8:30-8:45	109	2	0	2	0	113	633
8:45-9:00	113	0	3	2	0	118	483
Total	1166	9	37	13	5	1230	**7.15-8.15**
1:00-1:15	116	0	0	5	2	123	
1.15-1.30	115	2	0	3	0	120	
1.30-1.45	135	0	0	4	3	142	
1.45-2.00	141	2	0	3	0	146	531
2.00-2.15	169	3	0	9	4	**185**	**593**
2.15-2.30	115	0	0	5	0	120	593
2.30-2.45	127	0	0	9	2	138	589
2.45-3.00	96	0	0	3	2	101	544
Total	1014	7	0	41	13	1075	1.30-2.30

Table 4.3 shows that the maximum value is **771** vehicles in the period **(7.15 to 8.15)** and therefore the value of the PHV equals **771**vehicles per hour.

To calculate the value of PHF:

- PHV = 771 vehicles
- V_{15}: Maximum number of vehicles in 15 minutes within the maximum hour
- V_{15} = 286 vehicles (from table--).

$$\rightarrow PHF = \frac{771}{4 \times 286} = 0.719$$

✓ **Calculate DHV:**

The design flow rate can be calculated by dividing the peak hour volume by the PHF, but in this project needed a minimum number of vehicles so:

$$\rightarrow DHV = 771\, Vehicles/hour$$

✓ **Calculate ADT:**

$$\rightarrow ADT = \frac{771}{0.1} = 7710\, Vehicles/day$$

4.3 Design vehicle

According to ITE, the design vehicle selected should represent the vehicles that use the road regularly or frequently, not occasionally. Also, the selected representative vehicle for the modeling design and control system. This could be passenger cars, buss, truck, recreational vehicle. The selection of a design vehicle impacts the ultimate design characteristics of that speed humps.

Moreover, the main design controls are physical characteristics and properties of vehicles of different sizes.

Why the passenger car (PC) was chosen for the design? Firstly, passenger cars represent the largest percentage of traffic volume compared to mini bus, bus, and truck, as shown in Figure 4.2. Secondly, speed bumps that are designed for Passenger cars can generate energy from heavy trucks as well.

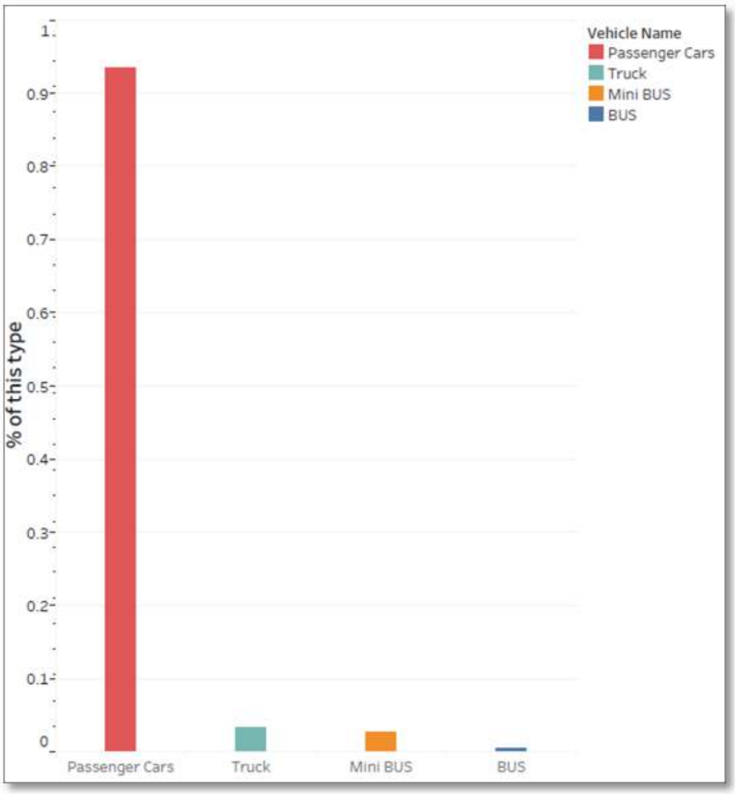


Figure 4.2 Percentage of vehicles.

In this study, Skoda Octavia was selected to be the design vehicle in order to design the speed bump. Although there are many types and brands of Passenger Cars, such as Hyundai, Volkswagen, Kia, BMW, etc. This is for many reasons, as follows:

- According to United Motor Trade (UMT), a Skoda Octavia car is the best seller in recent years.
- The rate of registered Skoda vehicle during the last three years is in increasing, as shown in Figure 4.3.
- Skoda is medium in weight compared to other models of passenger cars, as shown in Table 4.4.

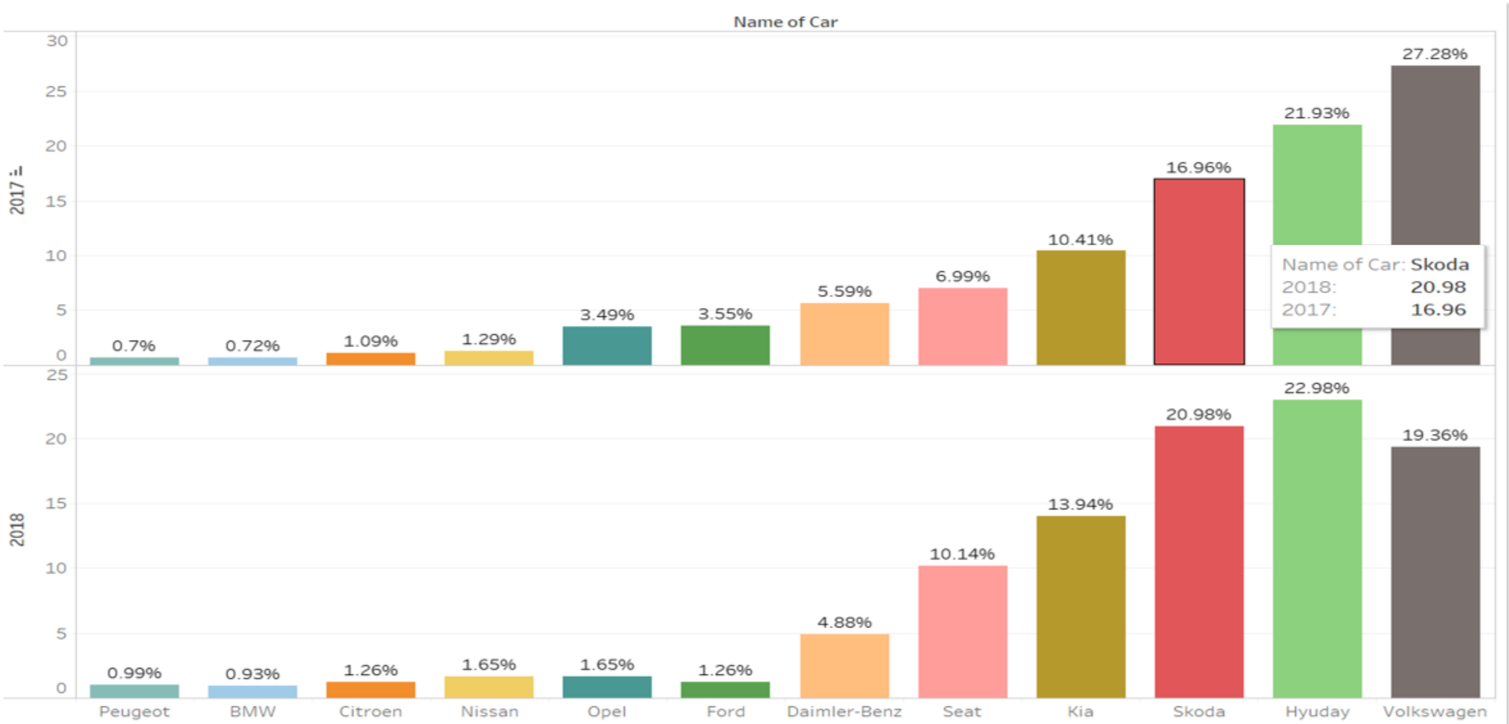


Figure 4.3 The percentage of car license for the years 2017 and 2018.

Table 4.4 Vehicle model weight (n) for different type of PC.

Volkswagen	**6720 – 34335**
Skoda	12017 – 15206

Hyundai	7112 – 22465
KIA	7799 – 26624
Seat	6671 – 20169
Mercedes-Benz	8829 – 29636
Ford	13038 – 13440
Opel	6573 – 20199
Nissan	3875 – 27321
Citroen	4758 – 22318
BMW	14715 – 14960
Peugeot	7259 – 22838

As a result, the Skoda is almost not the lightest car nor the heaviest، so in this project an Octavia type car was considered as design vehicle with weight 12753 N.

The side dimensions in (mm) of Skoda Octavia are shown in the Figure 4.4, also the dimensions of width, track front, track rear and wheel base are shown in Table 4.5.

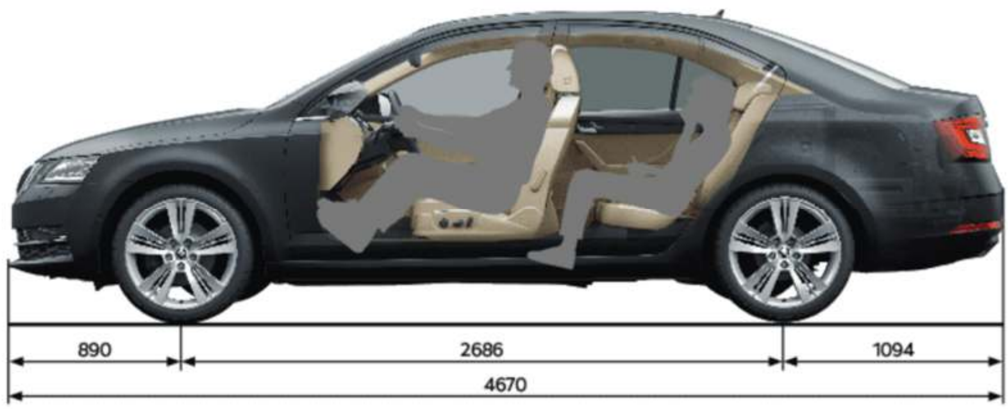


Figure 4.4 Vehicle dimension.

Table 4.5 Vehicle dimension.

