ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

School of Mechanical, Chemical and Material Engineering

Modification of Pedal Bicycle to Improved Solar Assisted Passenger Tricycle

A Project Submitted in Partial Fulfillment of the requirements for the award of degree of

Master of Science

in

Automotive Technology Teacher Education

By

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Department of Mechanical and Vehicle Engineering

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CANDIDATE'S DECLARATION

We hereby declare that the study project work which is being presented in the paper entitled **"Modification of Pedal Bicycle to improved Solar Assisted Passenger Tricycle"** in partial fulfillment of the requirements for the award of the degree of master of science in automotive technology teachers education is an authentic record of our own work carried out from February 2015 to June 2015 under the supervision of Mekonen Liben (Assistant Professor) and Mr.Nigusse Assefa (MSc),Department of Mechanical and Vehicle Engineering, Adama Science and Technology University, Ethiopia. The work embodied in this paper has not been submitted by us for the award of any other Degree or diploma. All relevant resources of information used in this paper have been duly acknowledged.

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This is to certify that the above statement made by the candidates is correct to the best of our knowledge and belief. This project has been submitted for examination with our approval.

Mekonen Liben (Asst. Prof)	__________________	__________________
Majer Advisor	Signature	Date
Ato Nigusse Assefa (MSc)	__________________	__________________
Co Advisor	Signature	Date

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Finally, we would like to say thanks to all individuals who helped us with their idea, skills and labor in this project work.

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ACRONYMS, ABBREVIATIONS AND SYMBOLS

BLDC	Brushless Direct Current
DC	Direct Current
SMEs	Small and Micro Enterprise's
SAT	Solar Assisted Tricycle
SPVs	Solar Powered Vehicles
PV	Photo Voltaic
PMDC	Permanent magnet direct current
DFE	Designing for Environment
SAPT	Solar Assisted Passenger Tricycle
Kg	Kilo gram
V	Volt
L	Liter
Pk	Pack
M	Meter
AISI	American Iron and Steel Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society of Testing and Materials
CS	Carbon Steel
AISC	American Institute of Steel Construction
ANSI	American National Standards Institute
ISO	International Standards Organization
TL	Large teeth of sprocket
TS	Small teeth of sprocket
RPM	Revolution per minute

ABSTRACT

This project focused on improved solar powered passenger tricycles suitable for countries like Ethiopia which found under developed country with huge population density and has no natural petrol resources. It was very much suitable of alternative energy such as solar energy for three wheeled vehicles and caters the need of economically poor class of society. It can be operated throughout the year free of cost. The most important feature of this solar tricycle is that it does not consume valuable fossil fuels thereby saving corers of foreign currencies, it is eco-friendly & pollution free, as it does not have any emissions.

The project was incorporated mechanical parts modification performed; solar cell and electrical parts installation were employed to accomplish the objectives of the project. various specific stage of process have take placed such as components required for solar tricycle has been selected in appropriately, various necessary parts of solar tricycle were modified and improved, and performance test done with fully functioned prototype.

In the principal contribution of this project was improved a solar assisted passenger tricycle that suitable for transportation used in rural and urban areas of our country, the load capacity was limited to two passengers without deriver and with a total weight of 268 kg which can be driven at a maximum speed of 30 kmp. As a part of paper work, the solar assisted tricycle is fitted with a DC motor on rear axle of a tricycle with power rating of 627 w and with a travelling speed of around 30 kmph. it was provided with a pair of Lead acid batteries of 60 Ah, a photovoltaic solar panel with capacity of 700 watt, surface area of selected solar panel was 1.76 m^2 *with input irradiance power of 1760 watt, a voltage regulator of 24v 32 amp, accelerator and motor controller of 24v 28.2amp. In most cities of our country the solar energy is so sufficient, while it is attractive to use solar tricycle than using man powered tricycle due to its advantages was discussed in the project. We have concluded from a given was that improved solar assisted passenger tricycle has a great deal to offer and it is going to be a big part of our future prospective.*

key words— *design books, solar three-wheeler, disabled people hybrid, solar tricycle and solar powered vehicle*

CHAPTER ONE

1. INTRODUCTION

1.1 Back ground of the study

As we all know, transportation facilities are the major factor in transporting of people and mobilization of goods in most parts of our planet as well as in Ethiopia. Most people use numerous means of transportation in many countries of our world. Again, the problem of transportation is still there in Ethiopia, although there are various means of transportation.

Ethiopia is one of the countries in Africa that have high density of population and it does not have own natural oil resource and production of petroleum as well. The fuel prices especially the petrol is raising steadily day by day to run the vehicles on the road and due to that there is problem of transportation in many parts of the country. To overcome these problems, an effort is being made to search some other alternative sources of energy for the vehicle and transportation needs. Accordingly, the one appropriate solution to this problem is redesign and modification of pedal bicycle to solar assisted passenger tricycle with full potential of technology in Ethiopia**.**

1.2 Statement of the problem

Nowadays, there is high demand of transportation and fuel, which then automotive vehicles demand is not affordable, especially with the current world price fluctuation, the problem becomes worst. Again, even though we say the economic development of the people allow them to buy the automobile as well as the fuel consumed, but the effect of global warming and climate change due to discharged carbon emission is the main concern these days.

Correspondingly, due to the rising demand of basic substructure availability like transport facility and population boosts in Ethiopia, subsequently uses of modified solar tricycle may reduce to some extent the problems of transportation.

In major cities of Ethiopia there is petrol and diesel powered three-wheelers called Bajajs. They are some of the most polluting vehicles on Ethiopian roads. They usually run on 2 stroke engines which are inherently more polluting than the regular 4 stroke engine.

Data collected reveals that in traffic conditions prevalent in most inner city areas, these Bajaj run only at 15-20 km/hr speed thereby producing even more pollution since they are designed to run efficiently at 40-45 km/hr. The pollution is further compounded by the fact that they continuously have to run in stop/start mode.

Therefore, the main purpose of this project is to resolve the high demand of transportation needs in Ethiopia, to minimize transportation cost, to introduce technology using renewable energy, to reduce environmental pollution, and also to create job prospects for unemployed people.

1.3. Objectives

1.3.1. General Objective

The overall objective of this project is to modify pedal bicycle to solar assisted passenger tricycle with improving a load capacity to two passengers in order to minimize the problem of transportation.

1.3.2. Specific Objectives

The following are the specific objectives for achieving the set goal.

- To select components required for solar energy application in tricycle.
- To design various parts necessary for modification.
- To modify pedal bicycle into solar powered tricycle with fully functional prototype.
- To construct simple passenger shield to protect occupant from flying dust, sun radiation and rain.
- To test the performance of SAT.

1.4. Significance of the project

The principal contribution of this project is to develop and modify a pedal bicycle to a solar assisted passenger tricycle with simple lighting system for better night illumination that suitable for transportation used in rural and urban areas of our country. With this project, there is a possibility of carrying out service efficiently and effectively with less cost and without the use of any fuel for driving; this generally the benefits will be:

- Utilization of alternative energy such as solar energy for three wheeled vehicles.
- Fulfillment of transportation needs in rural and urban areas of our country.
- Creation job opportunities for unemployed citizen the youth.
- Transfer of new technology in transportation system which is environmentally friendly
- Provision of transportation at low cost.
- Inspiring small and micro-enterprise (SME) for production of SAT.

1.5 Scope of the study

The scope of this project is limited to modification of a pedal bicycle to solar assisted passenger tricycle constructed on prototype level at reduce scale. The load capacity is limited to two passengers without deriver and with a total weight of 268 Kg which can be driven at a maximum speed of 30 KMP.

1.6 Limitations of the project

In this project is shown the prototype of the exact practical modification of Pedal Bicycle into Solar Assisted Tricycle on a reduced scale
Some of the limitations are listed as under:

1. Unavailability of necessary component parts in the market such as solar panel, DC motor and control system component.
2. Insufficient budgets;
3. Lack of equipment;
4. Malfunction of measuring tools;
5. Time restriction to finished project entirely;

CHAPTER TWO

2. LTERATURE REVIEW

2.1. Overview of solar tricycle

This paper provides idea of currently available three-wheelers for disabled people and proposes a new improved design of a solar powered three-wheeler suitable for countries like Bangladesh which is an under developed country with huge disabled/crippled people from war, accidents and diseases. This three-wheeler is operated by solar power and suitable for outdoor use. Solar power option enables the disabled people to use it at any place, even in remote areas where there is no electricity. A general survey had been conducted on disabled people using wheel chairs and manual three-wheelers and the opinions of the experts working with the disabled people are also taken in to consideration to identify the needs and requirement for designing the solar three-wheeler. The proposed solar three wheeler is meant to match and exceed the conventional three wheeler’s facilities with a more intelligent and efficient design. A solar panel to produce solar electricity, a battery system f or preserving electric power, an efficient motor, cushion seat, all terrain tires are used for this solar three-wheeler[12].

Tricycle rickshaw is propelled by human energy. A study has been performed with the existing model and design of tricycle rickshaws. It has been observed that traditional rickshaws use age old technology, poor mechanical design and hence non ergonomic in maneuverability. An effort has been directed to design a light weight, high strength, and ergonomically designed both human pulled and electric powered hybrid rickshaws. The proposed model will be powered with 400 W and 24 V DC motor in addition to the human power. Both the options may work independently as well as in hybrid mode [20].

The solar assisted bicycle developed is driven by DC motor fitted in front or rear axle housing & operated by solar energy. The solar panels mounted on the carriage will charge the battery & which in turn drive the hub motor. When the bicycle is idle, the solar panel will charge the battery. This arrangement will replace the petrol engine, the gear box & the fuel tank in case of a two wheeler or a chain sprocket, chain & gear shifting arrangement of a conventional bicycle being used by most common man. As a part of dissertation work, the solar assisted bicycle is fitted with a dc hub motor on front axle of a bicycle with power rating of 250W and with a travelling speed of around 25-30 kmph. It is provided with a pair of lead acid batteries of 35Ah each, a photovoltaic solar panel with capacity of 20 watt, a voltage regulator of 24v 10 Amp, accelerator and motor controller of 24v 25Amp. There is also a provision for charging of the battery with 220-240V, AC wall outlet supply, in case of poor solar supply due to cloudy weather.

As what had been mention earlier, there are several types of tricycle that can be categories that is paddle tricycle, motorized tricycle, and electric tricycle. The weakness of the tricycle make people do not like to used tricycle. First, paddle tricycle needs a lot of energy to paddle the tricycle. The user will surely be tired after used the tricycle. This will not suitable for student to use to go to the class because they will be tired when they are in the class and will lost their concentration while hearing the lecture. Next, motorize tricycle that used fuel as it prime mover. The tricycle use fuel that is costly. As a student, their allowance is limited and only can be used for their study material and for their food to survive at the campus. Besides that, motorize tricycle will make pollution that can be very bad for our environment especially in this period that global warming happen to the earth. Lastly, electric tricycle that generate by battery can be only be sufficient for about an hour. The user needs to find power supply to recharge the battery or else they need to paddle the tricycle that used more energy compare to the normal tricycle because of the weight.

In order to perform this project, literature review has been made from various sources like journal, books, article and others. This chapter includes all important studies which have been done previously by other research work. It is importance to do the literature review before doing the project because we can implement if there are information that related to this project. The most important thing before starting the project we must clearly understand about the topic that we want to do. So by doing the literature review we can gain knowledge to make sure we fully understand and can complete the modification process of the project. A review of the article was performed to identify studies that relevant to the topic of modification and improve with regard to PB, and on the subject of converting PB into SAT power. The search to find material that related to the topic is categories as solar panel, solar charger, battery, motor, solar tricycle and speed control.

2.2. Solar Assisted Passenger Tricycle

Designing of the solar three-wheeler has two major parts/aspects. Firstly, Designing the three-wheeler and it's components from mechanical and biomechanics point of view and secondly, incorporation of solar power system to the improved manual three-wheeler to achieve automation. Draw-backs of the available manual three-wheelers as well as needs and requirements from the disabled people (users) are seriously considered while making definite improvement in designing. Effective use of limited solar energy (due to limited space/module), energy storage and power requirements (load) are also seriously considered to balance and optimize the solar power system of the solar three-wheeler [1].The solar powering system of the tricycle consists of:

- Solar Array which collects solar energy and converts it to electrical energy
- Power trackers to achieve the proper voltage to be stored in batteries.
- Batteries to stir power.
- Motor controller which adjusts the power input to the motor.
- An electric motor which drives the vehicle

2.3. How Solar Assisted Passenger Tricycle works

The solar assisted tricycle developed is driven by DC motor fitted in front or rear axle housing & operated by solar energy. The solar panels mounted on the carriage will charge the battery & which in turn drive the DC motor. That means: Solar Array which collects solar energy and convert it to electrical energy –Power trackers to achieve the proper voltage to best ore in batteries-Batteries to stir power-Motor controller which adjusts the power input to the motor the non electric motor which drives the vehicle. The solar assisted Tricycle consist of following components DC motor, solar panel, voltage regulator, lead acid battery, motor controller, accelerator, bicycle [2].