Dimension Name	Dimension (mm)
Width of vehicle	1814

Width of vehicle with mirror	2017
Wheel Base	2686
Front Track (axle)	890
Rear Track (axle)	1094

The weight of design vehicle plays a key role in the mechanical design of speed bumps, which in turn affects the amount of energy produced. In addition, the vehicle's weight is carried by at least two axles: the front axle and the rear axle.

In order to know the force affecting the speed bump, the simplest model of a car is to treat the entire vehicle as a point mass. As shown in Figure 4.5 there is a vertical force balance for a stationary car. In addition, when there is an acceleration or deceleration of the vehicle, there will be an impact on the force affected by the vehicle on the speed hump.

Firstly, when the driver presses down on the brake pedal, the car pushes on the surface of the road in order to slow down, giving backward forces on both wheels on front track and causing the car to decelerate، which leads to an increase in weight on the front track. In addition, when the driver presses down on the gas pedal, this results in the car pushing back on the speed bump, giving an additional force on the wheels on the rear track, which leads to an increase in weight on the rear track. Secondly, it has been assumed that there is only one person inside the vehicle, Fuel weight, and there are no other external loads on the weight of the vehicle including air resistance, because the vehicle speed is very low (10-30) km/h.

The total weight can be determined based on equation 4.3.

$$Wt = Wv + Wd + We + Wf \qquad (4.3)$$

Where:

W_t: Total weight affecting on front / rear Track.

W_v: Weight from vehicle on front / rear Track when vehicle at rest.

W_d: Weight of driver.

W_e: Affecting weight when vehicle braking or accelerating.

W_f : Fuel weight.

Therefore, the lowest weight when vehicle is at rest، and this weight is the weight affecting the front track as shown in Figure 4.5, in addition, to the weight of the driver and other effects. Then:

$$Wt = 600.63 + Wd + We + Wf$$

The sum of the forces acting on the speed hump approximately more than 700 kg. So, Consider W_t=6867 N.

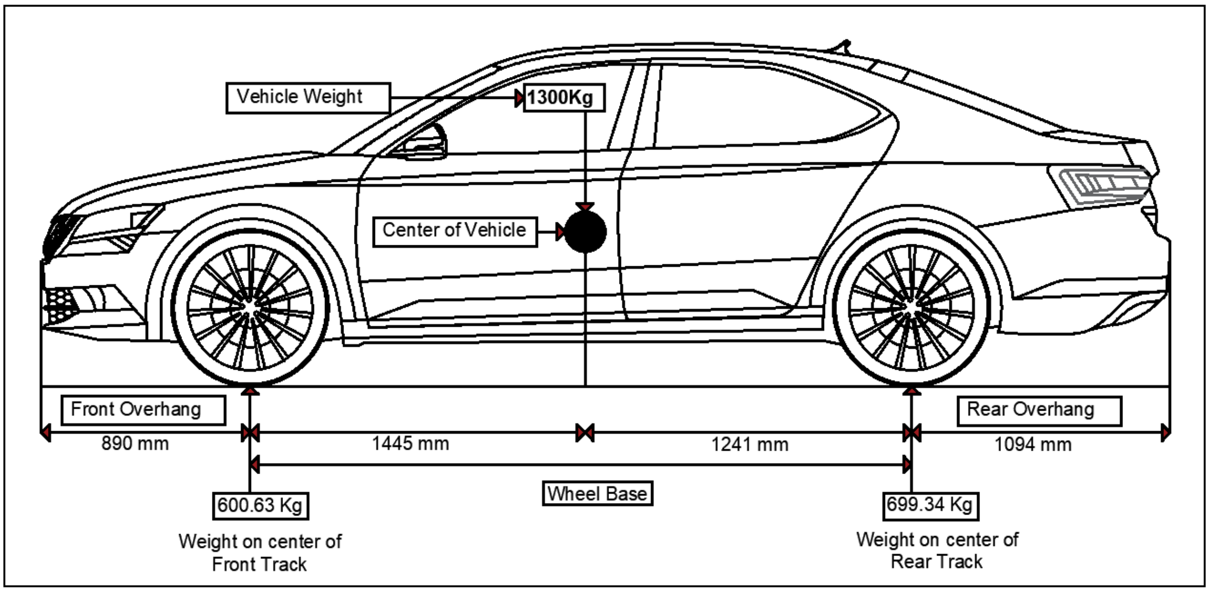


Figure 4.5 Vehicle dimension.

4.4 Speed Humps

Speed humps have been used as a traffic calming device in Nablus city to provide a vertical impediment to reduce the speed of vehicles travelling along the roadway, reducing conflicts between road users, and eliminate inappropriate driver behavior.

Therefore, the purpose of speed hump in traffic, as well as the principles for their use, is to promote highway safety and efficiency by providing for the orderly movement of all road users on streets.

Applications of speed hump according to Federal Highway Administration (FHWA):

• Appropriate for residential local streets and residential/neighborhood collectors.

• Not typically used on major roads, bus routes, or primary emergency response routes.

• Not appropriate for roads with 85th-percentile speeds of 45 mph or more.

• Appropriate for mid-block placement, not at intersections.

• Not recommended on grades greater than 8 percent.

• Work well in combination with curb extensions.

• Can be used on a one-lane one-way or two-lane two-way street.

According to the Nablus municipality, the development of speed humps is based on the following general criteria: In places where children and pedestrian are present, kindergartens, in residential neighborhoods, and near hospitals, and that they are placed on lit roads that have a speed of less than 60 km / hour.

Moreover, the process of monitoring and evaluation in Nablus city for speed humps came through dividing the city into different zones according to the Nablus municipality, as shown in Figure 3.2.

Through this evaluation, speed humps that do not satisfy general specification and are not in right place, approximately about 4%. Thus, the following problems are as observed:

- Lack of sufficient distance between the speed humps.
- The presence of speed humps at the intersection.
- Making speed humps from concrete by residents in front of their homes .Are not considered in this study.

Which in turn constitute a discomfort for drivers. The Number and percentage of these Speed Humps, as shown in Table 4.6.

Table 4.6 The number and percentage of speed humps that violate the FHWA standard.

Problem	Number of Speed Humps	Percent from the Total
Lack of sufficient distance between the speed humps.	15	3.93%
The presence of speed humps in the intersection.	1	0.26%

Furthermore, the number of speed humps obtained from Nablus city is 405 humps including some humps on Major Street but actual humps inside boarders of Nablus city is 382 as shown in figure 4.6

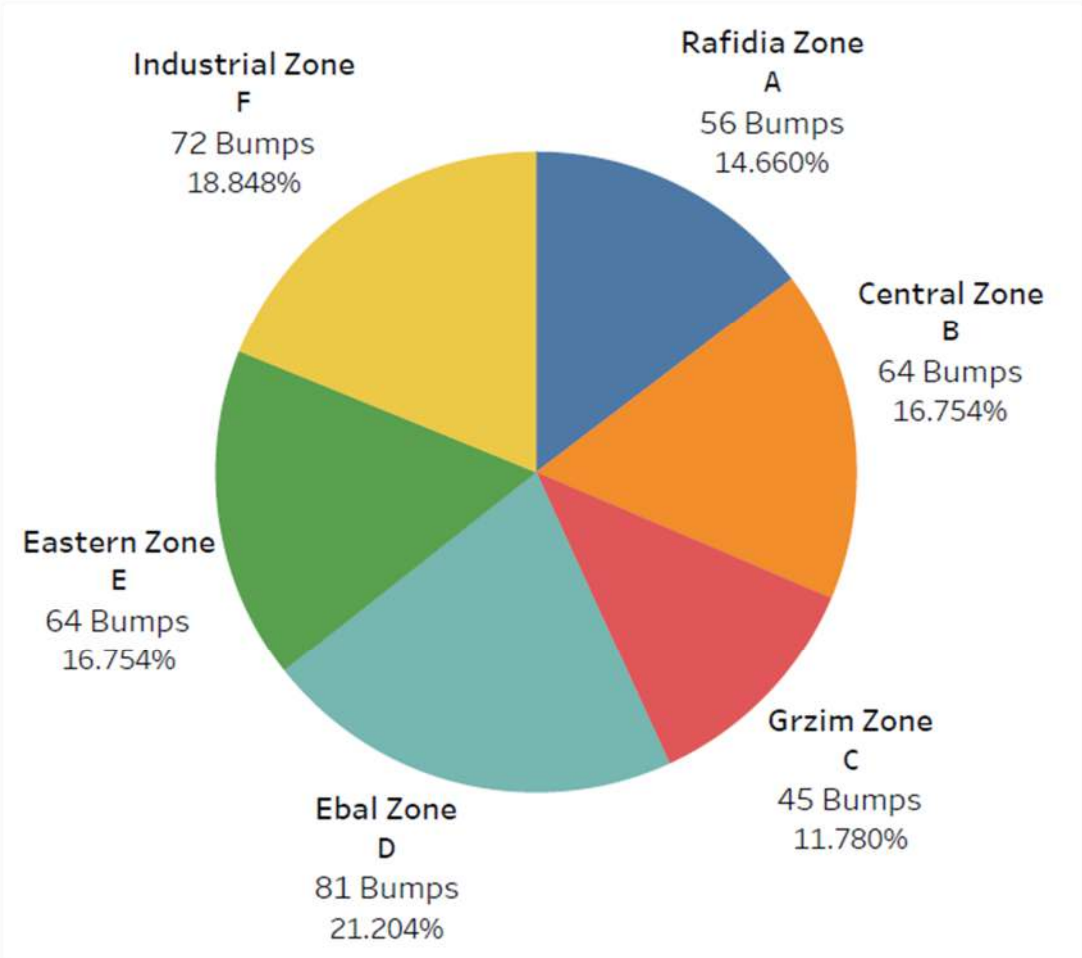


Figure 4.6 Number of speed humps in each zone.

According to FHWS, speed humps normally have a minimum height of 3 inches (7cm) to 4 inches (10cm) and a minimum travel length of approximately 12 feet (3.65m), although these dimensions may vary. In some cases, the speed hump may raise the roadway surface to the height of the adjacent curb for a short distance. In other words, the dimensions of the speed hump($L \times W \times H$), as show in the Figure 4.7.

Where:

L: Length of speed hump / width of the road (m).

W: Width of the speed hump (m).

H: Height of the speed hump from the middle (m).

Figure 4.7 Speed hump view.

The speed humps used in Nablus city are of two types: asphalt humps and plastic humps. Where the plastic speed humps constitute a very small percentage of the overall total speed hump. Also, the dimensions of the plastic speed humps approximately $(L \times 0.2 \times 0.05)$ m.

In contrast, speed humps that are made from asphalt vary in dimensions from one to another. For example, the width varies approximately from (2 -5) m and the height varies approximately from (7-12) cm, also the length of the speed hump is variable depending on the width of the street. As a result of these numbers, the most frequent dimension is $(L \times\ 4\ \times\ 0.07)$ m.

The cost of speed humps should be calculated to compare them with the cost of electricity generating speed humps. According to the municipality of Nablus, the cost of asphalt is 200 NIS/ton as a material. In addition to the cost of labor, it depends on the speed hump area. The total cost of the speed hump varies depending on the street width. Moreover, the cost of a single speed hump, that can be determined based on equation 4.4.

$$Ct = L \times W \times H \times\ \rho \times Cmaterial\ + Clabor \qquad (4.4)$$

Where:

C_t: Total cost per speed hump,(NIS).

L: Length of speed hump / width of the road (m).

W: Width of the speed hump (m).

H: Height of the speed hump from the middle (m).

ρ: Density of Asphalt, ($2.3 \frac{ton}{m^3}$).

$C_{material}$: Asphalt Cost per ton, ($200 \frac{NIS}{ton}$).

C_{labor}: Labor cost. ($20 \frac{NIS}{m^2}$).

As an example, the cost of the speed hump with "A29" can be calculated as in the follow:

- L = 8 m , W = 4m , H = 0.07m

$$Total\ Cost = L \times W \times H \times \rho \times Cm + Clabor$$

$$\rightarrow Total\ Cost = 8 \times 4 \times .07 \times 2.3 \times 200 + 8 \times 4 \times 20 = 1670\text{NIS}$$

5 SPEED BUMP DESIGN

As shown in graduation project 1, the SP mechanical system consists of springs, rack, gears, belt and pulleys. And that system is connected to an electric system for converting the resultant mechanical energy in to electrical energy by using a generator. And in this case a (DC) generator is used. In addition, an inverter and a buttery are connected to the generator. The inverter is for transmutation the direct current (DC) in to alternating current (AC), and the buttery is to storage the output energy for the low efficiency system time.

All the previous parts design dimensions are given values in Graduation project 1, but after more consultation and research some values are changed into more suitable ones. And more conditions are taken in consideration. In general, all the adjustments are to enhance the performance of the SBGEP and get higher efficiency in order to harvest larger amount of energy.

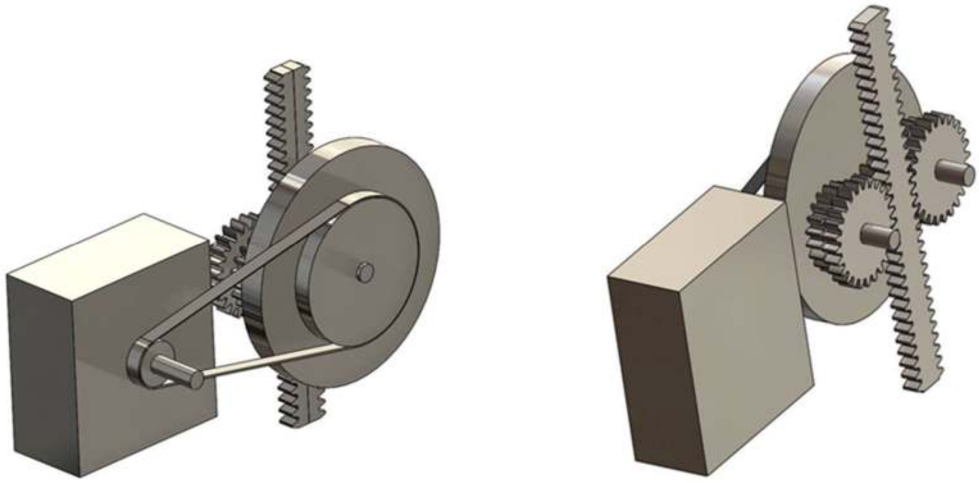


Figure 5.1 The SPGS by using Solid works.

5.1 Deflection calculations:

The purpose of this section knows the response or the deflection of the vibration system by applying some vibration analysis. The magnitude of deflection is important for the load calculations, to determine this magnitude an over damped single-degree-of- freedom system subjected to harmonic excitation is assumed, so it's formed by:

$$m\ddot{Y}(t) + c\dot{Y}(t) + kY(t) = F_0\cos(\omega t) \quad (5.1)$$

Where m the mass in (Kg) is, k is the stiffness of the spring in (N/m), c is the damping coefficient in (kg/s). $Y(t)$ is the displacement or the response of the damping system in (m), $\dot{Y}(t)$ is (velocity) the first derivative of the displacement in (m/s), $\ddot{Y}(t)$ is (acceleration) the second derivative of the displacement in (m/s^2). F_0 The acting force or load in (N), ω is the angular frequency in (rad/sec) and t is the time in seconds.

The total response solution equal the sum of the homogeneous solution and the particular solution,

$$Y(t) = Y_h(t) + Y_p(t) \quad (5.2)$$

The general response equation for over damping system has a form of,

$$Y_h(t) = A\, e^{\lambda_1 t} + B\, e^{\lambda_2 t} \quad (5.3)$$

$$Y(t) = e^{-\zeta w_n t}\left(Ae^{-w_n\sqrt{1+\zeta^2}t} + Be^{w_n\sqrt{1+\zeta^2}t}\right) \quad (5.4)$$

$C > C_c, \zeta > 1$

$$\lambda_{1,2} = -\zeta w_n \pm w_n\sqrt{\zeta^2 - 1} \quad (5.5)$$

$$A = \frac{-v_0 + \left(-\zeta + \sqrt{\zeta^2-1}\right) w_n y_0}{2\, w_n\sqrt{\zeta^2-1}} \quad (5.6)$$

$$B = \frac{v_0 + \left(\zeta + \sqrt{\zeta^2-1}\right) w_n y_0}{2\, w_n\sqrt{\zeta^2-1}} \quad (5.7)$$

Where A & B are constants, $\lambda_{1,2}$ are the roots of the response equation, w_n is the natural frequency of the system (rad/s), C_c is the critical damping coefficient (kg/s), v_0 and x_0 are the initial velocity and the initial displacement of the system respectively, ζ is the damping ratio which formed by,

$$\zeta = \frac{C}{C_c} \quad (5.8)$$

Initial conditions are $Y(0) = x_0 = 0, \dot{Y}(0) = v_0 = 0$

The speed bumps cover is made from plastic as shown in figure 1. The dimensions and mass of the cover are $(2m \times 0.5m \times 0.1m)$ and 50kg respectively. Figure 5.2 shows the cross-section of the speed bump where the inclination angle of it is 15°.

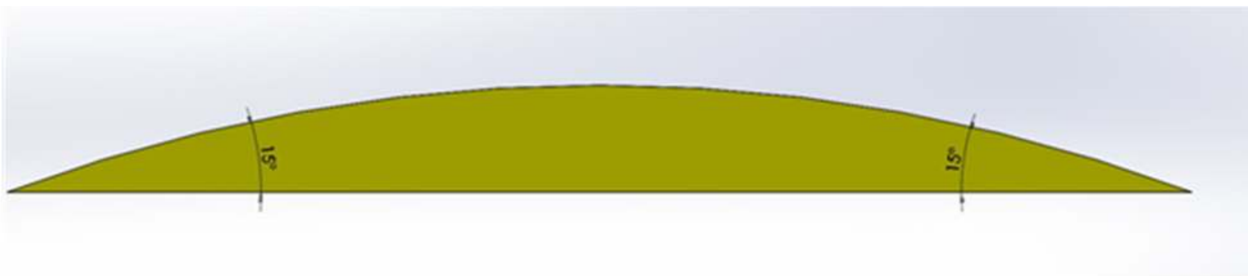


Figure 5.2 Speed bump view.

In this system there are at least 4 symmetric springs, that are connected in parallel,

$$K = \frac{G \times d^4}{8 \times n \times d^3} \quad (5.9)$$

Hence, G is the modulus of rigidity in (Gpa), d is the mean diameter of the spring in (m) and n is the number of coils. The substitution,

$$K = 18.238\ kN/m.$$

As mentioned before the 4 springs are connected in parallel, so for the equivalent magnitude of the spring's stiffness is by the summation of stiffness of those 4 springs,

$$K_{eq.} = K_1 + K_2 + K_3 + K_4 \quad (5.10)$$

$$K_{eq.} = 72.952KN/m$$

The constant w_n characterizes the spring–mass system, as well as the frequency at which the motion repeats itself, and hence is called the system's *natural frequency,*

$$w_n = \sqrt{\frac{K_{eq.}}{m}} \quad (5.11)$$

$$w_n = \sqrt{\frac{72952}{50}} = 38.197 \text{ rad/sec}$$

Each vibration can be characterized into one of 3 cases, for that the system refer to which case there are coefficient which called the critical damping coefficient, by multiplying the damping coefficient over the critical damping coefficient, the resulted no dimensional number is ζ,

$$C_C = 2\, m\, w_n \quad (5.12)$$

$$C_C = 2 \times 50 \times 38.197$$

$$C_C = 3819.7Kg/sec$$

ζ *to be* 1.05

$$\zeta = \frac{C}{C_C} \quad (5.13)$$

$$c = 4010.6856kg/sec$$

$$\lambda_{1,2} = -\zeta w_n \pm w_n \sqrt{\zeta^2 - 1}$$

$$\lambda_{1,2} = -1.05 \times 38.197 \pm 38.197 \sqrt{1.05^2 - 1}$$

$\lambda_{1,2} = -40.1 \pm 12.229$

<u>To find the initial conditions:</u>

Assuming that:

$v_{c1} = 15\ km/h$

$v_{c2} = 12\ km/h$

$x_0 = 0$

$$m_c v_{c1} + m_{sp1} v_{sp1} = m_c v_{c2} + m_{sp2} v_{sp2} \quad (5.14)$$

v_{c1} is the initial velocity of the vehicle at which the front wheels axle touching the SP (m/s), v_{c2} is the velocity of the vehicle when the front wheel axle is over the SP directly (m/s), m_c is the vehicle mass (kg), m_{sp1} is the SP mass (kg),

$$1300 * 15 * \frac{10^3}{3600} * \sin(15) + 0 = 1300 * 12 * \frac{10^3}{3600} * \sin(15) + (800 + 50) * v_{sp2}$$

$v_0 = v_{sp2} = 0.329$ m/sec;

From initial conditions A and B can be found

$Y_h(t) = A\, e^{\lambda_1 t} + B\, e^{\lambda_2 t}$ Such that $\lambda_{1,2} = \frac{-c}{2m} \pm \frac{\sqrt{c^2 - 4mk}}{2m} = -\zeta w_n \pm w_n \sqrt{1 - \zeta^2}$

$Y(0) = A + B = 0 \rightarrow A = -B$

$\dot{Y}(t) = A\left(\lambda_1 e^{\lambda_1 t} - \lambda_2 e^{\lambda_2 t}\right)$

$\dot{Y}(0) = A(\lambda_1 - \lambda_2) = 0.329 \rightarrow A = -0.0134$

$B = -A = 0.0134$

Calculating the time required reach maximum amplitude:

$At\ t_{max} = \dot{Y}(t_{max}) = 0$

$t = 0.295\ second$

About the homogenous solution:

$\therefore Y_h(t) = A\, e^{\lambda_1 t} + B\, e^{\lambda_2 t}$

$Y_h(t) = 3.6 \times 10^{-6} m$

Calculations of the particular solution:

The formula of the particular solutions of a single phase and over damping system can be expressed as,

$$Y_p(t) = A_s \cos(wt) + B_s \sin(wt) \quad (5.16)$$

Finding the force frequency:

8 cars pass in 1 minute (by using the transformation section data).