2.4. Main components of Solar Assisted Passenger Tricycle

This three-wheeler is operated by solar power and suitable for outdoor use. Solar power option enables the all people to use it at any place, even in remote areas where there is no electricity. are shown as below in figure 2.1. [9]

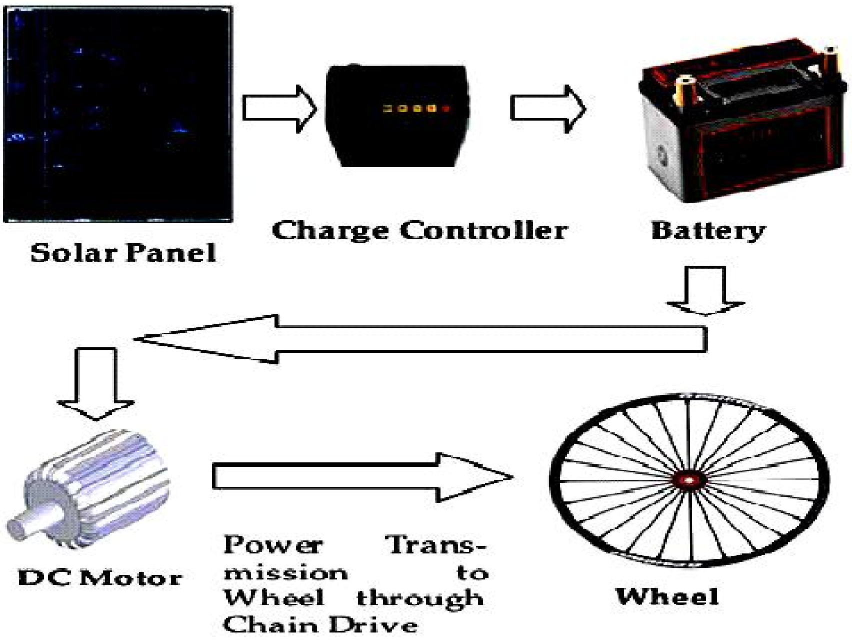


Figure 2.1: Diagram of main component solar assisted passenger tricycle system

2.4.1 Solar panel

Solar PV panels are designed to generate/collect desired energy required by the solar three-wheeler. Power needed to run the solar three-wheeler is indirectly supplied from solar panel. Basically this solar panel when exposed to the sunlight produces DC current (solar electricity) which is stored in a battery and used by motor as per the requirement, as and when required basis. Now, it is important to design the solar panel size and its power output in working condition. The solar panel consists of solar cells. The amount of power output of a solar cell depends on solar cell efficiency and solar cell area. Usually 30~36 solar cells connected in series are laminated together to make a so-called solar PV module.

Commercially, available single solar cell normally having the dimensions of (3"× 6"), (10 cm ×10 cm) etc. A (10 cm ×10 cm) solar sells electricity output is likely rated at 0.50 to 0.55 volts with 3 to 3.3 amps. Here, in the module, 36 cells are connected (in series) together so that in all operating conditions a PV module gives well above 12 volts, which is the required to charge a 12 V battery [14].

Solar cells are electrically connected and fabricated as a module with a sheet of glass on top to allow light to pass and protect the semiconductor from the weather. To obtain a desired peak DC voltage we will add solar cells in series, and to obtain a desired peak current, the solar cells are put in parallel position. Photovoltaic‘s is the field of technology and research related to the devices which directly convert sunlight into electricity. The solar cell is the elementary building block of the photovoltaic technology. Solar cells are made of semiconductor materials, such as silicon. One of the properties of semiconductors that makes them most useful is that their conductivity may easily be modified by introducing impurities into their crystal lattice[3][6].

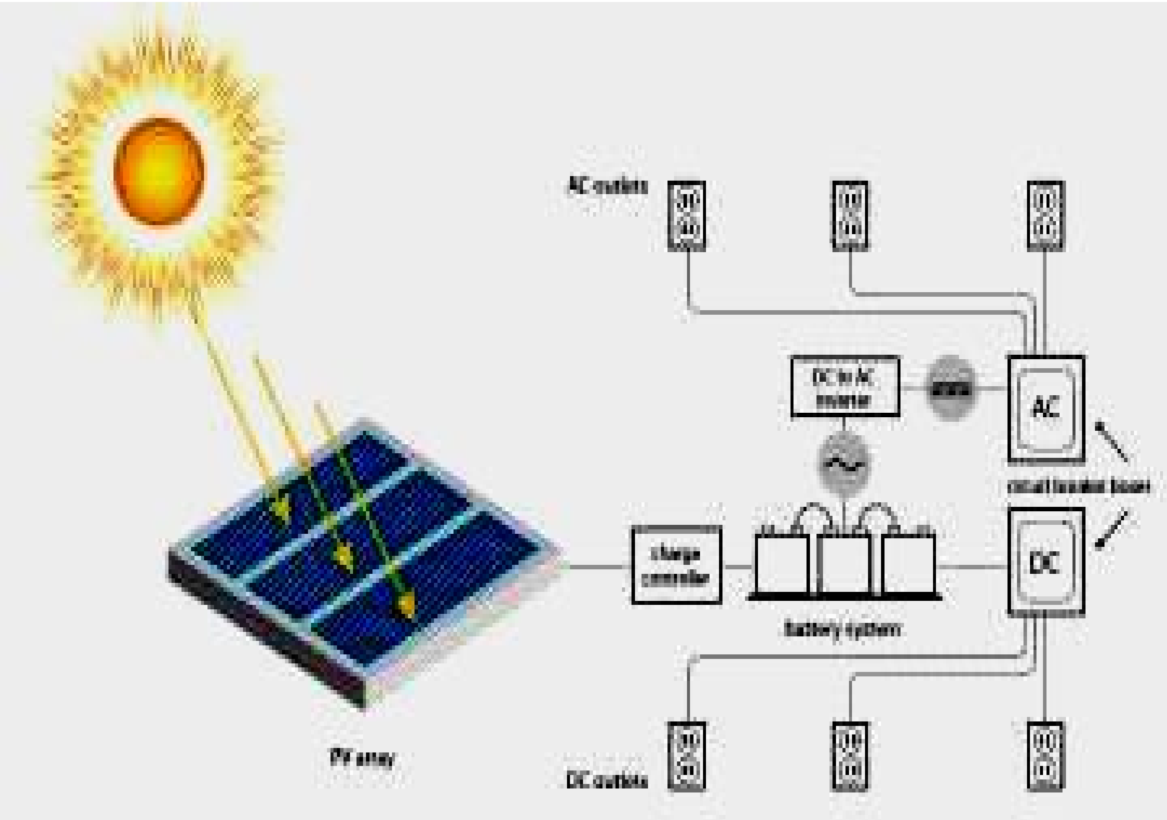


Fig 2.2: Solar radiation and energy storage

2.4.2 Voltage regulator

It is essential to regulate the voltage output from the solar panel before it is supplied to the battery. A voltage regulator is a power converter with an output DC voltage greater than the input DC voltage. This is used to regulate an input voltage to a higher regulated voltage.

The output of the solar panel is not always be stable due to fluctuations in intensity of sunlight, angular changes with respect to the direction of sunlight, as well as other environmental factors.

The output of the solar panel is the input of the boost converter, which then outputs into the battery for charging. Because the output of the solar panel will be varying constantly, we need a voltage regulator/boost converter that will take an input from a wide range of voltages and output a specific, constant voltage value.

A voltage regulator/boost converter is a power converter that will take in a DC voltage and output a higher value DC voltage. Our voltage regulator/boost converter requires output of the solar panel, which can range from 0V to 27.2V, and output for charging of the battery. We were initially attracted to the SPV Instruments Module because it has the characteristics of taking in an input range of 9.6V to 13.2V and outputting 24V at a maximum of 2-3 amps .This SPV has an area of 2.5 square inches so it is also small in size, which makes it very feasible to be placed anywhere on the bicycle. We go thought the battery voltage & we need to supply 24V in order to charge it [6][15][21].

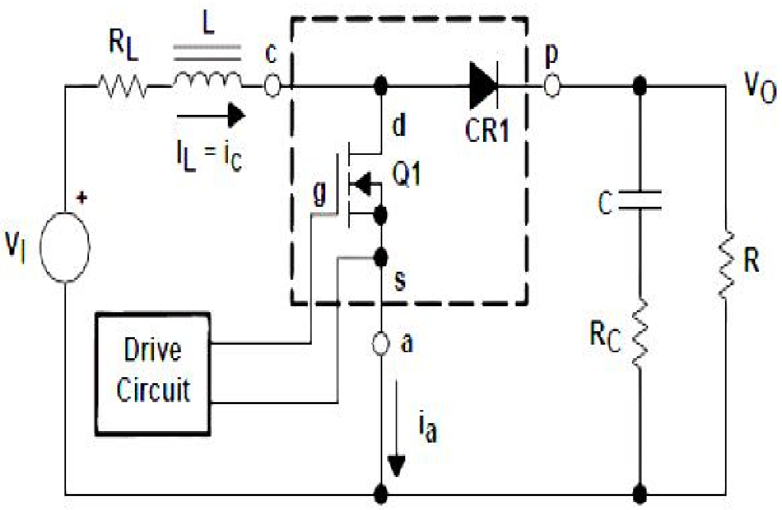


Fig2.3: Circuit diagram of Voltage Regulator

2.4.3 Lead acid Battery

Lead acid batteries are one of the most popular types of battery in electronics. Although slightly lower in energy density than lithium metal, lead acid is safe, provided certain precautions are met when charging and discharging. This have a many advantages over other conventional types of batteries, the lead acid battery is the optimum choice for a solar assisted bicycle.

Current supplied from battery indicates the flow of energy from the battery and is measured in amperes (or Amps). The higher the current flow faster the battery will discharge. A battery is rated in ampere-hours (abbreviated Ah) and this is called the battery capacity.

This project revolves around supplying and utilizing energy within a high voltage battery. It demands for a battery with longer running hours, lighter weight with respect to its high output voltage and higher energy density. Among all the existing rechargeable battery systems, the lead acid cell technology is the most efficient and practical choice for the desired application. The battery chosen for this project was a high capacity lead acid battery pack designed specifically for vehicles. Plastic casing is provided to house the internal components of the battery [4] [7]

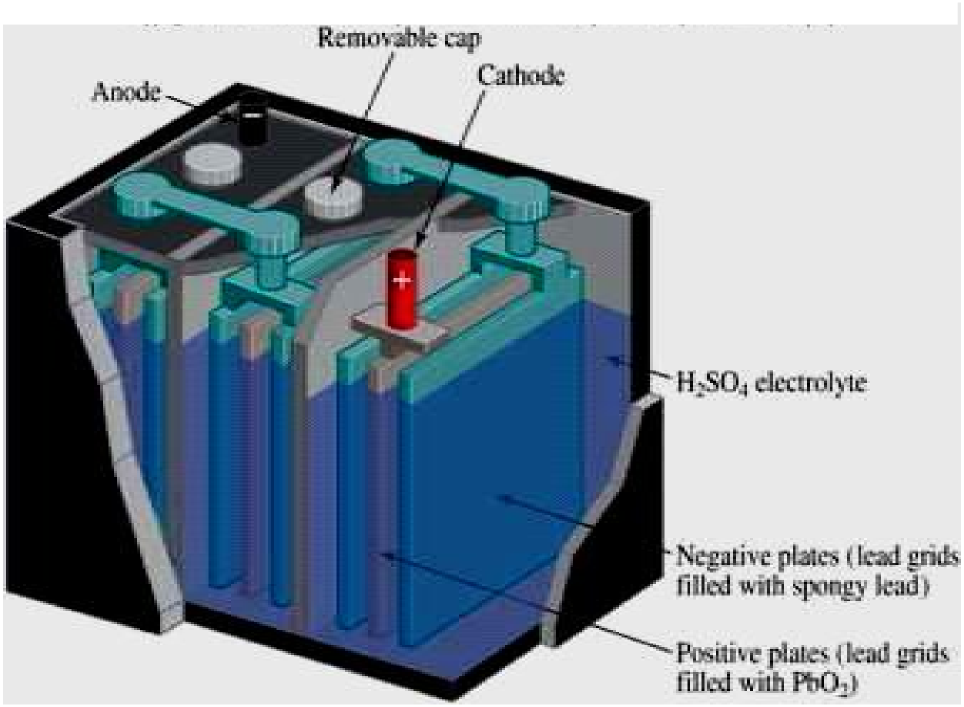


Fig2.4: Parts of lead acid battery cell

2.4.4 Motor controller

The motor controller (Fig2.5) is an important component of the system. It is essential to control the amount of power supplied and to drive the BLDC motor. The controller converts the DC voltage from battery to an alternating voltage with variable amplitude and frequency that drive the hub motor at different speeds (Fig.11). It basically consists of MOSFET transistors and small microprocessor that vary from detecting any malfunctions with the motor hall sensors, the throttle, to protect functions against excessive current and under-voltage, which are ideal for protecting the system [5] [15].

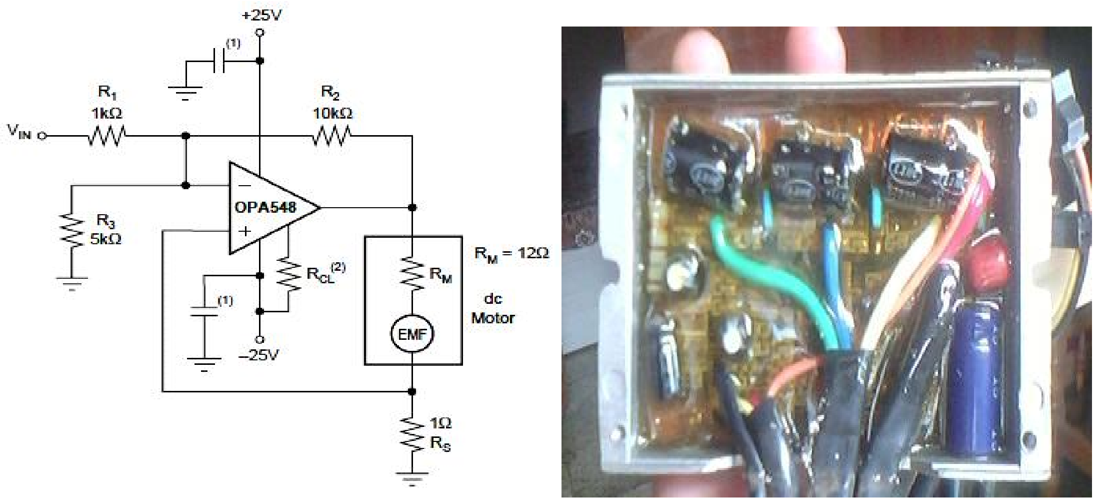


Fig 2.5: Circuit diagram of motor controller

2.4.5 Accelerator/throttle

In this project the solar tricycle has maximum speed boat SAT is 30km/h. It is required to vary the speed depending upon the road conditions &traffic. Therefore an accelerator or a throttle illustrated in the Fig.2.6 is necessary. Throttleallowsustodrivethemotorfromzerospeedtofullspeed.Thethrottleisfittedon right Sid of the handle brand is connected to controller. The throttle converts DC voltage from battery to an alternating voltage with variable amplitude and frequency that drives the DC motor at different speeds [8][21].