Hence, 8 pushes/60 sec. = 0.133 push/ sec., which is equal the frequency

$f = 0.133$ push/ sec.

Because the system assumed as an over damping system so there is no insurance that the back axle of the wheels will reach the SP before the system back to its equilibrium state after the front axle leave the SP.

So,

$$\omega = 2\,\pi\,f \quad (5.17)$$

$$\omega = 2\pi(0.133)$$

$$\omega = 0.835\ rad/sec$$

The force calculations,

$$f_0 = \frac{F_0}{m}$$

$$f_0 = \frac{800 \times 9.81}{50}$$

$$f_0 = 156.96\ N/kg$$

$$A_s = \frac{(w_n^2 - w^2) f_0}{(w_n^2 - w^2)^2 + (2\, w_n w)^2} \quad (5.19)$$

$$B_s = \frac{2\,\zeta\, w_n w\, f_0}{(w_n^2 - w^2)^2 + (2\, w_n w)^2} \quad (5.20)$$

Where A_s and B_s are constants.

$$A_s = \frac{(38.197^2 - 0.835^2)156.96}{(38.197^2 - 0.835^2)^2 + (2(38.197)(0.835))^2}$$

$$A_s = 107.426 * 10^{-3}$$

$$B_s = \frac{2(1.05)(38.197)(0.835)(156.96)}{(38.197^2 - 0.835^2)^2 + (2(38.197)(0.835))^2}$$

$$B_s = 49.34 \times 10^{-4}$$

After compensation the value of the particular solution is,

$$Y_p(t) = 0.1053\, m$$

$$\therefore Y(t) = Y_h(t) + Y_p$$

$$\therefore Y(t) = 3.6 \times 10^{-6} + 0.1053$$

$$\therefore Y(t) \cong 0.10539\, m$$

This is the total deflection of the system.

5.2 Mechanical System Specifications

5.2.1 Specification of Gears

The SPGS gears are divided into 2 sets, the first set included 2 pinions and 2 faces rack, the second set included 1 pinion and 2 gears, each set contents will be specified detailly.

First set (2 pinions + 1 rack):

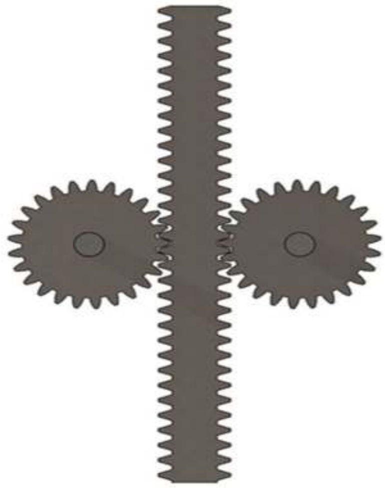


Figure 5.3 the first set by using Solid works

5.2.1.1 Pinions

Material	Pressure angle (Ø)	Full depth tooth (K)	Number of teeth (NP)	Module (m)	Pitch diameter (d)	Face width (F)
Stainless Steel 303.	25°	1	12 teeth	4 mm/tooth	48 mm	25 mm

5.2.1.2 Rack

Material	Pressure angle (Ø)	Length LR	Number of teeth (NP)	Module (m)	Pitch Hight (H)	Face width (F)
Stainless Steel 303.	25°	200 mm	12 teeth	4 mm/tooth	110 mm	25 mm

Second set (1 pinion + 2 gears)

5.2.1.3 Pinion

Material	Pressure angle (∅)	Full depth tooth (K)	Gear ratio mG	Number of teeth (NP)	Module (m)	Pitch diameter (d)	Face width (F)
Stainless Steel 303.	25°	1	3	12 teeth	4 mm/tooth	48 mm	25 mm

5.2.1.4 Gears:

Material	Pressure angle (∅)	Full depth tooth (K)	Number of teeth (NG)	Module (m)	Pitch diameter (dG)	Face width (F)
Stainless Steel 303.	25°	1	36 teeth	4 mm/tooth	144 mm	25 mm

5.2.2 Specification of springs

- Type:

Helical spring.

- Material:

Music wire ASTM A228, squared and ground Ends.

- Shear modulus of rigidity:

G = 80 Gpa.

- Wire diameter:

d = 9.197 mm.

- Mean diameter:

D = 69.596mm.

- Spring stiffness:

K = 18.238 KN/m.

- Number of active coils:

Na = 12 coils.

- To avoid buckling:

$L_o < 5.26D \rightarrow L_o < 355$ mm.

Selecting Lo = 280 in,

Preset = 10% Lo = 28 mm.

- Solid length:

LS = 128.7 mm

5.3 Specification of Pulleys and belt

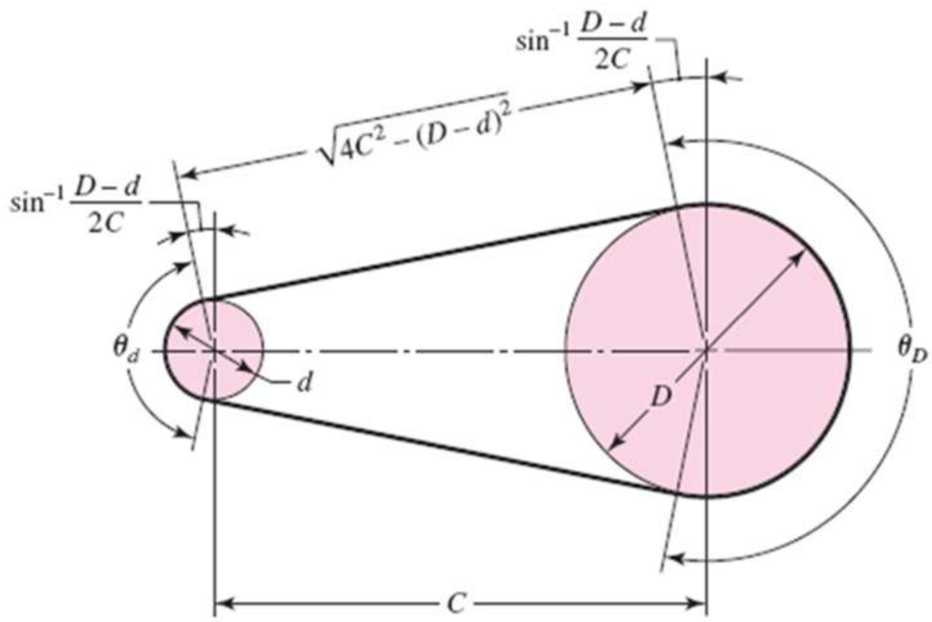


Figure 5.4 Pulleys and belt.

- Diameter of larger pulley:

$D = 300\ mm$

- Diameter of smaller pulley:

$d = 25\ mm$

- Centers distance:

$C = 300\ mm$

- Contact angle of smaller pulley:

$$\theta_d = \pi - 2\, sin^{-1}\frac{D-d}{2\,C} = 2.189\ \ rad$$

- Contact angle of larger pulley:

$$\theta_D = \pi + 2\, sin^{-1}\frac{D-d}{2\,C} = 4.093\ rad$$

- Belt length:

$$L = \sqrt{4C^2 - (D-d)^2} + \frac{1}{2}(\mathrm{D}\theta_D + d\theta_d) = 1174.58\,mm$$

5.4 Energy calculations:

$$F = 800\,kg \times \sin(15) \times 9.81 = 2031.21\,N$$

$$T = F \times \left(\frac{d}{2}\right)$$

$$T = 2031.21 \times (0.024) = 48.749\,N.m$$

$$w = 0.835\,rad/sec$$

$$P = T \times w$$

$$P = 48.749 \times 0.835 = 40.7\,watt$$

$$The\ power\ for\ each\ car = \frac{40.7}{8} = 5.088 watt$$

$$The\ power\ for\ each\ push = \frac{5.088}{2} = 2.544\,watt/push$$

5.5 Large vehicle problem

When a load is applied to a piece of metal, it must deflect first elastically, and if the load is high enough, it will also do this plastically. Elastic deflection is when the material returns to its previous shape after unloading. During plastic deflection, the metal receives a permanent deformation and cannot return to its previous shape after unloading.

The springs make possible to maintain a tension or a force in a mechanical system, to absorb the shocks, and to reduce the vibrations, this depends on the durability of each spring. In the case of mechanical design, the risk of spring fatigue depends on other factors too, such as the designed stress in the spring, alongside the amplitude of the pulsation. In addition, if the impact weight is much higher than the bearing force of the spring, the mechanical system in this case will cause a breakdown of its parts. Therefore, the high-loaded spring elements in this project must survive a very high number of cycles with high mean stress as well as high amplitude stress.

In this project, the design vehicle is of medium size, so it is possible that if there are very heavy vehicles such as trucks, it is possible while passing over the SBGEP that they lead to failure of the SBGEP. Therefore, there are many solutions to prevent these problems.

First, the use of rubber with the spring, which is called spring rubber, and in this case the rubber plays an important role in absorbing the extra force on the spring, and the use of rubber resulting from recycling the wheels of vehicles that are characterized by their ability to endure is an important thing, as there are different types of rubber used with springs and made of polyurethane as shown in figure 5.4. So it can be a low-cost solution.

Figure 5. 5 Rubber coil spring spacer.

Moreover, there are other solutions that can be used to prevent system breakdown in the event of heavy vehicles. Using two layers of springs in the system, the first layer bears the design vehicle, and the spring in this case reduces to the required level in the design process. As for the second layer of springs, it is used in the event of huge vehicles such as large trucks, and these springs bear this high weight as in figure 5.5.

Figure 5. 6 Designed to withstand the weight of large vehicles.

5.6 Maintenance:

5.6.1 Gears:

Gear failure happens when a gear is no longer able to do its function, as the name suggests. This can happen, separately or together, for a number of reasons, and when it does, it could have a ripple effect that causes the whole system to shut down.

Popular Gear Failure types:

• Wear and tear: When the gear is used repeatedly, wear and tear occur and is basically unavoidable.

• Corrosion. Corrosion is a chemical degradation that often occurs over time, or when certain kinds of substances are exposed to the gear.

• Pitting. Pitting happens in the gear as a series of small pits, which generally occurs due to an inappropriate fit, or excessive loads or stress.

The American Gear Manufacturers Association (ASGMA), that supply a method for gear design. In the (AGMA) methodology, there are many fundamental stress equations, bending stress, fatigue stress, pitting resistance and so on. But to use such these calculations there must be a very specific information's about the material and the manufacturing way of the gear. Which could be tough to have in in our situation.

But in general, the most parameter for longing the gear life is the suitable and good lubrication. The main advantage for gear lubrication, is reducing the friction coefficient and limit the temperature rising from gear contacting, to avoid wear and failure.

The suitable type of lubrication depends on the type of gear and the velocity. As know the used type of gears in this system is spur gear and the calculated tangential velocity which was 0.328 m/sec. by knowing these data the required lubrication type is Splash lubrication (oil bath method), which is the most suitable method for the system type of application.

According to the material, Tensile testing, also known as tension testing, is a fundamental materials science and engineering test in which a sample is subjected to a controlled tension until failure. Properties that are directly measured via a tensile test are ultimate tensile strength, breaking strength, maximum elongation and reduction in area. The most property cared about is the breaking strength, also known as fracture strength which is the stress at which a specimen fails via fracture. According to the selected material for the different types of gears that chosen for this project which is Stainless Steel 303, the fracture strength is 1520 Mpa [1].

5.6.2 Springs:

Springs life time in general affected by main factors increasing the elasticity and the load limit, and these two factors depend on many factors. In order to get a long-life time spring, this means large wire diameter, small outer diameter, decreasing the number of coils and the free length. All of the previous demands suits with the system springs.

According to the used material, high carbon steel is the most used type for manufacturing springs, because of its availability, easily worked with, low cost. In the system case, the used material is tempered high carbon steel which called music wire is ASTM A228, this type of materials is very common for spring's material. This material has a very high mechanical properties, as shown in the figure 5.7.

Material	Music Wire ASTM A 228
Nominal Analysis	C - .70 - 1.00% Mn - .20 - 60%
Minimum Tensile Strength	230-399
Modulus of Elasticity E psi x 10^3	30
Design Stress % Minimum Tensile	45
Modulus in Torsion G psi x 106	11.5
Maximim Temp. °F	250°
Maximum Temp. °C	121°
Rockwell Hardness	C41-60

Figure 5.7 ASTM mechanical properties.

But after many read research, the life time for most of springs when it has to be changed after 10000-15000 uses or about 5 years on average. And that average depends on the spring design, manufacturing material, applied stress and environmental conditions [2].

5.6.3 Belt:

Belt is the faster part in the SBGEP that susceptible to have problems, and the biggest danger that threatens the belt performance is the wear. The most basic tip to prevent the belt from wear and then failure is cleaning the belt once a month from dust. This is easy preventative maintenance that can help eliminate major problems before they have a chance to occur [3].

5.7 Predicted struggles and solutions for the mechanical system:

Nablus has a relatively temperate Mediterranean climate brings hot, dry summers and cool, rainy winters. Spring arrives around March–April and the hottest months in Nablus are July and August with the average high being 29.6 °C (85.3 °F). The coldest month is January with temperatures usually at 6.2 °C (43.2 °F). Rain generally falls between October and March, with annual precipitation rates being approximately 656 mm (25.8 in).

In general, the rain average in Nablus is high with other Palestinian cities. So, the designed SBGEP exhibited to damage because of the leakage of the water rain, so there must be precautions to protect the designed system, especially because the inner parts of the SBGEP included electrical devices which are very sensitive and may burn because of drop of water. Furthermore, early wear, disruption of the system components and making its ability to produce energy less. Therefore, it is necessary to find solutions to prevent water leakage into the system in order to preserve the energy-producing ratio.

In order to prevent surface runoff from entering the system, the system needs many components, such as rubber resulting from recycling the car wheels, Over 1 billion pneumatic car tires are annually manufactured worldwide (Wikipedia, 2018). Therefore, many old tires need to be disposed of, which in turn may cause environmental pollution. In order to take advantage of this rubber and preserve the environment through its recycling and use within the system, because of its many advantages as a high durability higher than the durability of regular rubber because it contains black fillers, which are composite components that are added to modify the physical properties of regular rubber. In addition to its impermeability to water and its high elasticity. (Bijarimi et al., **2010).**

Figure 5.8 Rubber slides.

Furthermore, Channel Steel section as a major component. Where it is used to keep the rubber running smoothly in and out while descending and running the speed bump. In addition, plate of steel is used as a channel in the event that water enters the system and push it out of system. Finally, there is a small gap before the system in order to reduce the force of water pushing on the system and form a channel to drain the water to the edges of the street.

The figure 5.9 shows parts that help protect the system from water entering the system.

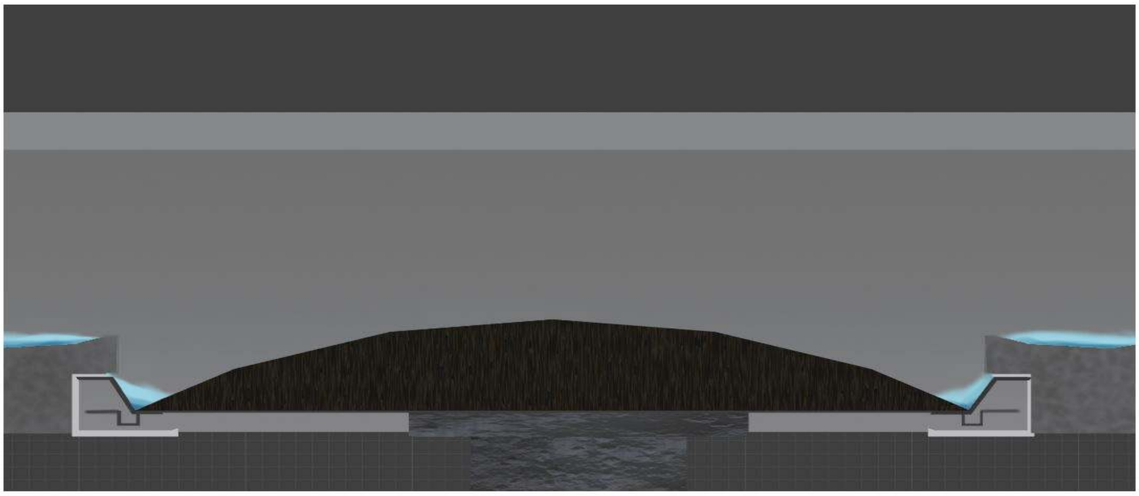


Figure 5.9 Speed bump component to prevent water enter into system.

5.8 Design of solar panel

Solar street light working principle is easy and simple. Solar street lights have photovoltaic cells that are responsible for converting the sunlight's radiation into electricity. The device's semiconductor materials facilitate the process of conversion of solar energy into electricity. The energy conversion process is known as the "photovoltaic effect." The electrical energy is stored in the solar batteries. If the illumination decreases to 10lux, the circuit voltage of approximately 4.5V will be opened by the solar cell board. Then, the amount of voltage value moving from the battery to other parts of the street light system will be determined by the charge and discharge controller. Moreover, the charge and discharge controller are also known for protecting the battery.

According to Masader's Renewable Energy Company, Polycrystalline solar cells are of two types according to their size of 18 watts and 50 watt Then, the number of poles on which we could place the solar cells using the GIS program was chosen, which was 258 poles, depending on the number of poles closest to the speed bumps within a distance of 15 - 20 meters. The amount of energy produced from solar cells 18 watt and 50 watt are 18.576 KW and 51.6 KW, respectively, as shown in the Table 5.1.

Table 5.1 Daily produced power from Solar Panel.

Cell Type	Polycrystalline 18W	Polycrystalline 50W
Maximum power /hr.	18 watt	50 watt
Average working hours per day	4	4
Maximum power / day	72	200
Number of Cells	258	258
Total power from Cells/day	18576 watt	51600 watt

Furthermore, according to Nablus municipality the daily amount of consumed power for lightening poles and signals traffic when using led lamp is 8230.04 KW. The table 5.2 shows the coverage rate of the solar panel from the energy consumed in Nablus city.

Table 5.2 Daily produced power from Solar Panel

Cell Type	Polycrystalline 18W	Polycrystalline 50W
Total power from Cells/day	18.576 KW	51.600 KW
Total Power Consumed	8230.04 KW	
Coverage Rate	0.23%	0.63%

The results showed that the use of solar panels 18 watt or 50 watt as a support to cover the consumed energy was not feasible because it covers only 0.22% and 0.63% respectively.

5.9 Batteries

Today, batteries are used for alternative energy needs to supply inverter, lighting, and other devices. Each battery has a specific capacity written on it, in ampere-hours

It is important to know the appropriate capacity in order to avoid two problems: the first is wastage, by choosing very large capacity, and thus the cost is high. The second is discontinuation when choosing a capacity that is less than required.

There are many types of batteries, but the economical ones are of the acid and lead plates, and the majority is 12 volts or 24 volts.

In this project, acid-free batteries, which are known as **Gel batteries**, are considered as closed acid SLA batteries, also known as VRLA (Valve Regulated Battery). They are harmless, maintenance free, and can be used safely anywhere. Usually, a gel type is preferred for applications that require frequent or daily use, where the charging and discharging process takes place almost daily.