Fig 2.6: Throttle/Accelerator

2.4.6 DC Motor

The prime mover to be used in this solar three-wheeler is a permanent magnet D.C. motor. In this project the main reason for using this motor is that it is highly efficient and the flux density does not decrease with time. It's performance characteristics suite very well to the requirement of our solar three-wheeler. At standard load condition, the motor needs 627Watts. This power will cover the required power needed to run the solar three-wheeler at a speed of 30 km/hr. If the load increases or the three-wheeler climbs up-ward slope, then the current will also increase and power output of the motor will also increase. However, considering standard power requirement and the safety, the designed motor power capacity is set to 500 W. The PMDC (permanent magnet direct current motor) was chosen for its power rating and cost. A 0.76kW motor is chosen for the ideal electric power for a tricycle which is smooth in minute sound than other motor (make by MMC electric company pvt.ltd).
The motor runs on 24 volts DC, with a rated speed of 300 rpm and a rated current 19 amps as shown in Fig 2.7[1][10].

Fig.2.7: PMDC Motor

2.4.7. SAT body structure

The present design of an improved electric tricycle is an attempt to explore the inherent short comings of conventional tricycle. Some standard parts of a commercially available Bajaj and bicycle are selected as standard components requirement. They include chain and sprocket, freewheel, wheel and axle, etc. Standard motorcycle and scooter ball bearings were selected instead of conventional rickshaw bearing to get less frictional resistance in shafts. Material selection of the chassis plays crucial part in providing the desired strength, endurance, safety and reliability to the vehicle. Two main materials under consideration are: AISI 1018 and 4130 Chromalloy steel.
The strategy behind selecting the material for roll cage was to achieve maximum welding area, good bending stiffness, minimum weight and maximum strength for the pipes. So, after market analysis on cost, availability and properties of these two alloys, AISI 1018 was used of the following dimensions: Outer Diameter: 25.6mmWall Thickness: 3.50 mm .The frame is provided with two independent rear suspensions adopted from motorcycle. These suspensions are supposed to provide comfortable ride to the passengers and riders. The front wheel suspension is a fork type one. The front and rear subassemblies of the designed tricycle is pivoted at the center with two swing arms. The adjustable driver seats with arm and head rest have been provided both for agronomy and comfort [21][22].

2.4.8. SAT chassis and frame

The Chassis/Frame of the presently available three-wheeler is heavy and wheels are of big sizes. So while designing, unnecessary weight is reduced to meet the requirement. Comparatively smaller wheels are selected; keeping in mind that the weight of the solar three-wheeler should be as low as possible and must have required strength. The solar three-wheeler chassis is designed by using steel pipes reinforced with angle bars where necessary [2][11].

Finally, the chassis or frame is made by steel pipes having 20 mm diameter with 2 mm thickness. Reinforcement in bends etc. is done by 20 mm×20 mm angle bars as necessary. To avoid accidents and ensure safety, the sharp edges, bends etc. are rounded. Total weight of the loaded solar three-wheeler (with a person) will be 268 kg. Four iron pipes (Steel ASTM-A36) are to bear the load as frame/chassis and the maximum static deflection of the used pipes will around 0.66 mm, which is acceptable. All the three wheels are of equal size having the diameter of 40 cm each. All terrain tires are used for better traffic ability. The body of the solar three-wheeler is made of pipes, steel sheets of minimum possible thickness and woods for lighter weight. An adjustable waterproof cushioned seat is attached with the chassis. The solar panel is set on the top (overhead) with panel mounting frame made of light steel pipes duly attached to the main frame/chassis. While modeling; sharp edges, bends, nails are avoided to avoid accidents and ensure better safety [15][21][22].

2.4.9 Power Transmission Component

2.4.9.1 Drive Shaft

Shaft is a common and important machine element. It is a rotating member, in general, has a circular cross-section and is used to transmit power. The shaft may be hollow or solid. The shaft is supported on bearings and it rotates a set of gears or pulleys for the purpose of power transmission. The shaft is generally acted up on by bending moment, torsion and axial force.

Standard sizes of Shafts

Typical sizes of solid shaft that are available in the market are,

Up to 25 mm 0.5 mm increments
25 to 50 mm 1.0 mm increment
50 to 100 mm 2.0 mm increments
100 to 200 mm 5.0 mm increments

Material for Shafts

The ferrous, non-ferrous materials and nonmetals are used as shaft material. Depending on the application, some of the common ferrous materials used for shaft are discussed below.

Hot-rolled plain carbon steel

These materials are least expensive. Since it is hot rolled, scaling is always present on the surface and machining is required to make the surface smooth.

Cold-drawn plain carbon/alloy composition

Since it is cold drawn it has got its inherent characteristics of smooth bright finish. Amount of machining therefore is minimal. Better yield strength is also obtained. This is widely used for general purpose transmission shaft.

Alloy steels

Alloy steel as one can understand is a mixture of various elements with the parent steel to improve certain physical properties. To retain the total advantage of alloying materials one requires heat treatment of the machine components after it has been manufactured. Nickel, chromium and vanadium are some of the common alloying materials. However, alloy steel is expensive. These materials are used for relatively severe service conditions. When the situation demands great strength then alloy steels are used. They have fewer tendencies to crack, warp or distort in heat treatment. Residual stresses are also less compared to CS (Carbon Steel) [22].

2.4.9.2 Chain

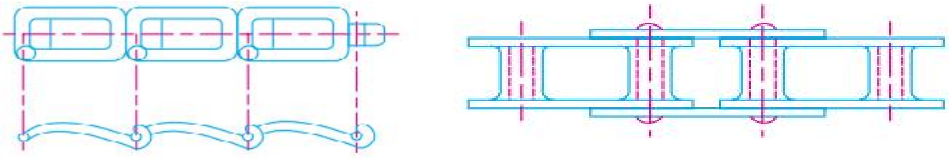
The chains are made up of number of rigid links which are hinged together by pin joints in order to provide the necessary flexibility for wrapping round the driving and driven wheels. These wheels have projecting teeth of special profile and fit into the corresponding recesses in the links of the chain as shown in Fig. 21.1. The toothed wheels are known as *sprocket wheels or simply sprockets*. The sprockets and the chain are thus constrained to move together without slipping and ensures perfect velocity ratio [22].

Fig. 2.8 Chain

The conveyor chains are of the following two types:

1. Detachable or hook joint type chain, as shown in Fig. 21.5 (*a*), and

2. Closed joint type chain, as shown in Fig. 21.5 (*b*).



(a) **(b)**

Fig. 2.9 Conveyor chains

The chains are mostly used to transmit motion and power from one shaft to another, when the centre distance between their shafts is short such as in bicycles, motor cycles, agricultural machinery, conveyors, rolling mills, road rollers etc.

The chains may also be used for long centre distance of up to 8 meters. The chains are used for velocities up to 25 m / s and for power up to 110 kW. In some cases, higher power transmission is also possible.

Chain is used to transmit motion from pedal or DC motor to SAT wheel. Advantage of chain drive No slip takes place during chain drive, hence perfect velocity ratio is obtained.

- Occupy less space than belt.
- It gives transmission efficiency of 98%
- It gives fewer loads on the shafts
- It transmit more power than belts
- It can operate under atmospheric condition.

In this project, due to the above stated advantage of chain over the others it was selected to transmit motion from DC motor to rear drive wheel [21][22].

2.4.9.3 Sprocket

Sprockets manufactured from good quality iron castings are suitable for the majority of applications. For arduous duty it may be necessary to use steel sprockets having 0.4% carbon content. For extremely arduous duty the tooth flanks should be flame hardened. There are other materials which may be specified for particular requirements. Stainless steel for example is used in high temperature or corrosive conditions [21].Sprockets are usually of 3 main types; one piece sprockets of steel or cast iron, two pieces split sprockets and sprockets with bolt on tooth segments[22].

Main types of sprocket are illustrated in figure 2.10.

One piece sprockets of steel

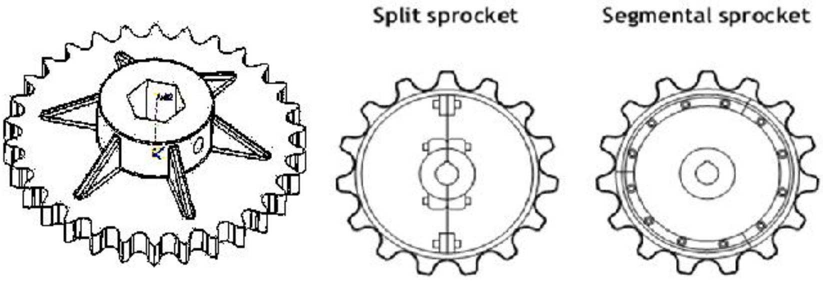


Fig 2.10Main types of sprocket

The majority of sprocket in use is the one piece cast iron or fabricated steel design and is usually parallel or taper keyed to a through shaft. If quick detachability is necessary without dismantling shafts or bearings the sprockets may be of the split type. These are made in two half sections and the mating faces machined to allow accurate assembly with the shaft in place. Sprockets with removable tooth segments are particularly useful where sprocket tooth wear is much more rapid than chain wear. With this type of sprocket, segments of teeth can be replaced one at a time without having to disconnect or remove the chain from the sprockets, thus considerable expense and downtime can be saved [17][23].

One piece sprockets type was selected in this project due to its most availability in the market and lowest in cost when compared with other types of sprockets.

CHAPTER THREE

3. METHODS AND MATERIALS SELECTION

3.1 Method

In this project, mechanical parts modification, solar cell and electrical parts installation are employed to accomplish the objectives of the project. Various related reading materials, books, journals, previous research works on pedal bicycle and solar assisted tricycle technology are referred in order to have comprehensive understanding of the subject under research and to review other similar research works.

The related literature would be reviewed thoroughly to obtain the necessary information for the modification process. The various stages of the project process which have taken are outlined below.

1. Literature review

   Literature review has taken place on the modification of PB into SAT.

2 .Modification of bicycle to tricycle will be done according to the design

- Dismantle part of the bicycles
- Redesign newly tricycle chassis
- Assemble and reinforce the chassis with appropriate materials

3. Installation of solar system will be done

- Fit brushless motor appropriately
- Install solar panel and controllers and connect to brushless motor

4. Installation of simple lighting system

- Draw a circuit diagram
- Install all lighting system components as per the diagram

5. Finishing and varnishing SAT

- Painting and décor the body parts
- On road performance test

3.2 System design

3.2.1 Proposed Pedal Bicycle specification

Proposed Pedal Bicycle gives detailed specifications of PB prepared for modification into improved SAT. Mountain model bicycle have been selected for this modification process [16][17].

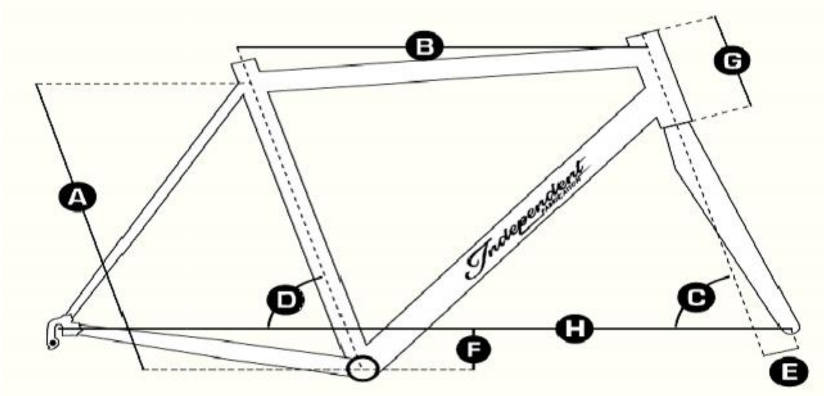


Fig.3.1:Mountain Road Bike Frame

A Size
B Top Tube Length
C Head Tube Angle
D Seat Tube
E Fork Offset
F BB Drop
G Head Tube Length
H Wheel Base

Table.3.1: Specification of Road Bike [16][17][21]

Name	Specification
A Size	44cm
B Top Tube Length	48cm
C Head Tube Angle	71.5
D Seat Tube	73
E Fork Offset	45mm
F BB Drop	48mm
G Head Tube Length	84mm
BB Width	68mm
Rear Axle Spacing	130mm
Chain Stay Length	41.5cm

Seat Post Size	27.2mm

3.2.2 Estimation of solar tricycle weight

One of the requirements is to keep the SAT weight at a minimum. There are practical reasons for keeping the SAT weight at minimum. As more weight is added to the tricycle the power train must overcome larger forces. The forces worth considering which are directly related to the SAT weight are the force of the tires rolling resistance, force of hill climbing and the force of linear acceleration. The weight estimated is given in a table below [17] [20].

Table 3.2 solar tricycle specific components weight

S/N	Item	Weight (Kg)
1	Chassis and body	47
2	Battery	14
3	DC motor	5
4	Solar panel	12
Total		78

3.2.3 Determining the wheel speed

The estimated maximum velocity required at a level road is 30km/hr or 8.33m/s. The given wheel diameter is 0.541m.

$V = r x \omega_{w\ max}$ …………………………………………………………… (3.1)

Where: V is linear velocity of the SAT in m/s

r is the radius of the wheel in meter (m)

$\omega_{w\ max}$ is the wheel maximum angular velocity of the SAT in rad/sec

$N_{w\ max}$ is maximum speed of wheel in rpm

Then $\omega_{w\ max} = \frac{V}{r}$

$$= \frac{8.33}{0.27}$$

$$= 30.8 \text{ rad/sec}$$

$$N_{wmax} = \frac{60 \times \omega w \ max}{2 \times \pi} \quad \ldots\ldots (3.2)$$

$$= \frac{60 \times 30.8}{2 \times \pi}$$

$$= 294.11 \text{ rpm}$$

3.2.4 Estimating DC motor capacity for SAT

Choosing a motor was the first step in creating an appropriate system for the SAT. The project was to be driven by DC motors that were configured to turn a sprocket. The sprocket is used to transmit rotary motion to the wheel. The primary technical consideration defining the motor choices for any particular application are the speed, torque and power required by the load [1][3][5].