Gel batteries have a service life of 3 to 5 years. It can also perform a deep discharge cycle in which it may discharge up to70% of the charge contained in it and thus its efficiency is very good.

The price of gel batteries varies according to their storage capacity, as the more capacity the battery increases, the more expensive it is. The price of gel batteries ranges from 1000 to 1500NIS, according to a source company in the market. Gel batteries can be considered the least expensive over the period of use due to their superiority in the total number of cycles. A specially designed charging regulator should be used for gel batteries to ensure they are properly recharged or else they may be damaged prematurely.

The battery should be separate and placed with the charging regulator in a metal box.

- **To determine the number of batteries needed to store speed hump energy:**

1. Calculate the electrical energy generated by each speed hump

$$\text{Total Power (P)} = \text{Traffic Volume} \times \text{Energy produced by one car} \quad (5.21)$$

2. Calculate the production capacity of speed bump per hour

$$\text{Production Capacity} = \frac{P}{24} \times \text{DOD} \times 2 \quad (5.22)$$

Where:

- $\frac{P}{24}$: Average Daily Power Production
- DOD : Depth of Discharge ≈ 1.3
- 2: Factor to maintain battery charge rate for two days when traffic is low

3. Calculate the necessary battery capacity

$$\text{Cb} = \frac{\text{Production Capacity}}{\text{Vb}} \quad (5.23)$$

Where:

- C_b : Battery capacity, measured in ampere hourly
- V_b : The battery voltage (here is equal to 12 volts)

4. Calculate the number of batteries required

$$\text{N} = \frac{\text{Cb}}{\text{C.}} \quad (5.24)$$

Where:

- C_b : Battery capacity
- C. : Battery capacity available in the market

According to the above-mentioned method, the number of batteries needed to store the energy produced by each speed bump was found.

As a result of the variation in the volume of traffic from one speed bump to the other, four types of batteries of different capacity were used for storage to suit the volume passing on the speed bump and this was analyzed using the Mat lab program.

Table 5.3 shows the different types of batteries used, with the number of each type and the number of speed bumps connected to each type and the total cost.

Table 5.3 The different types of batteries used

Buttery Type	No. of Butteries	No. of Speed Bumps	Price For 1buttery	Total Cost
50AH	143	143	1000	143000
100Ah	95	95	1200	114000
150AH	47	47	1350	63450
200AH	130	120	1500	195000

6 ECONOMICAL FEASIBILITY STUDY

6.1 Introduction

The feasibility study is important to determine the success of any project, especially when introducing a new idea, as the feasibility study helps to consider the possibility of the idea's success or failure, thus guides the person to cancel it before delving into it and incurring losses, the feasibility study works to give the complete and comprehensive picture for the project by developing a workflow plan, knowing any expected risks and trying to avoid them, in addition, to determine the potential costs and profits, and the feasibility study can give new solutions and alternatives that open inspiring horizons for people with projects to ideas and improvements that were not taken into account that may increase the profit rate.

In this chapter, various aspects of economic analysis of SBGEP system are discussed such as life cycle cost analysis, electricity price, interest rates, costs, and revenue. Thereafter, the impacts of modeling and design of a SBGEP system on economic analysis are reviewed. The feasibility of adopting a SBGEP system, particularly in Nablus city, is then discussed.

The feasibility study is based on three main study market survey, technical study and economic analysis as discussed below.

6.2 Market Survey:

The amount of energy consumed for street lighting in Nablus is 8230 KW per day, 237,730 KW monthly and 3,003,963 KW annually. The cost of 1 kilowatt is approximately 0.5531 NIS. This means, the electricity used by street lighting only costs the municipality approximately 131,489 NIS per month, 1,661,492 NIS annually. These numbers are based on the fact that the used lighting is 70 W LED lamp.

6.3 Technical study:

The technical feasibility study assesses the details of how speed bump will be produced and how much it will cost. This study is divided into three sections: initial cost estimation, operating expenses and revenues.

6.3.1 Initial Cost Estimation

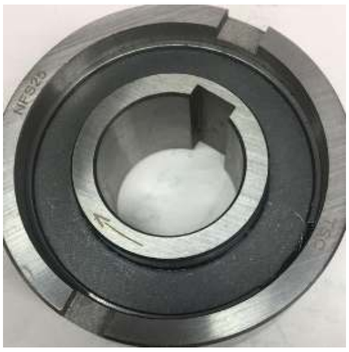
Estimating the cost of the project is a process of predicting the cost and resources needed to complete the project within a specified scope, the cost estimate is calculated for each project component and the total amount that determines the project budget. Cost estimation help in identifying project risks and provides an option to discuss alternatives if new requirements are needed to be added.

In this section, the initial cost for the project will be calculated which includes the calculation of the cost of preparing the speed bump, the cost of preparing the sites for laying the speed bumps, in addition to the cost of installing and connecting speed bump with the electricity network.

6.3.1.1 Cost of Manufacturing Tools

This section deals with the components of the SBGEP system with the number of units required and the price of each component. Table 6.1 shows the components of the prototype with the cost, table 6.2 shows the needed number of butteries and how much it will cost.

Table 6.1 Components costs.

Component	Image	Price (NIS)	No. unit	Total cost
One way Bearing		31.5/piece	6	6x31.5 = 189 NIS
Charger Contractor		300/piece	1	1 × 300 = 300 NIS
Fly Wheel		168/piece	2	2 × 168 = 336 NIS
Gear		122.5/piece	4	4 × 122.5 = 490 NIS

Generator		300/piece	1	1× 300 = 300 NIS
Inverter		500/piece	1	1 × 500 = 500 NIS
Pillow Block Bearing **9/li**		12/piece	30	30× 12 = 360 NIS
Pinion		24.5/piece	4	4 × 24.5 = 98 NIS
Rack		50/piece	2	2 × 50 = 100 NIS

Rubber		22.4/ton	1	1 × 22.4 = 22.4 NIS
Saving Box		200/piece	2	2× 200=400 NIS
Shaft		30/piece	6	6×30=1800 NIS
Speed Bump Cover		224/piece	2	2 × 224 = 448 NIS
Spring		350/piece	6	6 × 350 = 2100 NIS

Steel Plate		$40/m^2$	1	1 × 40 = 40 NIS
Steel Tube Section		980/m	2	2 × 980 = 1960 NIS
Wire 6mm		3.5/piece	2	2 × 3.5 = 7 NIS
Wire 16mm		8/piece	4	4 × 8 = 32 NIS

For one lane roads, one unit of the prototype will be implemented with width equal to the lane width, as one speed bump. The costs above are taking considering for two lane 8 m width as an average. For manufacturing a prototype with two units it will cost 8562 NIS.

In this project Gel butteries were used depending on the storage capacity of each and the power generated from the bumps that will be stored inside them. The required number of each type and the cost is illustrated in table 6.2.

Table 6.2 Cost for all batteries in Nablus city.

Buttery Type	No.	Buttery cost	Total cost
Battery 200AH	130	1500	195,000
Battery 150AH	47	1350	63,450
Battery 100AH	95	1200	114,000
Battery 50AH	143	1000	143,000
Total	515,450		

6.3.1.2 Preparing the site

Preparing the site for installing SBGEP system, and this requires drilling in the street to reach the appropriate depth for installing the prototype according to the operational dimensions.

The price includes the removal of the current hump and any obstacles that obstruct the drilling, the transfer of drilling products to the designated places in addition to the manpower that may be required.

According to the specifications, the drilling process with dimension of $(0.5 \times 0.5 \times 8)$ m, in addition to the labor cost, is equivalent to approximately 1000 NIS.As for installing the speed bump and connecting it on the electricity network, it costs 200 NIS.

Consequently, the cost of a single speed bump for manufacturing, installing and connecting to the electricity network is equal 9762 NIS, and in total the cost of all the 405 speed bumps in the city is equivalent to 4,469,222 NIS. The capital cost which represents the capital investment for the project is summarized in the table 6.3.

Table 6.3 Capitalize cost of the total project.

Capital Cost (NIS)	
Manufacturing Cost Per Speed Bump	8562
Cost of The Excavations	1000
Cost of Installation and Operation	200
Total Cost Per Speed Bump	9762
Number of Speed Bumps	405
Cost of Butteries	515,450
Total Cost of The Whole Project	4,469,222

6.3.2 Revenues.

The main economic benefit used in the research is a function of the amount of electricity that is produced and the price that would have been paid for. According to the theoretical study, the prototype generates 2.544 W/vehicle. All speed bumps in the city will give a total of 5251 KW/day of electricity. The electricity produced by all speed bumps in Nablus is calculated in Excel sheet (Appendix C).

According to the Northern Electricity Company, there is 15% of losses in the electricity grid. Furthermore, the prototype efficiency will decrease with time and usage with what is known as depreciation, the efficiency is assumed to decrease by 15%. In total, 30% of losses is predicted to be in the system. The output power used, including loss will be as follows:

$$\text{Effictive power} = \text{Total power produced} - 0.3 \times \text{Total power produced}$$

For that, the output power from speed bumps in the city is 3675 KW /day .Street lighting consumes about 8230 KW/day, which means the system can cover 44.66% of the electricity needed as shown in table 6.4.

Table 6.4 Total amount of power generated.

Total amount of power generated per day	
Power from all speed bump (KW/day)	5251
Losses on System %	30
Effective Power from Prototype (KW/day)	3676
Power consumed by street lighting (KW/day)	8230
Covered rate %	44.66

The revenue is the price of the electricity produced، which equals the price of 1 kilowatt 0.5531 NIS multiplied by the amount of effective electricity produced. Table 6.3 summarizes the annual revenue from the project.

Table 6.5 Annual Revenue

Revenue	
Power from Prototype (KW/day)	3676
The Price of One Kilowatt (NIS)	0.5531
Revenue in One Day (NIS)	2033
Annual Revenue (NIS)	742,073

6.4 Economic Analysis

Economic analysis is defined as a "systematic approach to determining the optimum use of scarce resources, involving comparison of two or more alternatives in achieving a specific objective under the given assumptions and constraints". Economic analysis attempts to "measure in monetary the private and social costs and benefits of a project to the community or economy". Therefore, the economic analysis of the SBGEP system must have a broad perspective.

Informed economic decision about the installation of SBGEP systems includes detailed analysis of its benefit cost analysis. It involves comparing the flow of costs and benefits from a project or investment, where the flows are discounted to net present equivalent values. Results are then expressed in a variety of ways. For example, net present value (NPV), internal rate of return (IRR), benefit-cost ratio (BCR) and payback period (PBP) as financial indicators for the project.