3.2.4.1 Determining the required power of the SAT

During the SAT design, some of the most important design parameters to beconsidered are: v_{max}, a_{max}, etc. Such important design parameters can be predicted from tricycle dynamics. For instance, the maximum SAT velocity (v_{max}) is limited by the maximum Power available at the driving wheels ($P_{w\ max}$).
The maximum SAT (a_{max}) is limited by the maximum tractive force ($F_{tr\ max}$) available at the driving wheels. The maximum tractive force in turn depends on the maximum torque available at the driving wheels ($T_{w\ max}$). Power required to drive the SAT depends on rolling resistance of the tire in the road, aerodynamic drag force, inertial resistance in acceleration, gradient resistance and transmission losses etc. A SAT is riding on a level road at a constant V_{max}. Considering a 'one dimensional tricycle dynamics', the tractive and resistance forces: F_{tr}, R_{rl} and R_a can be determined. In this project the overall dimension of improve solar assisted tricycle has been described as shown in the table 3.3 below [8][10][11][13][15].

Table 3.3: dimension of SAT

SAT Dimensions	
Length (**L**)	*2100 mm*
Width (**W**)	*1100 mm*
Height (**H**)	*1500 mm*
Wheelbase (w_b)	*1560 mm*

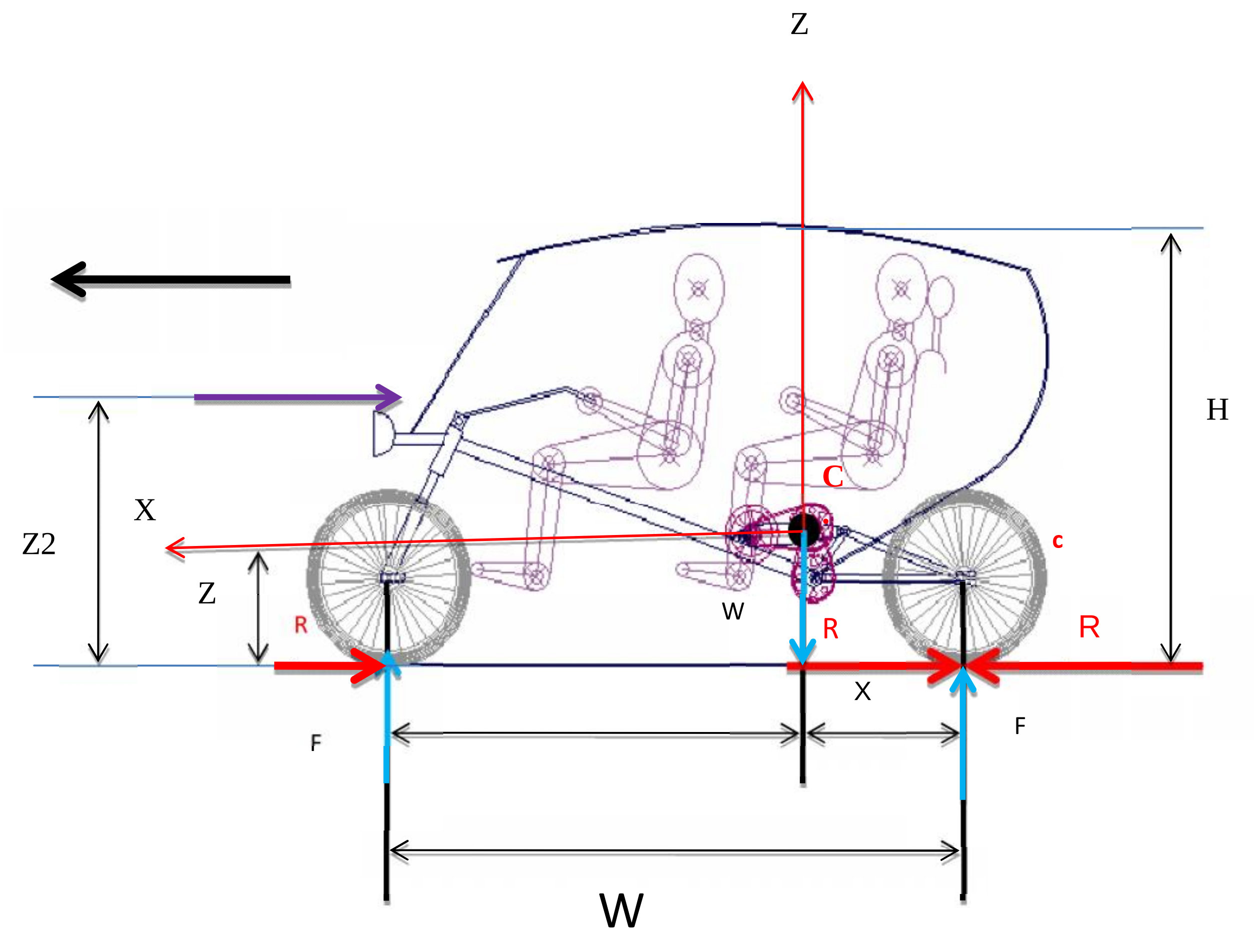


Figure 3.2dimension of the SAT

$P_{rq} = R_t \times V$ … ………………………………………………………..….. (3.3)

Where, P_{rq} is power required in Newton

$R_t$is Rolling resistance of the tire

V is velocity of the SAT in m/s

The power required by wheel at maximum speed was calculated as equation 3.4.

$P_{rq\ @\ vmax} = F_{te} \times V_{max}$……………………………………...…… (3.4)

Where: $P_{rq@\ Vmax}$ is power required at maximum velocity in watt

F_{te} is tractive force in Newton

V_{max} is maximum velocity of SAT in m/s

When the SAT is in equilibrium in an inertial form of reference the vector sum of all forces acting upon the SAT must be zero. Furthermore, according to Newton's first law of motion, a body acted on by zero net forces moves with constant velocity and zero acceleration. By this statement the following is true for non-accelerating object:

$\Sigma F = 0$ ……………………………………………………………..…… (3.5)

Where: Σ F is the sum of all force vectors acting on the object. By implementing the forces acting on the SAT, equation 3.6 is obtained:

$$F_{te} = F_{ad} + F_{rrl} + F_{rrr} + F_{hcn} + F_{la} + F_{\omega a} \text{……………………………….. (3.6)}$$

Where: F_{te} is tractive force,

F_{ad} is force of aerodynamics,

F_{rrl} is force of rolling resistance at left,

$F_{rr\,r}$ is force of rolling resistance at right,

F_{hc} is force of hill climbing,

F_{la} is force of linear acceleration and

$F_{\omega a}$ is force of angular velocity.

It shall be noted that at maximum speed the force of linear and angular acceleration are zero, F_{la} = 0N and $F_{\omega a}$ = 0N, because at constant speed the acceleration is zero. Also the driving surface's gradient at the maximum speed is zero degree 0^{o}. So, equation 3.6 is reduced to:

$$F_{te} = F_{la} + F_{rrl} + F_{rrr} \text{………………………………………………… (3.7)}$$

The force of aerodynamic drag, often referred to as simply air drag, can be described by the following equation:

$$F_{ad} = \frac{1}{2} \times \rho_a \times C_d \times A_{PF} \times V^2 \text{ ……………………………………… (3.8)}$$

Where: ρ_a is density of local air ≈1.225 kg/m^3

C_d is coefficient of drag = 0.3

A_{FP} is the Projected Frontal area in m^2

$$A_{PF} = SF \times W_2 \times H \text{ ………………………………………………… (3.9)}$$

Where: SF is safety factor approximately 0.75 to 0.85. In this project 0.8 was selected.

W is width of SAT = 1.1m

H is height of SAT = 1.45m

$A_{PF} = 0.75 \times 1.1 \times 1.45 = 1.196\text{m}^2$,in volume

$F_{ad} = \frac{1}{2} \times 1.225 \times 0.3 \times 1.196 \times 8.33^2 = 15.25\text{N}$

The rear force of rolling resistance (Frr) at left and right side depends on the SAT weight, tires characteristics and the gravitational constant.

$$Frr = Frrl + Frrr = mg\,\mu_{rr} \text{ … … …… … … … … … … … … … … … (3.10)}$$

Where: m is mass of SAT including driver and two passengers,

g is gravitational constant and

μ_{rr} is coefficient of friction = 0.02 [design book]

$$F_{rr} = 268 \times 9.81 \times 0.02 = 52.58\text{N}$$

F_{te} = 15.25 + 52.58= 67.83N
P_{rq} @V_{max}= 67.83 × 8.33= 565 Watt
$P_{w\ max}$ = P_{rq} @V_{max}= 565Watt

$$P_{m\ max} = \frac{Pwmax}{\eta t} \quad (3.11)$$

Where: Pm max is maximum power required from DC motor,
Pw max is maximum power required at the drive wheel and
η_t is transmission efficiency approximately 90%

$$P_{m\ max} = \frac{565}{0.9}$$
$$= 627 \text{ Watt} = 0.627\text{kW}$$

Therefore, in this project the maximum power required from DC motor to drive the SAT on a level road at maximum velocity of 30km/hr is approximately 0.627kW. Now in order to select the DC motorthat meet the functional requirements and the design parameters power, torque and speed of the DC motor was calculated.

3.2.4.2 Determining DC motor speed

Maximum angular velocity $\omega_m$is achieved when no load is applied.

$$\omega_m = \frac{Eb}{Kb} \quad (3.12)$$

Where, $\omega_m$is maximum angular velocity in rad/sec
$E_b$is back electromotive force in volt
K_b is back electromotive force constant in V/rad/sec
For the required DC motor in this project the back electromotive force constant (K_b) given by the manufacturer is 0.123 V/rad/sec[1][19].

$$E_b = V - I_a \times R_a \quad (3.13)$$

Where, V is supplied voltage to DC motor from the battery in volt
$I_a$is armature current in ampere
R_a is armature resistance in ohms
To determine maximum current flow to the armature the following equation is used [19]:

$$P_{in} = P_{dev} + P_l \quad (3.14)$$

Where P_{in} is power input from the battery in Watt
$P_{dev}$is maximum power developed in Watt
P_l is power loss in armature

$$V \times I_a = P_{dev} + I_a^2 \times R_a \quad (3.15)$$

$V \times I_a = P_{dev}$ + percentag of loss$\times P_{dev}$……………………………………. . (3.16)

In this project, since the maximum power required from DC motor is 565 Watt, minimum efficiency required is 80%, so maximum power loss is 25%, the armature resistance is 0.20 Ωand battery voltage is 24V then equation 3.16 becomes:

$$24 \times I_a = 627 + 0.25 \times 627$$

$$I_a = \frac{783.75}{24}$$

$$= 32.65A$$

The maximum current required by DC motor to obtain maximum power was 32.65A.
Then E_b was calculated as equation 3.13 as follow:

$$E_b = 24 – 32.65 \times 0.20$$

$$= 17.47V$$

Finally the no load maximum angular velocity was calculated as equation 3.12 as follow:

$$\omega_m = \frac{17.47}{0.12}$$

$$= 145.58 \text{ rad/sec}$$

Maximum no load revolution per minute ($N_{m\,max}$) was calculated as follow:

$$N_{m\,max} = \frac{\omega X\ 60}{2\pi}$$

$$= \frac{145.58\ X\ 60}{2\pi}$$

$$= 1390 \text{ rpm}$$

Determining gear ratio of motor and large sprocket of SAT

The gear ratio of a chain drive is given by:

$$G_r = \frac{N1}{N2} \quad \text{……………………………………………………………} (3.17)$$

Where N_1= speed of rotation of smaller sprocket in rpm
N_2= speed of rotation of larger sprocket in rpm[19][23].

$$G_r = \frac{N1}{N2} = \frac{1390}{294} = \frac{4.73}{1}$$

$$= 4.73 \approx 5:1$$

3.2.4.3 Determining the torque of DC motor

In order to compute the electric torque to be generated by the motor to start the SAT from rest, first it needs to calculate the total force exerted by the system on the motor**.**
In this modification straight movement was only considered without giving a consideration of moving up a hill (neglecting the horizontal components of gravitational force)[1][15].

The total force on the SAT at rest is the friction force F_f which can be determined as:

$F_f = \mu mg$ ……………………………………………........ (3.18)

Where, μ is the coefficient of friction

m is mass of the tricycle

g is gravitational acceleration

The distance from the center of the turning axis to the outside of the wheel is the radius of the wheel. The total wheel torque required to start the SAT is given by:

$T_w = F \times r$ …………………………………………………….. (3.19)

$= \mu mgr$

Where: r is radius of the tire = 0.29m

μ is coefficient of friction = 0.20 [for Asphalt road from design book]

T_w is the wheel torque

$T_w = \mu mgr$

$= 0.20 \times 268 \times 9.81 \times 0.29$

$= 152.48$Nm

The torque required by the DC motor to start the Solar Tricycle from rest is:

$T_m = T_w \text{ x } \eta t \text{ x} \frac{T1}{T2}$……………………………………………… (3.20)

$T_m = 152.48 \text{ x } 0.9 \text{ x } 1/5$

$T_m = 27.446$Nm

3.2.4.4 The selected brushless DC motor specification for SAT

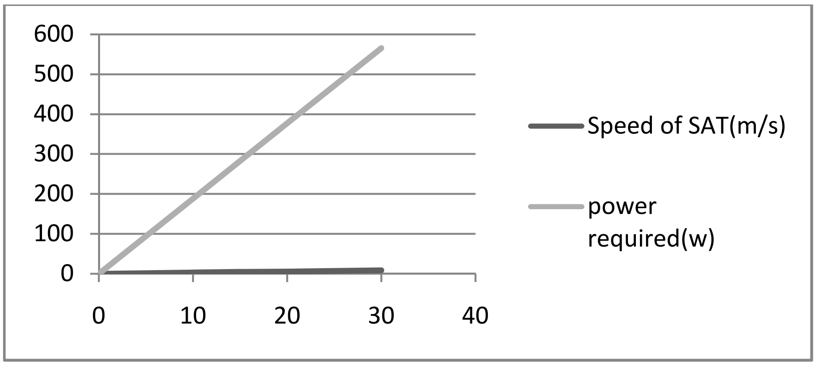
The Table 3.4 shows specification for the DC motor. The specification describes the technical characteristics of DC motor and used in estimation of battery capacity as well as controller selection [15][19].