6.4.1 Net Cash flow

To financially analyze this project. It's needed to express the project in terms of cash flow. Cash flow represents the flow or movement of money at some specific time over some period of time. Figure 6.1 shows the cash flow with its input data.

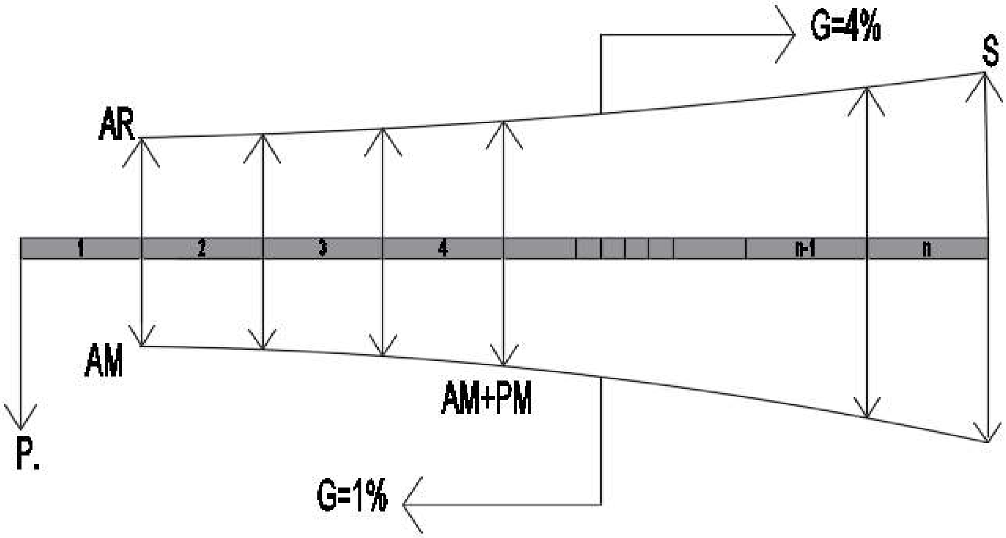


Figure 6.1 Cash Flow with input data

Where:

- P_o: Capital Cost of the Project = 4,469,222 NIS
- AM: Periodic Maintenance Cost for the system = 510,057 NIS
  (This value is expected to increase by G=1% every year)
- PM: Total Cost of all batteries = 515,450 NIS
  (This value is expected to be every four years)
- AR.: Revenue of the project = 742,073NIS
  (This value is expected to increase by G=4% every year, this percent represents the growth rate of vehicles in Nablus city)
- S: Salvage Value of the system at the end of period = 672,624 NIS
- n: Lifetime of the system = 20 years

Table 6.6 Cash flow inflows and outflows.

Cash outflow	
Initial Cost	-4,469,222
Periodic Maintenance per year	-510,057
Maintenance of battery Per 4 Year	-515,450
Maintenance Growth (g_2) %	1.0
Cash inflow	
Revenue Per Year	742,073
Salvage Value	672,624
Revenue growth (g_1) %	4.0

The cash flow is fundamental to every economic study. It occurs in many configurations and amounts —isolated single values, series that are uniform, and series that increase or decrease by constant amounts or constant percentages. For this economic study, cash flow is geometric gradient series that either increases or decreases by a constant percentage each period. This change occurs every year on top of a starting amount in the first year of the project. The uniform change is called the rate of change (g). Figure 6.2 shows increasing and decreasing geometric gradients starting at an amount A_1 in time period 1.

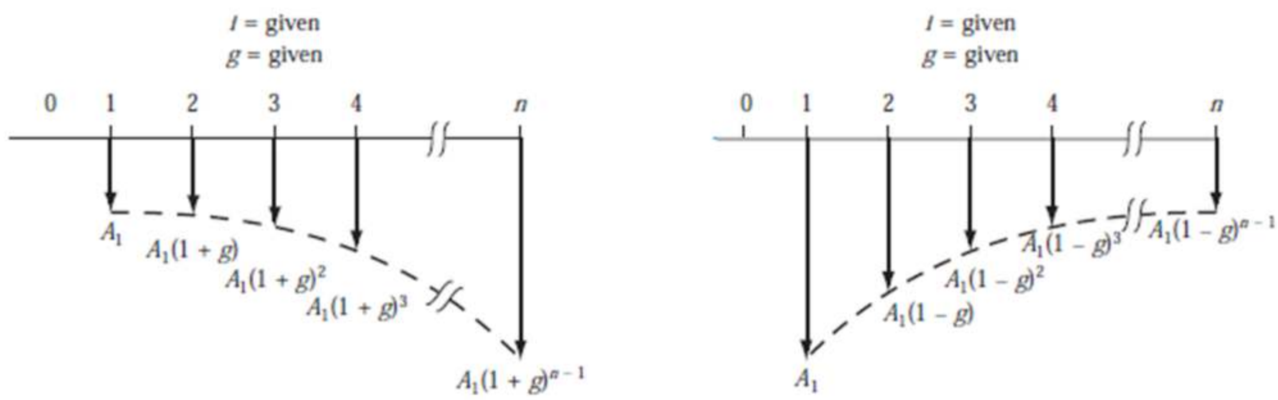


Figure 6.2 Geometric gradient series.

It is common for annual costs such as maintenance to go up by a constant percentage, for that the periodic maintenance will increase by 1% each year, and the revenue will increase by 4% due to the growth rate of the vehicles in the city. The formula to deal with such series is as the following:

$$At = A1(1+g)^{t-1} \quad (6.1)$$

Where:

At: Annual cost at time equal t.

A_1: Initial cash flow in year 1 of the geometric series.

g: Constant rate of change, in decimal form, by which cash flow values increase or decrease from one period to the next. The gradient g can be + or -.

t: period time.

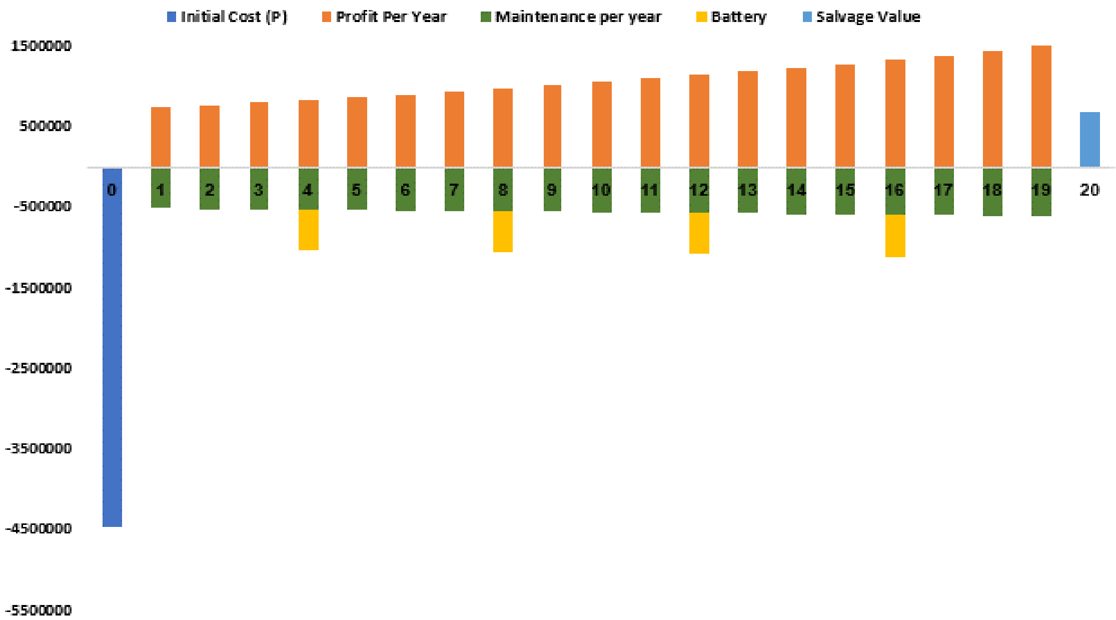


Figure 6.3 Cash Flow diagram.

After finding the revenue and the periodic maintenance per year, the net cash flow can be calculated by the equation below:

$$Net\ cash\ flow = chash\ inflows - cash\ out\ flows \quad (6.2)$$

Net Cash flow: Net cash flow is the difference between a company's cash inflows and outflows within a given time period.

Cash out flow: The money that would be spent.

Cash inflow: The amount of money that would be received.

After paying for all operating costs and debt payments, a project has a positive cash flow when it has excess cash. If a project is paying more for expenses than it earns, it has a negative cash flow.

Table 6.7 Net cash flow.

Year	Initial Invest Cost	Revenue Per Year	Maintenance per year	Battery	Salvage Value	Net Cash Flow
0	-4469222					-4469222
1		742072.9685	-510057			232015.9685
2		771755.8872	-515157.57			256598.3172
3		802626.1227	-520309.1457			282316.977
4		834731.1676	-525512.2372	-515450		-206231.0695
5		868120.4143	-530767.3595			337353.0548
6		902845.2309	-536075.0331			366770.1978
7		938959.0401	-541435.7835			397523.2567
8		976517.4017	-546850.1413	-515450		-85782.73955
9		1015578.098	-552318.6427			463259.4551
10		1056201.222	-557841.8291			498359.3926
11		1098449.271	-563420.2474			535029.0232
12		1142387.241	-569054.4499	-515450		57882.79152
13		1188082.731	-574744.9944			613337.7367
14		1235606.04	-580492.4443			655113.596
15		1285030.282	-586297.3688			698732.9131
16		1336431.493	-592160.3425	-515450		228821.1507
17		1389888.753	-598081.9459			791806.807
18		1445484.303	-604062.7654			841421.5377
19		1503303.675	-610103.393			893200.2822
20					672624	672624

6.4.2 Present-Worth Analysis (PW)

Present worth is an equivalence method of analysis in which a project's cash flows are discounted to a single present value. It is perhaps the most efficient analysis method that can be used for determining project acceptability on an economic basis.

In the PW analysis, all future costs and revenues are transformed to equivalent monetary units now; that is, all future cash flows are converted (discounted) to present amounts at a specific rate of return, which is the MARR. The MARR, or minimum attractive rate of return, is the minimum profit an investor expects to make from an investment in a project. In this project the MARR or initial i% is assumed to be 2%.