Table 3.4 Specification for selected DC motor

Parameters	Specification
DC motor type	Brushless DC motor
Maximum power output	0.627kw @ 1390 rpm
Minimum peak torque at start	27.44Nm
Maximum speed	1390 rpm
Maximum voltage	24V
Maximum current	32A
Minimum Efficiency	80%

Table .3.5: powers required for driving the SAT at different speed

Speed of SAT(km/h)	Speed of SAT(m/s)	power required(w)
0		0
10	3.33	188.33
20	5.5	376.66
30	8.33	565



Graph.3.1**:** Speed Vs. power required of SAT

3.2.5 Determining Battery capacity of SAT

The battery chosen for this project was a high capacity lead acid battery pack designed specifically for solar tricycle [19].

The power required from battery by DC motor was calculated as equation 3.2.

$$P_{batt} = \frac{P_{m\,max}}{\eta_m} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . (3.21)$$

Where, P_{batt} is power required from battery

$P_{m\,max}$ is maximum power of DC motor

η_m is DC motor efficiency

$$P_{batt} = \frac{627}{0.80}$$

$$= 783.75 \text{Watt}$$

The power required by DC motor from battery is 783.75 Watt, but there is a lighting system accessory such as head, tail, brake and turn signal lights. By assuming power required by lighting accessories (P_l) is 50 Watt, therefore, maximum power required from battery is the sum of P_{batt} (783.75 Watt) and P_l (50 Watt) which is equal to 833.75 Watt required from battery to operate the solar tricycle [4].

a. Determining battery voltage

A common nominal voltage of battery modules is 12V, 24V, 36V, 48V, and 60V.For better energy storage and cost nominal voltage of 24V was selected. Also the nominal voltage of 24V is the vehicles technology and industry's preferred standard voltage for the solar and electric tricycles [11]. To obtain 24V nominal voltages with Lead acid cells that are rated 12V requires 2 batteries to be connected in series. Each battery is rated with maximum discharge current according to capacity rating [4][19].

b. Determining battery capacity rate of SAT

As mentioned above, a battery can be both charged and discharged at various rates i.e., the current level, which in turn determines how long the charging takes and how long the discharging lasts. These rates are usually specified in terms of the capacity rate. Not surprisingly a discharge rate of 1C means that the battery is discharged at the same rate as its nominal capacity, so at this rate it takes one hour before being nominally discharged. Discharging the battery at a lower rate will allow it to do so for a longer time [8, 16].
In order to determine battery C rate battery current and discharge time should be solved first.

$$P_{batt} = V_{batt} \times I_{batt} \quad (3.22)$$

Where V_{batt} is battery nominal voltage

I_{batt} is battery current

$$I_{batt} = \frac{Pbatt}{Vbatt}$$

$$= \frac{833.75}{24}$$

$$= 34.7A$$

To operate DC motor and other electrical accessories at maximum power battery should supply continuously 34.7A current. One of this project scopes is to drive the SAT with fully charged battery for 30km. By assuming that the average person driving velocity of SAT in City is 20km/hr, in order to meet this requirement battery should deliver or discharged continuously for 2 hours. In order to prolong the life of the battery it is recommended to operate the battery using only 60% of its capacity [8][21]. Therefore the minimum capacity of the battery is determined by dividing the required capacity by a factor of 0.6

$$C_{rate} = \frac{Ibatt \ X \ Tdis}{0.4} \quad (3.23)$$

Where: C_{rate} is battery capacity rate

$$C_{rate} = \frac{34.7 \ X \ 1}{0.6}$$

= 57.83Ahr

Ampere hour capacity is the amount of current that a battery can deliver for 6 hours without the cell voltage dropping below 1.75 volts with an electrolyte temperature 80^0F [16][17]. Therefore, to determine the required ampere hour capacity equation (3.24) below is used.

$$\text{Ampere hour capacity} = \frac{\text{Crate}}{6} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.24)$$

$$= \frac{61.53}{6}$$

$$= 10.225\text{Ahr}$$

In this project by considering availability of material and better energy storage 15Ahr capacity lead acid batteries were selected.

Table 3.6: Specifications of lead acid Battery [7]

Type of Battery	Sealed Lead Acid
Size (l× w × h)	210×140×356 mm.
Number of Batteries	Two Batteries connected in series
Voltage	12 V
Amp-Hour Rating	61.53 Ah
Battery current	36.92A
Standby Battery Voltage	25.4 V

3.2.6 Determining solar panel capacity for SAT

The battery system stores the electric energy and must be rechargeable by an external power source. The battery charger is a converter that draws high power factor alternative current from a sun light. Battery chargers come in various forms depending on the charging method and battery type. The charger shall be equipped with safety detection circuits that prevent faults such as over voltage, too high charging rate and overcharging. The charger must also be able to detect and cut off charging when the battery is fully charged [8, 16].

A. **Solar cell characteristics**

There are three type of solar panel that available in commercial, these solar panel classified by their characteristics and working efficiency as shown in the figure 3.3(1, 2 and 3)

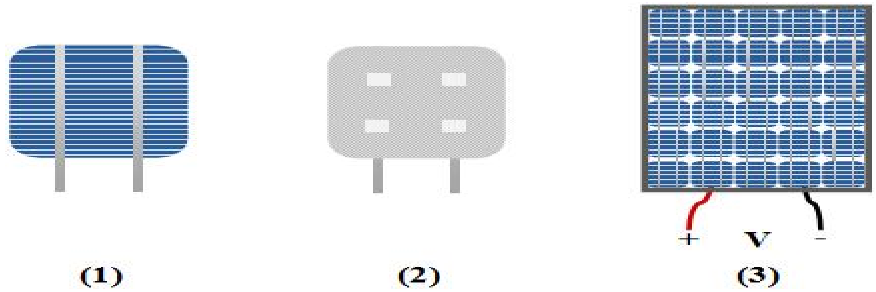


Figure 3.3: Example of mc Si or sc Si cell and panel.

1) **Front of solar cell:** Horizontal stripes collect the current and minimizes the resistance and are connected to bus bars (vertical), used for connection to other cells.
2) **Back of cell:** Square contact points are used to connect bus bars from previous cell.
3) **Panel layout:** All cells connected in series [8][16].

B. Solar System Calculation and Design

Solar panel (PV) is a device which can convert energy from light energy (proton) to electrical energy. Each panel is rated by its DC output power. Solar panels are normally 12V DC output. In large solar panel24V or 48V DC output also seen. For our project we have been selected 24V volts for higher efficiency [8][16].

C. To calculate the solar system we have to measure

In this project we wants to setup a solar system for 627 watt DC motor (12 volt DC) and other accessories about 50 watt, then the total load is about 677 watt, we need to have 2 hours back up time.

Then total load (2hour × 677watt) = 1354 (watt per hour)

To measure the battery ampere for the above load.

Volt = 24 V

I =56.4 AH

Thus, Battery is needed 24 volt, 56.4 AH.

Now to calculate the solar panel:

Gene rally a battery charging current = 50% of its AH

Charging current = 28.2 A

Solar panel needed = 1.4 A 24 V

= 676.8 watt

In this project we have been selected the solar panel that has 676.8 watt capacity and we recommended the charge controller is 24 Volt, 28.2 Amp

D. **Efficiency of Solar panel:**

Output power is the power we get from solar panel. Input power is the light fall in solar panel. To increase our efficiency of solar panel we recommended like fig.3.4: solar panel . The light comes from sun in earth surface is $1M^2$=1KW.It means from $1m^2$ space we could get maximum 1KW energy [14] [15][17]. Our solar panel surface area is 1.76 $m^{2,}$

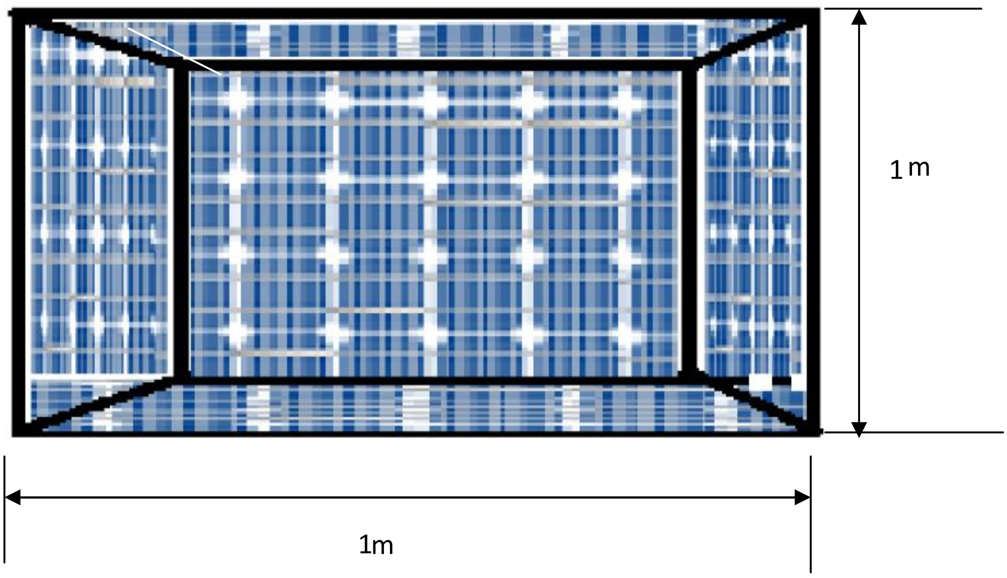


Fig .3.4: solar panel size

Where, $1m^2 = 1kw$

$1.76m^2 = 1760w = 1.76kw$

So that, our solar panel deliver 1760 Watts power from the surface area of solar panel 1.76 m^2 then the efficiency of solar panel is

Efficiency = $\frac{676.8}{1760}$ x 100

Efficiency = 38.45%

E. **Solar Panel Specification**

In this project we have been described the selected solar panel specification as shown in the table 3.7 below.

Table 3.7: Specifications of Solar Cell [5]

Maximum Power	700 (Watt)
Charging Current (Amp)	28.2
Open Circuit Voltage (V)	22
Max Power Voltage (V)	24
Short Circuit Current	1.316
Power Measured at Standard Test Condition	1000 w/m2
Size	1.76 m^2
Lifespan	15

3.2.7 Control system design

To drive and control the BLDC motor, the use of a motor controller was implemented. The motor controller is an essential device for any motor driven device. The motor controller is analogous to the human brain, processing information and feeding it back to the end user. Of course, the applications of a motor controller vary based on the task that it will be performing. One of the simplest applications is a basic switch to supply power to the motor, thus making the motor to run. As one utilizes more features in the motor, the complexity of the motor controller increases. The control system design comprises PB start and stop design, SAT speed control design and power transmission system design [8][16].

A. Motor controller selection

The motor controller is designed to control the electrical energy obtained from the batteries to drive the motor depending on the signal from the driver. The motor controller used in the SAT is designed to control DC motor speed [11]. Motor controller performs the complex task of deciding how much current actually reaches the motor at a given time. This determination of current by the motor allows the SAT to accelerate, decelerate, or stay at a constant speed [3]. The motor controller of an EV must be matched to the voltage and type of motor being controlled so logically. The motor's speed is regulated by the amount of voltage sent to it by the controller according to input provided by the throttle mechanism. This input is then sent to the motor as a series of pulses to represent the corresponding percentage of throttle being applied ranging from 0% (none) to 100% (full). The motor controller selected for this project was shown in figure 3.5 below [11].

Fig 3.5: Electric DC motor controller

In this project we have been described the selected motor controller specification as shown in the table 3.8 below.

Table 3.8: Specification of motor controller [5]

System voltage (V)	24
Max. load output current	30
End of charge voltage (V)	24
Boost charge voltage (V)	27
Ambient temperature (ºC)	0-50

For this project the controller was specified with 24V, 32A, 5 terminals and specially designed for SAT. When the accelerator handle not twisted the switch would be turned “off” and no current would be fed into the motor [8][16].

F. Tricycle speed control (Accelerator/throttle)

To control the current supplied to the DC motor potentiometer is designed to give a signal to a motor controller.

In this design the SAT speed is controlled by varying the excitation current of the motor by twisting the throttle handle to turn the potentiometer from zero to maximum position and releasing the throttle (the return spring of the throttle handle return it into free position) to return the potentiometer from its maximum to zero position. In this project we have been described the selected acceleration or throttle specification as shown in the table 3.9 below.

Table .3.9: Specifications of Accelerator/throttle [5]

Supply Voltage (V)	24
Return Voltage (V)	4
Max. load output current (A)	25
Handle Bar Diameter(mm)	22
Three wires red, green, black	install for 12v and 24v supply

3.2.8 Power transmission component design

The power transmission system is that a part of the SAT, which transmits mechanical energy to the traction wheel causing the SAT to move. In the case of SAT power is transmitted from DC motor to the rear wheel. While doing so, it makes the wheel to spin and moves passenger from one place to other.
There are different ways to transfer power from the motor to the wheels. Some of the popular techniques are belt drive; gear drive and chain drive [23][24].In this project, chain drive system has selected due to its advantages and it's commonly used in motorcycle to transmit power to the rear wheel.

3.2.11.1 Sprocket and chain drive overview

The normal function of a chain sprocket is not only to drive or be driven by the chain, but also to guide and support it in its intended path [23][24].
Belt drives may lead to slipping. In order to avoid slipping steel chain are used .projecting teeth of special profile and fit into the corresponding recesses in the links of the chainas shown in figure 3.6: The toothed wheels are known as sprocket wheels or simply sprockets. The sprocket and the chains are thus constrained to move together without slipping and ensures perfect velocity ratio [23].

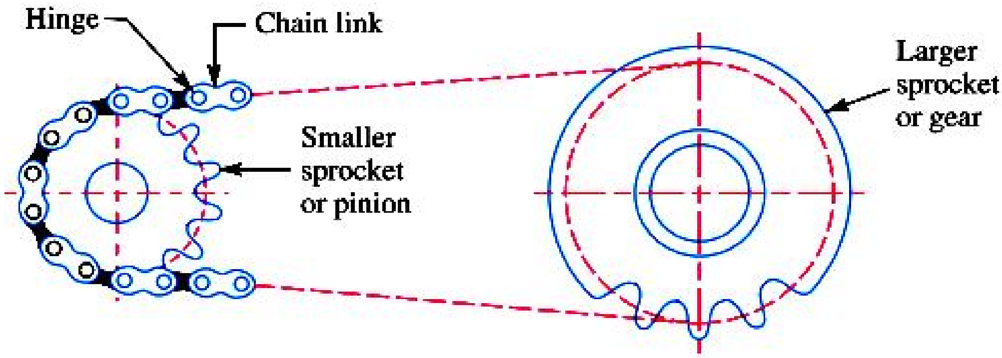


Figure 3.6: Sprocket and chain

In this project, due to the above stated advantage of chain over the others it was selected to transmit motion from DC motor to rear drive wheel.
One piece sprockets type was selected in this project due to its most availability in the market and lowest in cost when compared with other types of sprockets.

3.2.11.2 Relation between pitch (p) and pitch circle diameter (D)

Pitch of chain is the distance between the hinge center of a link and the corresponding hinge center of the adjacent link. Pitch circle diameter of chain sprocket is the diameter of the circle on which the hinge centers of the chain lie, when the chain is wrapped round a sprocket. As the link of the chain is rigid, pitch of the chain does not lie on the arc of the pitch circle [23]. Figure 3.7 illustrates the relation between pitch and pitch circle diameter.

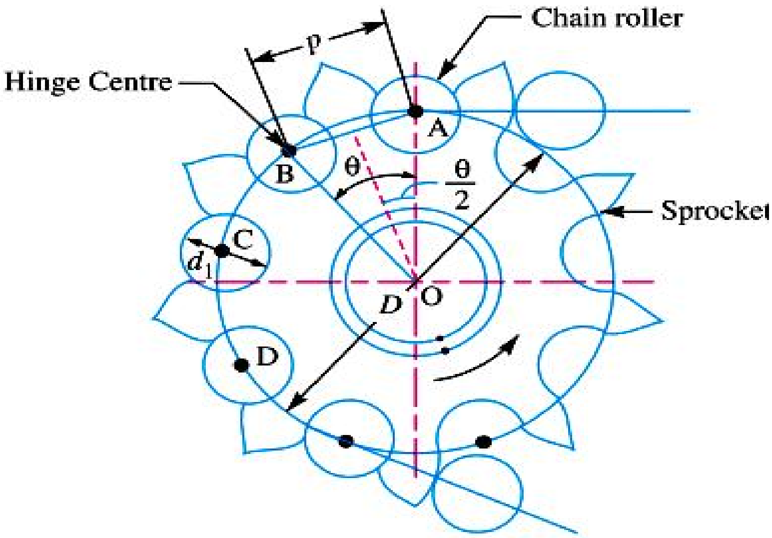


Figure 3.7: Chain wrapped around a sprocket

3.2.11.3 Chain drive design

The tooth form of a sprocket is derived from the geometric path described by the chain roller as it moves through the pitch line, and pitch circle for a given sprocket and chain pitch. The shape of the tooth form is mathematically related to the chain pitch (P), the number of teeth on the sprocket (N), and the diameter of the roller (d1) [23].

Consider one pitch length AB of the chain subtending an angle θ at the center of sprocket or pitch circle shown in figure 3.6:

Let D = Diameter of the pitch circle

T = Number of teeth on sprocket

The pitch of chain can be obtained by:

$$P = AB = 2AO\sin\left(\frac{\theta}{A}\right)$$

$$= 2X\frac{D}{2}\sin\left(\frac{\theta}{A}\right)$$

$$= D\sin\left(\frac{\theta}{A}\right)$$

Where, $\Theta = \frac{360}{T}$

$$D\sin = \frac{360}{2T}$$

$$D\sin = \frac{180}{T}$$

The sprocket outside diameter (Do), for satisfactory operation is given by:

$$Do = D + 0.8d1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (3.27)$$

Where; d1 is diameter of the chain roller

The angle $\frac{\theta}{2}$ through which the link swings as it enters contact is called angle of articulation.

A. Selection of sprocket materials

Choice of material and heat treatment will depend upon shape, diameter and mass of the sprocket. Table 3.8 can be used as a simple guide to the correct selection of sprocket material [23][24]. In this project, since the number of teeth of sprocket used was more than 30 and there is moderate vibration, so mild steel was selected for sprocket gears.

B. Determining the reference diameter of driver sprocket

Determination of chain speed for the driver sprocket on grounds of sprocket revolution is based on the formula in equation 3.28[24] or [24, p 6].

$V = \frac{Ds \; X \; N}{12100}$ ……………………………………….. (3.28)

Where V = Speed of chain in m/s

DS = Driver sprocket or smaller sprocket reference diameter in mm

N = Driver sprocket revolution in Rpm

Finally, the required driver sprocket reference diameter can be derived from the shaft revolution and chain velocity:

$$D_S = \frac{V * 12100}{N}$$

$$Ds = \frac{8.33 \; x \; 12100}{1390}$$

Ds = 72.51 mm or 7.51 cm, it is the actual diameter of the driver sprocket or small sprocket

C. Determining the reference diameter of driven sprocket

The required driven sprocket reference diameter (D_L) can be derived from the velocity ratio of achain drive (VR) and driver sprocket reference diameter (D_S)[11] [24]:

$D_L = D_S \times VR$ ……………………………………………………………….. (3.29)

$= 72.51 \times 4$

$= 290$ mm

In this project according to the numerical analysis of the design, the diameter of the pitch circle of the smaller sprocket (D_S) and the larger sprocket (D_L) are 72.51 mm and 290 mm respectively.

D. Determining the number of teeth of sprockets

The table 3.10 allows for determining the sprocket's number of teeth on the basis of the desired gear ratio. The sprocket's number of teeth can be determined by means of the table 3.10 hereunder and the gear ratios matching the chosen number of teeth can be determined directly [23].

In this project, the number of teeth was selected based on the table 3.9, for gear ratio of 5 the driven sprocket number of teeth (TL) is76 and driver sprocket number of teeth (TS) is 16 [13].

Table 3.10: Gear ratio and the teeth number of the sprockets

Driven sprocket no. of teeth	Driving sprocket number of teeth												
	13	14	15	16	17	18	19	20	21	22	23	24	25
13	1.00												
14	1.08	1.00											
15	1.15	1.07	1.00										
16	1.23	1.14	1.07	1.00									
17	1.31	1.21	1.13	1.06	1.00								
18	1.38	1.29	1.20	1.13	1.06	1.00							
19	1.46	1.36	1.27	1.19	1.12	1.06	1.00						
20	1.54	1.43	1.33	1.25	1.18	1.11	1.05	1.00					
21	1.61	1.50	1.40	1.31	1.23	1.17	1.10	1.05	1.00				
22	1.69	1.57	1.47	1.38	1.29	1.22	1.16	1.10	1.05	1.00			
23	1.77	1.64	1.53	1.44	1.35	1.28	1.21	1.15	1.09	1.04	1.00		
24	1.85	1.71	1.60	1.50	1.41	1.33	1.26	1.20	1.14	1.09	1.04	1.00	
25	1.92	1.79	1.67	1.56	1.47	1.39	1.32	1.25	1.19	1.14	1.09	1.04	1.00
26	2.00	1.86	1.73	1.63	1.53	1.45	1.37	1.30	1.24	1.18	1.13	1.08	1.04
27	2.08	1.93	1.80	1.69	1.59	1.50	1.42	1.35	1.29	1.23	1.17	1.12	1.08
28	2.15	2.00	1.87	1.75	1.65	1.56	1.47	1.40	1.33	1.27	1.22	1.17	1.12
30	2.31	2.14	2.00	1.88	1.76	1.67	1.58	1.50	1.43	1.36	1.31	1.25	1.20
32	2.46	2.28	2.13	2.00	1.88	1.78	1.68	1.60	1.52	1.45	1.39	1.33	1.28
35	2.69	2.50	2.33	2.19	2.06	1.95	1.84	1.75	1.67	1.59	1.52	1.46	1.40
36	2.77	2.57	2.40	2.25	2.12	2.00	1.89	1.80	1.71	1.63	1.57	1.50	1.44
38	2.92	2.72	2.53	2.48	2.24	2.11	2.00	1.90	1.81	1.73	1.65	1.58	1.52
40	3.08	2.86	2.67	2.50	2.35	2.22	2.10	2.00	1.90	1.82	1.74	1.67	1.60
42	3.23	3.00	2.80	2.63	2.47	2.34	2.21	2.10	2.00	1.91	1.83	1.75	1.68
45	3.46	3.21	3.00	2.81	2.65	2.50	2.37	2.25	2.14	2.04	1.96	1.88	1.80
48	3.69	3.43	3.20	3.00	2.82	2.67	2.52	2.40	2.28	2.18	2.09	2.00	1.92
52	4.00	3.71	3.47	3.25	3.06	2.89	2.74	2.60	2.48	2.36	2.26	2.17	2.08
54	4.15	3.86	3.60	3.38	3.18	3.00	2.84	2.70	2.57	2.45	2.35	2.25	2.16
57	4.38	4.07	3.80	3.56	3.35	3.16	3.00	2.85	2.71	2.59	2.48	2.38	2.28
60	4.61	4.28	4.00	3.75	3.53	3.34	3.16	3.00	2.86	2.72	2.61	2.50	2.40
68	5.23	4.86	4.54	4.25	4.00	3.78	3.58	3.40	3.24	3.09	2.96	2.84	2.72
70	5.38	5.00	4.67	4.38	4.12	3.89	3.68	3.50	3.33	3.18	3.05	2.92	2.80
72	5.54	5.14	4.80	4.50	4.24	4.00	3.79	3.60	3.43	3.27	3.13	3.00	2.88
76	5.84	5.43	5.07	4.75	4.47	4.23	4.00	3.80	3.62	3.45	3.31	3.17	3.04
80	6.15	5.71	5.34	5.00	4.70	4.45	4.21	4.00	3.81	3.63	3.48	3.34	3.20
84	6.46	6.00	5.60	5.25	4.94	4.67	4.42	4.20	4.00	3.81	3.65	3.50	3.36
95	7.31	6.78	6.33	5.94	5.59	5.28	5.00	4.75	4.52	4.32	4.13	3.96	3.80
114	8.78	8.15	7.60	7.13	6.72	6.35	6.00	5.70	5.43	5.18	4.95	4.75	4.56

E. Determining the pitch of sprocket

The pitch of smaller sprocket (Ps) was:

$$P_s = D_s \sin\left(\frac{180}{T_s}\right) \ldots \qquad (3.30)$$

$$= 72.51\text{mm} * \sin\left(\frac{180}{16}\right)$$

$$= 14.14\text{mm}$$

A standard for the pitch was given in table 3.10, so, for this project pitch of 12.70mm was selected from this table to match the designed sprockets.

F. Determining the outside diameter of sprockets

$$D_{OS} = D_S + 0.8d_1 \qquad (3.31)$$

Where d_1 is diameter of the chain roller = 7.2mm

$D_{OS} = 72.51 + 0.8 \times 7.2$

$= 78.27mm$

The outside diameter of the larger sprocket (D_{OL}) was:

$$D_{OL} = D_L + 0.8d_1 \qquad (3.32)$$

$= 290 + 0.8 \times 7.2$

$= 295.76mm$

G. Determining length of chain and center distance

For optimum wear life, center distance between two sprockets should normally be within the range 30 to 50 times the chain pitch [23] [24].

Recommended center distances of chain drive along the drive small sprocket and large sprocket can be found as shown in table 3.11 [24].

Table 3.11 Standard center distances for chain drives [23][24]

Pitch	Inch mm	3/8 9.525	1/2 12.70	5/8 15.87	3/4 19.05	1 25.40	1 1/4 31.75	1 1/2 38.1	1 3/4 44.45	2 50.80	2 1/2 63.50	3 76.20
Centre distance	mm	450	600	750	900	1000	1200	1350	1500	1700	1800	2000

In this project, depending on the space available in motorcycle and selected pitch 600 mm center distance (X) was selected from table 3.11.

An open chain drive system connecting the two sprockets is shown in figure 3.8 below.

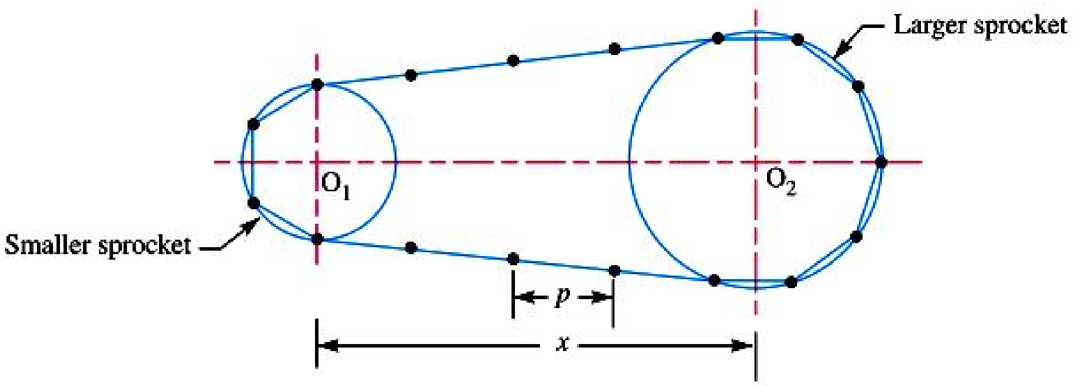


Figure 3.8: Length of chain

T_1 = Number of teeth on the smaller sprocket
T_2 = Number of teeth on the larger sprocket
P = Pitch of the circle and
X = Center distance
L = length of chain
The length of chain must be equal to the product of the chain links (K) and the pitch of the chain.
L = K x P ………………………………………………………………………….. (3.33)
The number of chain links can be obtained from the following expression, i.e.

$$K = \frac{T1 + T2}{2} + \frac{2X}{P} + \left[\frac{T2 - T1}{2л}\right]\left[\frac{T2 - T1}{2л}\right]\frac{P}{X} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.34)}$$

$$K = \frac{16 + 76}{2} + \frac{2 * 25}{14} + \left[\frac{76 - 16}{2л}\right]\left[\frac{76 - 16}{2л}\right]\frac{14}{25}$$

The value of K as obtained from the above expression must be approximated to the nearest evennumber. So the number of chain links is 101mm.
In this project the number of chain links and pitch of the chain are 116 and 12.70mmrespectively.
The length of chain (L) was:

L = L × P

= 101 X 14
= 1414mm

H. Factor of safety (FS) for chain drives:

The factor of safety for chain drive is defined as the ratio of the breaking strength (W_b) of thechain to the total load on the driving side of the chain (W).