The equivalent present worth P_g of geometric gradient series including initial amount of annual worth A_1 is represented by the following equation:

$$Pg = A_1 \left[\frac{1-\left(\frac{1+g}{1+i}\right)^n}{i-g} \right] \quad , \qquad i \neq g \tag{6.3}$$

To find the present worth of the project, all future cash flows such as the periodic maintenance, revenues and salvage value are converted to an equivalent worth P at t=0.

To find the equivalent present worth of the maintenance P_{g1}, A_1 is the cost 510057 NIS at first year, i = 2%, g=1% and n project lifetime 20 years.

$$P_{g1} = 510{,}057 \left[\frac{1-\left(\frac{1+0.01}{1+0.02}\right)^{19}}{0.02-0.01} \right] = -8{,}707{,}533 \text{ NIS}$$

The equivalent present worth of the revenue P_{g2} is calculated as the following with g=4%:

$$P_{g2} = 742{,}073 \left[\frac{1-\left(\frac{1+0.04}{1+0.02}\right)^{19}}{0.02-0.04} \right] = 16{,}555{,}874 \text{ NIS}$$

The buttery maintenance every 4 years is converted to the equivalent present worth P_B by the equation below:

$$P_B = F \left[\frac{1}{(1+i)^n} \right] \tag{6.4}$$

$$= 515{,}450\left[\frac{1}{(1+0.02)^4}\right] + 515{,}450\left[\frac{1}{(1+0.02)^8}\right] + 515{,}450\left[\frac{1}{(1+0.02)^{12}}\right]$$

$$+ 515{,}450\left[\frac{1}{(1+0.02)^{16}}\right] = -1{,}698{,}034 \text{ NIS}$$

Finally, the equivalent present worth of the salvage value P_S:

$$P_S = 672{,}624\left[\frac{1}{(1+0.02)^{20}}\right] = 452{,}657 \text{ NIS}$$

The total PW is found to be:

$$\mathrm{PW} = -\mathrm{P_O} - \mathrm{P_{g1}} + \mathrm{P_{g2}} - \mathrm{P_B} + \mathrm{P_S}$$

$$= -4{,}469{,}222 - 8{,}707{,}533 - 1{,}698{,}034 + 16{,}555{,}874 + 452{,}657 = 2133742 \text{ NIS}$$

The PW of the project exceed zero, that is, the project is economically justified and consider as a revenue project.

6.4.3 Internal Rate of Return (IRR):

Rate of Return is the rate paid on the unpaid balance of borrowed money, or the rate earned on the unrecovered balance of an investment, so that the final payment or receipt brings the balance to exactly zero with interest considered A project is not economically viable unless it is expected to return at least the MARR. To determine the rate of return, develop the ROR equation using either a PW or AW relation, set it equal to 0, and solve for the interest rate.

$$0 = \mathrm{PW}$$

$$0 = -4{,}469{,}222 - 510{,}057(\mathrm{P/g}, 0.01, i^*, 20) - 515{,}450[\,(\mathrm{P/F}, i^*, 4) + (\mathrm{P/F}, i^*, 8)$$
$$+ (\mathrm{P/F}, i^*, 12) + (\mathrm{P/F}, i^*, 16)] + 742{,}073(\mathrm{P/g}, 0.04, i^*, 20)$$
$$+ 672{,}624(\mathrm{P/F}, i^*, 20)$$

Using MATLAB software to solve the equation, the i* (IRR) found to be equal 5.34 %. Since the IRR greater than the MARR, 5.34 % > 2%, the project is economically viable.

6.4.4 Benefit Cost Ratio (B/C):

The benefit-cost ratio indicates the relationship between the cost and benefit of project or investment for analysis as it is shown by the present value of benefit expected divided by present value of cost which helps to determine the viability and value that can be derived from investment or project. If that investment or the project has a B/C value that is greater than one, then the project can be expected to return or deliver a positive net present value.

$$B/C = \frac{PW\ of\ benefits}{PW\ of\ costs} \tag{6.5}$$

The PW of benefits from the project was found to be $(16{,}555{,}874 + 452{,}657 = 17008531$ NIS), the total PW of costs in the project $(4{,}469{,}222 + 8{,}707{,}533\ + 1{,}698{,}034 = 14875789$ NIS). Therefore, the B/C ratio for the project:

$$B/C = \frac{18{,}060{,}679}{15{,}289{,}477} = 1.14 > 1$$

The B/C ratio 1.18 greater than 1, that gives an indicator that the project is expected to deliver a positive net present value, which is correct since the PW for the project is positive.

6.4.5 Payback Period (np)

Payback analysis is another use of the present worth technique. It is used to determine the amount of time, usually expressed in years, required to recover the first cost of an asset or project.

The payback period (n_p) is an estimated time for the revenues, savings, and any other monetary benefits to completely recover the initial investment plus a stated rate of return. There are two types of payback analysis as determined by the required return:

1. No return; i=0%: also called simple payback, this is the recovery of only the initial investment.
2. Discounted payback; i >0%: the time value of money is considered in that some return, must be realized in addition to recovering the initial investment.

To calculate the payback period for i =0% or i>0%, determine the pattern of the net cash flow series,

No return, i =0%; NCF_t varies annually: $0 = -P + \sum_{t=1}^{t=np} NCF$

Discounted, i >0%; NCF_t varies annually: $0 = -P + \sum_{t=1}^{t=np} NCF\ (P/\ F\ \ , i, t)$

Solving the second equation using MATLAB software, the payback required to recover the initial investment plus the IRR is 15.5 years.

6.4.6 Capital Recovery (CR):

Capital recovery (CR) is the equivalent annual amount that the asset, process, or system must earn (new revenue) each year to just recover the initial investment plus a stated rate of return over its expected life. Any expected salvage value is considered in the computation of CR.

To compute the CR:

$$CR = -P_O\left[\frac{i(1+i)^n}{(1+i)^n-1}\right] + S\left[\frac{i}{(1+i)^n-1}\right] \qquad (6.6)$$

$$CR = -4{,}469{,}222 \times \left[\frac{0.02(1+0.02)^{20}}{(1+0.02)^{20}-1}\right] + 672{,}624 \text{ n} \times \left[\frac{0.02}{(1+0.02)^{20}-1}\right]$$

$$= -245{,}640\ NIS$$

Each year the project must earn 245,640 NIS just to recover the initial capital cost and a stated rate 2%.

6.5 Economic Analysis for Design Alternatives

The following table shows the results of cost and the economic analysis on the three alternatives that were mentioned previously.

Table 6.8 Results of economic analysis for design alternatives.

Cost Item	Maximum Flow	Average Flow	Minimum Flow
Number of speed humps	57	276	72
Initial Invest Cost (NIS)	641,957	3,053,373	773,893
Periodic Maintenance per year (NIS)	71,786	347,595	90,677
Maintenance of battery Per 4 Year (NIS)	85,500	358,950	72,000
Revenue Per Year (NIS)	279,890	452,477	9,707
Salvage Value (NIS)	94,666	458,381	119,578
Net Present Value (NIS)	4,159,006	233,478	−452,291
Internal Rate of Return (NIS)	35.4	2.57	-44.12
Benefit Cost Ratio (%)	2.93	1.02	0.82
Payback Period (years)	3.1	18.7	More than 20

The alternative of speed bumps with the maximum flow is selected since the PW of its costs is the lowest; it has the numerically largest PW value and the largest IRR.

7 CONCLUSION AND RECOMMENDATIONS

In Palestine, the main energy source is the imported energy from neighboring countries due to lack of domestic energy resources. The Israel Electricity Corporation (IEC) is the largest electricity supplier. The percent of electricity supplied by the IEC is very large and cost a lot. Therefore, energy saving projects were established in different cities to reduce the consumption of electricity. Most of these projects focused on reducing energy used in street lighting, for example, (Ramallah City Street Lighting Project, 2015) and (Photovoltaic Energy Source for Street Lighting in Hebron/ Palestine Using GSM Technology, 2014).

Street lighting is one of the basic public services, its importance lies in being a visual guide for street users and achieving safety and security requirements as lighting reduces the rate of accidents on the roads, increases safety on the road path, helps pedestrians avoid the risk of accidents, helps reduce arrival time as it helps the driver to drive at the fastest design speed possible thus saving time and reducing accidents gives a high economic return.

7.1 Conclusions

The overall goal is to design an electric power generation system and reduce large amounts of greenhouse gas (GHG) emissions. Moreover, with the application of the electric hump, which transforms mechanical energy into electrical energy through the use of an electric generator, this system was used because of its high efficiency and applicability due to its available components. In addition, the use of alternatives in renewable energy sources strongly supports the provision of energy needs, due to the high demand for non-renewable energy sources, the high costs and the increase in the quantities of GHG emissions in the air. By applying this system, it can be used for various purposes such as lighting pols, traffic lights, etc.

All of that effort is to reduce the Palestinian dependence of electricity on the Israeli occupation, 87% of the Palestinian electricity imported from the occupation electric corporation while less than 8% from the Palestine electric company, therefore enhancing the economy of the Palestinian government, which is the biggest target of the project.

Based on the results of the research and using the developed design of the speed bump, the electric power generated from speed bump is 2.544 W/vehicle. In other words, one speed bump on average can light up 11 lamps (7W LEDs) over a distance of 0.6 Km from the road network.

Moreover, in this research there are several proposals for the implementation of the project. Firstly, the application of the project to all speed bumps in the city, as these speed bumps cover 44.66% of the energy consumption used for lighting in the city. Also, the payback period within 15.5 years and there are profits of NIS 5 million within 20 years.

Secondly, the application of the project to the speed humps on which there is a high flow in the city, which constitutes 14.1% of the total number of speed bumps, as these speed bumps cover 38% of the energy production from the speed bumps and 17% of the energy consumed in the city. Also, The payback period within 3.1 years and there are profits of NIS 5.4 million within 20 years. So, applying SBGEP only to speed humps that have a high traffic volume instead of applying it to all of Nablus city is feasible and effective.

Finally, the addition of solar panel to the electrical speed bumps system was not feasible, as the coverage rates of solar cells 18 Watts and 50 Watts were 0.23% and 0.63%, respectively. Where this percentage did not support to improve the electricity generation system in city.

7.2 Recommendations

However, the amount of energy produced by the new mechanical system, which considered about 44.66% of the energy consumed in the lighting poles and traffic signals, is very acceptable, it is recommended to study replacing the mechanical system by a hydraulic one, since the hydraulic system could be easier in installation and has a smaller size.

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