FS = $\frac{W_b}{W_l}$ ……………………...3.35

The breaking strength of the chain may be obtained by the following empirical relations [32],
W_b= 101 P^2in Newton for roller chains
= 106 P in Newton per mm width of chain for silent chains
Where, P is the pitch in mm.
The breaking strength (W_b) of the roller chain in this project was:

W_b= 106 P^2 = 101 × 14^2
= 19796 N
= 19.796kN

The total load on the driving side of the chain is the sum of tangential driving force (F_T),centrifugal tension in the chain (F_C) and the tension in the chain due to sagging (F_S).

$W = F_T + F_C + F_S$ …………………………………………..……………..(3.36)

Tangential driving force acting on the chain was:

$$F_T = \frac{\text{Power tranmsimited}}{\text{Speedofchain}} = \frac{P}{V} \quad (3.37)$$

Where, V Speed of chain

P Power transmitted

$$F_T = \frac{P}{V} = \frac{627W}{8.33} = 75.27\text{N}$$

Centrifugal tension on the chain was:

Where, FC is centrifugal force of chain

m is mass of chain in kg/m length

$FC = mV^2$ ……………………………………………………………… (3.38)

$= 1.2 \times 8.33^2$by assuming mass of chain is 1.2 kg

= 83.26 N

Tension in the chain due to sagging was:

$F_S = K \times mg \times X$ ……………………………………………………….. ……..(3.39)

Where m = mass of chain in kg/m length

X = Center distance in meter

K = Constant which takes into account the arrangement of chain drive

Take, 2 to 6 when the center line of the chain is inclined to the horizontal at an angle of less than 40^0 [23].

Take, 1 to 1.5 when the center line of the chain is inclined to the horizontal at an angle of greater than 40^0 [13].

$F_S = 4\times 1.2 \times 9.81 \times 1.5$ by taking value of K = 4

= 70.63 N

Then, the total load on the driving side of the chain (W) was calculated as equation 3.36 [7].

= 83.26 + 75.65 + 70.63

= 229.56**N**

Hence, Factor of safety (FS) = $\frac{19796}{229.56N}$

= 86.23N

I. Power transmitted by chains

The power transmitted by the chain on the basis of breaking load is given by equation 3.40.

$$P = \frac{WbXV}{FSXKs} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.40)$$

Where, P is power transmitted by chain drive in watt

W_b= breaking load in Newton's,

V = velocity of chain in m/s,

FS = factor of safety and

K_S = service factor = $K_1 \times K_2 \times K_3$. The values of these factors are taken as follows:

Load factor (K_1) for constant load = 1

Lubrication factor (K_2) for continuous lubrication = 0.75

Rating factor (K_3) for 8 hrs per day = 1

So, $K_S = 1 \times 0.75 \times 1 = 0.75$

The power transmitted by the chain on the basis of breaking load for this project was:

$$P = \frac{WbXV}{FSXKs}$$

$$= \frac{19796 \text{ X } 8.33}{86.23 \text{ X } 0.75}$$

= 2549.78 watt

In this project the maximum power to be transmitted by chain (1390 Watt) is less than the power transmitted by the chain on the basis of breaking load (2549.78 Watt), so the designed sprocket and chain transmit the required power without breakage [24].

3.2.12 Design of drive Shaft

A shaft is a rotating machine element which is used to transmit power from one part to another.

In case of this project the drive shaft was used to transfer the rotation of DC motor to wheel shaft through the tensioned chain by means of sprocket that fitted on it and designed shaft was carried load and two spinning wheels show fig 3.9: [23].

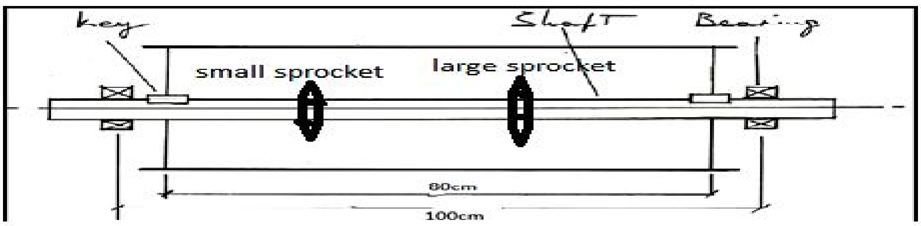


Fig. 3.9: design of drive shaft with two sprockets

The shaft transmits 0.76kW at 1390 rpm to the wheel via large sprocket drive. The torque (T) on the shaft can be obtained as,

$$T = \frac{60 \ x \ P}{2\pi N} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (3.41)$$

$$= \frac{60 \ x \ 627}{2\pi x \ 347.5} =$$

$= 17.33 = 17.33 \ K_L$

Where P = power on wheel shaft and

k_L= load factor

= 1.58 [design book]

T = $17.33 \times 1.58 = 27.38$Nm = 27,380 Nmm

As our project recommendation, material for the shaft to be use

SAE = 1030 [32]

S_{ut} = 527Nm

S_{yt} = 296 Nm

Where; S_{ut} is ultimate strength

S_{yt} is yield strength

For solid shaft:

$T_{max} < 0.3S_{yt}$

= 0.3 × 296 = 88.8 MPa or

$T_{max} < 0.18S_{ut}$

= 0.18 × 527 = 94.86 MPa

Where: τ is tensional shear stress, Consider minimum value of

τ_{max} = 88.8 N/mm2 (without key way)

τ_{max} = 88.8 × 0.75 = 66.6N/mm (With key way)

$$D^3 = \frac{16 \ xT}{\pi X \tau} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(3.38)$$

$$= \frac{16 \ x \ 28{,}380\text{Nmm}}{\pi \ X \ 88.8 \ Nmm2}$$

D =1638.4557mm^3

D = 11.789mm

Considering bending stress develop on a shaft therefore diameter of shaft will be increased by 50%

d=11.789±1.5

d=17.68mm

d=18mm (standard diameter for design data book page no:-182)

d=18mm

Therefore diameter of designed shaft is 18mm

Shear force and bending moment diagrams along shaft**,** given the distribution of shear forces, being equal and opposite, between the bearings and the keys the moment along the shaft is maximum and constant, from one keyway location to the other while numerical relation of shear force and bending moment described as shown in figure 3.10:[23][24].

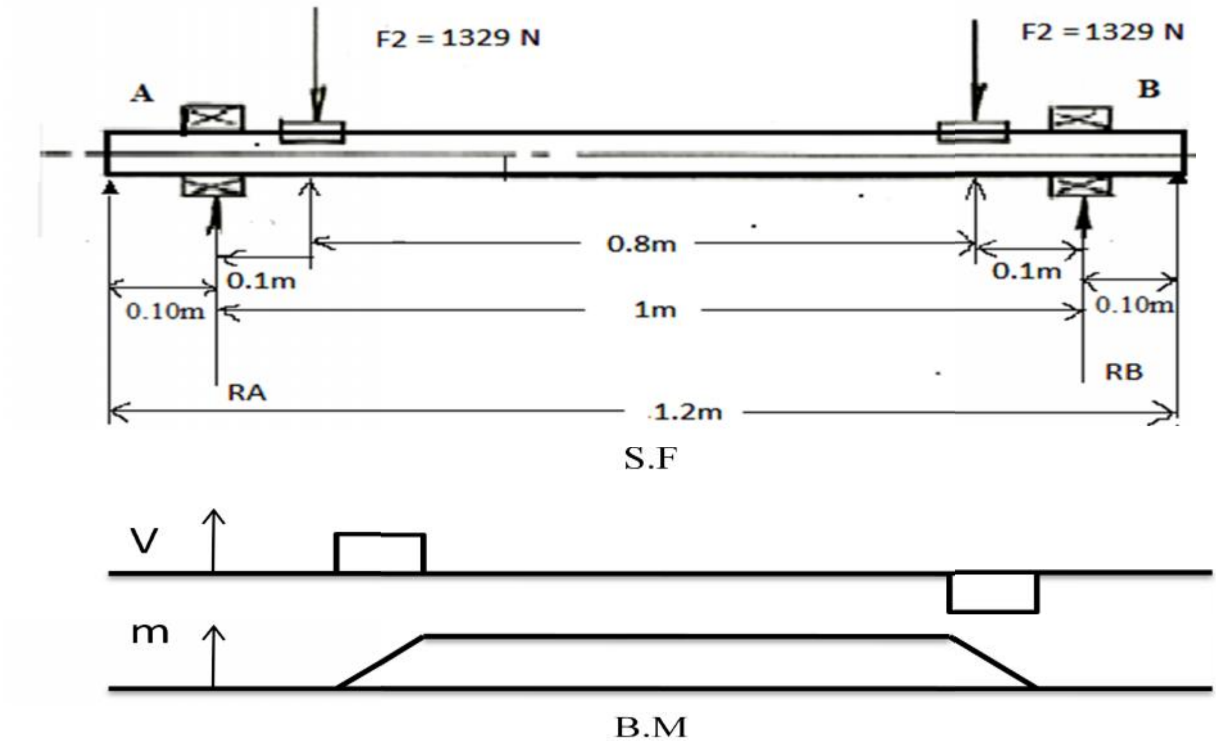


Fig. 3.10: shear force and bending moment of designed shaft

Let R_A and R_B=Reactions at A and B respectively

$R_A + R_A$= total load acting downwards at F_1 and F_2

W= weight of SAT

W = mg

Where; W is weight of SAT

m is mass of SAT

g is gravity

m = 278 kg

g = 9.81 m/s^2

W = 278 kg x 9.81m/s^2

=2629 N

$R_A + R_B$=2629N

S.F= Shear force

B.M= maximum bending moment

B.M=R_A x L_A at R_A =1329N x 0.1m=133Nm

B.M=R_B x L_B at R_B =1329N x 0.1m=133Nm

Material Selection for the Shaft

Most shafts are made from steel, either low or medium carbon. However, high quality alloy steel or mild steel usually heat treated, may be chosen for critical applications. Other metals, e.g. Stainless steel or aluminum alloy, may be used where corrosion is a problem or lightness is required.

3.3 Selection of materials

The selection of a proper material, for engineering purposes, is one of the most difficult tasks of the designer. The best material is one which serves the desired objective at the minimum cost, weight of materials and high strength material, some of main selected materials are listed below in the table 3.12.

The following factors should be considered while selecting the materials:

- weight and strength of materials
- Availability of the materials
- Suitability of the material for the working condition and
- The cost of material

The material selection for various components of this project is done considering the above factors. Among the materials selected in this project the fiber glass, wooden, plastic and synthetic, Chromalloy steel, Alloy Steel, mild steel is the most used due to the following reasons[23];

- The material should have light in weight.
- The material able to resist corrosion.
- The material should have enough strength.
- The material should not distort by heat.
- The material should fatigue resistant.
- Easy machining and
- welding ability

Table 3.12 List of selected material for the project [7]

№	Name of materials	Specification
1	Bicycle	Conventional
2	Solar panel	12volt,350W
3	Motor	DC 627W, 1390rpm,60Ah
4	Throttle/Accelerator/	Variable Resister
5	Battery	12v 50A Lead acid
6	Sheet metal	0.8mm thickness (mild steel)
7	Square pipe(RHS)	20x20mm
8	Round bar	6mm in diameter
9	Driver sprocket	36 teeth diameter 16cm
10	Round pipe	20mm diameter

3.4. Modification Process of SAT

A. Frame and chassis of SAT with a Design

In this project we have been modified the frames of the SAT with new design, comparatively smaller wheels are selected; keeping in mind that the weight of the solar three-wheeler should be considered relatively as low as possible and must have required strength. The modification process performed as show in fig 3.11.

Fig. 3.11 modification process

The solar three-wheeler chassis is designed by using steel pipes reinforced with angle bars where necessary. The chassis can withstand necessary loads as well as absorbs vibration and shocks of the ground.

The overall length and width are also increase to some extent as per the design and carrying capacity for about two passengers and one driver. The chassis or frame is made by steel pipes having 20 mm diameter with 2 mm thickness. Reinforcement in bends etc. is done by 20 mm×20 mm angle bars as necessary as shown in the figure 3.12.

Fig 3.12: Modified Frame and chassis of SAT

B. Construction of Body

The designed body of the SAT is made of pipes, steel sheets of minimum possible thickness and woods for lighter weight as shown in the figure 3.13. Two main materials under consideration are: AISI 1018 and 4130 Chromalloy steel. The strategy behind selecting the material for roll cage was to achieve maximum welding area, good bending stiffness, minimum weight and maximum strength for the pipes. During construction of the body we should be consider the frame is provided with two dependent rear suspensions. The adjustable driver seats with arm and head rest have been provided both for agronomy and comfort. Finally, the body work should be includes, an adjustable waterproof cushioned seat is attached with the chassis. The solar panel is set on the top (overhead) with panel mounting frame made of light steel pipes duly attached to the main frame/chassis [23].

Fig 3.13: Constructional of body of SAT

Aerodynamic

In this project aerodynamics effect should be considered in body design of a SAT in order to increase speed of the SAT and reduce drag coefficient. Let us assume that a flat plate body is held against a flow of air and that the air particles are inelastic and simply drop away from the perpendicular plate surface as shown in the figure 3.14. The density of air is the mass per unit volume and a cubic meter of air at sea level has an approximate mass of 1.225 kg, therefore the density of air is 1.225 kg/^{m}

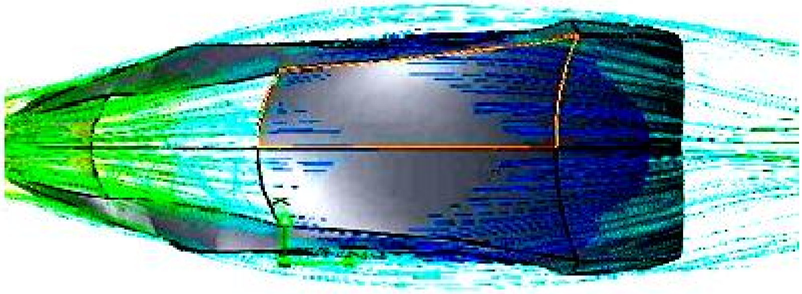


Fig.3.14: aerodynamic effect of the SAT

The force of aerodynamic drag, often referred to as simply air drag, can be described by the following equation:

$$F_{ad} = \frac{1}{2} \times \rho a \times C_d \times A_{PF} \times V^2 \text{ ………………………………………………. } (4.1)$$

$$F_{ad} = \frac{1}{2} \times 1.225 \times 0.3 \times 1.196 \times 8.33^2 = 15.25N$$

In this project to reduce the SAT aerodynamic resistance and drag coefficient, we should be consider the following type of SAT body drag redaction:

- Profile edge rounding or chamfering
- Bonnet slope and windscreen rake
- Roof and side panel cambering
- Rear side panel taper
- Underbody rear end upward taper

C. Power transmission component

In the modification process should be consider proper placement of power transmission components that modified in according to the design such assprocket, shaft and chain. While motor needs to be placed in the correct position in order for the two modified sprockets through the modified chain in the transmission system to be aligned and to be propel the shaft as perfect as possible show on the fig 3.15:[23][24].

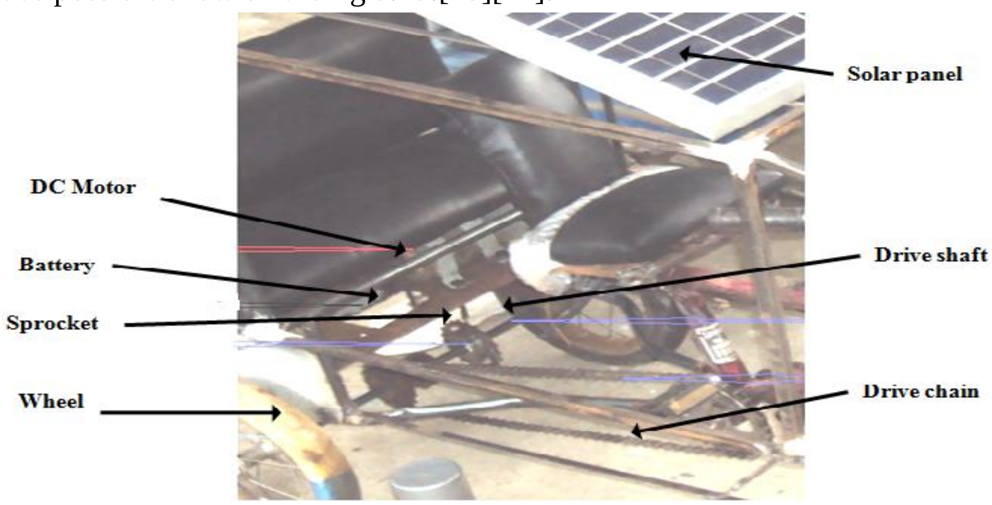


Figure.3.15: Power transmission component

Safety Component

In this project, to improve passenger safety condition the SAT should be includes Brake system, simple lighting system which is used to make interior and exterior illustration at night and also to give signal for other vehicles driver in order to avoid an accident such as head light, turn signals, and side marker light, tail lights, brake light, interior lights and horn in order to minimize the accident and to keep comfort of the passengers as well. In each steps of SAT modification process especially in chassis and body construction all the required safety evaluation will be done. While sharp edges, bends, nails are avoided to avoid accidents and ensure better safety. Consequently, installation of mechanical and electrical part of the SAT has been performed as per the standard of the materials quality.

3.5. Cost estimation for modification

In this project value engineering approach or concept was taken in to account during the design process. Value engineering defined as an organized approach in identifying unnecessary costs in design and construction to reduce cost without sacrificing quality or performance requirements [20]. The accessories which are not critical in modification of PB into SAT are included in design process of this project. The modification cost of PB into SAT was estimated around 30,986 birr. The modification cost break down was shown in table 3.13below.

Table 3.13 Materials and its price [7,11]

№	Name of materials	Specification	Total Prices(Birr)		Remark
1	bicycle	Conventional	1500	00	
2	Solar panel	24volt,700W	4500	00	
3	Motor	DC 350W, 300rpm	4000	00	
4	Accelerator	Variable Resister 24V	100	00	
5	Different type switch	Two-way & Single way 12v	200	00	
6	Side view mirror	Assembly L & R Convex	100	00	
7	Turn signal	Case lens & Lamp 12v	400	00	
8	Battery	12v 50A Lead acid	2800	00	

9	Head light	sealed	1100	00	
10	Horn	12 volt	200	00	
11	Wire	appropriate color & diameters	500	00	
12	Sheet metal	0.8mm thickness (mild steel)	400	00	
13	Square pipe	RHS 20x20mm	4500	00	
14	Round bar	6mm in diameter	300	00	
15	Electrode	Arc welding 300mm*3mm	200	00	
16	Sponge	12mm thickness	200	00	
17	plastic cover	Hard plastic	100	00	
18	Paint	White & Red for iron& anti rust	320	00	
19	Bolts & nuts	M-6mm	300	00	
20	Washer	0.8-12mm thickness	100	00	
21	Rivet	5mm	80	00	
22	Cloth	Hard nylon	400	00	
23	Glue	For attaching	150	00	
24	Ply wood	16mm thickness	200	00	
25	Driver sprocket	36 teeth diameter 16cm	200	00	
26	Body filler	Wet for finishing work	100	00	
27	Round pipe	20mm diameter	500	00	
28	Invertors/step-up	500watt	3000	00	
29	Flasher	12 volt	400	00	
Total			**26,850**	**00**	
Other cost			**3186**	**00**	
Total			**30,986**	**00**	

3.5.1 Operating cost of SAT

When considering the operating cost of SAT, there only one operating costs. The operating cost is made up of replacing the batteries and solar panel spread out over their lifecycle.

Assuming 2 years cycle life of the lithium ion batteries and solar panel is 15, the battery pack cost of 2800 and solar panel is 4500 would be spread over the mileage span of those 2 and 15 years to each other respectively.

1. **Determining battery cost and solar panel**

The operating cost is made up of replacing the batteries and solar panel spread out over their lifecycle. Since the life cycle of Lead acid batteries are greater than 2500 [12, 37] and the cost of those batteries are 4500 birr when estimated four year usage depending on riding frequency. The operating cost of replacing the batteries and solar panel spread out over their lifecycle per day was calculated as equation.

$$Bc = \frac{\text{cost of 2 battery}}{\text{lifecycle}} \quad \text{……………………………………………….. (3.50)}$$

Where Bc is cost of battery pack per day

$$B_C = \frac{2800}{720}$$

B_C = 3.889birr per day

$$SPc = \frac{\text{cost of sp}}{\text{life cycle}} \quad \text{…………………………………………………….(3.51)}$$

Where SP_C is cost of solar panel per day

$$SP_C = \frac{4500}{5400}$$

SP_C = 0.833 birr per day

Determining total operating cost of SAT per month

$C_T = (B_C + SP_C)\,30$

Where C_T total operating cost of SAT per month

$C_T = (3.889 + 0.833)30$

C_T = 141.66 birr per month

3.5.2 Operating cost of SAT

In this project, cost per day not to be considered for the improved solar assisted tricycle operating cost, it only use solar energy to propeller the SAT without any charge

3.5.3 Maintenance cost

Relatively, a maintenance cost of SAT is greatly less than other electric bicycle and tricycle as well. And it has only simple maintenance cost like cleaning and greasing.

CHAPTER FOUR

4. TEST RESULT AND DISCUSSION

4.1. Dimension of Modified Parts of solar powered Passenger Tricycle

The modified parts of solar assisted passenger tricycle such as, solar seat, passenger seat, passenger cover, DC motor support driver sprocket and overall body construction are represented using the desired dimensions indicated in figure 4.1. The final assembly of the solar powered passenger tricycle is also represented using the desired dimensions indicated by in figure 4.1. Name of Component Parts of SAT that has been modified are listed below.

1. Passenger cover support dimension
2. Passenger seat dimensions
3. Front wheel
4. Handle bar
5. Driver sprocket gear
6. Foot pedal
7. Front wheel handle bar support and front fork
8. Passenger seat and support seat dimension
9. Passenger body dimension
10. Wheel drive axel and bearing support
11. Left and right side view assembly of solar powered tricycle

Fig. 4.1: Dimensional parts of the SAT

4.2. Testing the functionality of SAT

For testing purpose we have used ordinary solar panel due to unavailability of the designed high efficiency solar panel in the local market of Ethiopia; in this project to show the functionality of SAT the following items listed below in the table 4.1 with different specifications from the designed one are used.

Table 4.1 Components specification for functional testing

S/N	Items	Specification
1	Solar panel	24V two panels
2	Batteries	24 V two 12 volt and 60Ahr capacity battery
3	DC motor	24V, 700 Watt and efficiency o f 85%
4	DC motor controllers	24V
5	Battery charger	24V and 5A

4.3 No load Testing

In this project, the required no load test was done at the work shop of Mechanical and Vehicle Engineering Department of Adama Science and Technology University. At this point the solar tricycle was ready for a functional test. And the rear two wheels were still not connected to the road surface for safety reasons. The first test was to simply power the system with solar energy and verify its functionality. Powering the system with solar energy consists of the following sequence:

i. Charging the SAT battery with solar energy that fall on the surface of solar panel for two hour continuously as illustrated in the figure 4.1
ii. Raise two rear wheels and put the rear side frame on the safety stand as illustrated in the figure 4.2
iii. Turn on the main key switch to enable motor controller and DC controller to turn on. The throttle was then tested and the motor successfully run at variable speeds determined by throttle twist amount.

Figure 4.2 SAT on Solar irradiance Figure 4.3 SAT on safety stand

In this project before starting no load measurements solar panel output power and battery pack voltage were measured and found 677watt and 24 V respectively. The no load test was performed and it took almost 2 hrs to complete the tests. After the test is completed the battery voltage remained was 17.3 V. In no load test of the SAT the following tests are performed under point (a and b)

a. The DC motor speed (rpm) was measured by using digital type tachometer while rotating freely with free wheel on safety stand and the required rpm was obtained by turning the throttle handle.
b. Wheel speed (rpm) was measured by using digital type tachometer while wheel was rotating freely and the required rpm was obtained by turning throttle handle.
c. Current drawn by DC motor was measured by using ammeter
d. Voltage supplied to DC motor from controller was measured by using volt meter

4.3.1 Relation of wheel speed (rpm) with current, voltage and power at no load condition

To show the relation the following test results are obtained and listed in table 4.2.

Table 4.2 No load test results

Wheel speed (Nin RPM	Current(I) in A	Volt (V) in V	Power (P) in (watt)
50	5.34	3.10	16.55
100	10.67	6.15	65.62
150	16	9.30	146.4
200	21.33	12.66	259.59
250	26.66	15.34	406.56
290	32	18.76	580.9

As observed from table 4.2 and figure 4.2 above when wheel revolution increases the current supplied to DC motor is almost linearly increases up to where the maximum power is developed then it s gradually decreases up to maximum revolution of the wheel. But the voltage supplied to DC motor is directly proportional wit h wheel revolution. The maximum wheel revolution obtained in 1st shift was 290 rpm

4.3.2 Relation of throttle twist with wheel speed (rpm), current and voltage at no load

NB: Table and data graph should be included at different shifting lever

Table 4.3 Throttle twist Vs wheel speed (rpm), current, voltage and power developed at no load

Throttle twist in %	Wheel Revolution(Nin RPM	Current(I) in A	Volt (V) in V	Power (P) in (watt)

20	0	0	2.1	0
40	80	6.4	8.5	54.44
60	150	12.86	14.14	181.84
80	250	19.66	18.25	358.8
100	290	32.1	23.4	751

As observed from table 4.3 and figure 4.5 above when throttle was twisted more the current supplied to DC motor is almost linearly increases up to where the maximum power is developed then its gradually decreases up to maximum revolution of the wheel. But the voltage supplied to DC motor and wheel revolution is directly proportional with amount of throttle twist.

In general, as the shift increases at the same throttle twist position the wheel revolution, current, voltage and power are increased; the result has been obtained from the prototype no load test performed but the obtained result of the above table 4.2 and 4.3 were multiplied three time to offer the actual result of SAT.

Measuring the current drawn to DC motor by using millimeter

Measuring wheel revolution by using tachometer

Figure 4.4 Picture captured during no load test

CHAPTER FIVE

5. SUMMARY, CONCLUSIONS, RECOMMENDATION AND EDUCATIONAL IMPLICATIONS

5.1 Summary

We have summarized the main points, aspects and contents of the project study were described in the following:

- Most people use numerous means of transportation in many countries of our world. Again, the problem of transportation is still there in Ethiopia, although there are various means of transportation.
- The main purpose of this project is to resolve the high demand of transportation needs in Ethiopia, to minimize transportation cost, to introduce technology using renewable energy, to reduce environmental pollution, and also to create job prospects for unemployed people.
- The scope of this project is limited to modification of a pedal bicycle to improved solar assisted passenger tricycle constructed on prototype level at reduce scale. The load capacity is limited to two passengers and with a total weight of 268 Kg which can be driven at a maximum speed of 30 KMP.
- Some limitations of the project were addressed such as unavailability of necessary component parts in the market such as solar panel, DC motor and control system component, insufficient budgets, lack of equipment and time restriction to complete the project.
- Solar tricycle was consists DC motor, solar panel, and voltage regulator, lead acid battery, motor controller, accelerator, etc.
- Method, material selection and system design of components were played crucial part in providing the desired strength, endurance, safety and reliability; and all the required numerical analysis and design calculation of the SAT components were included in chapter three.
- Sequentially, no load tests of SAT performed by simply power the system with solar energy and verified its functionality.
- Finally, the result were obtained and described; the DC motor speed (rpm) was measured by using digital type tachometer while rotating freely with free wheel on safety stand and the required rpm was obtained by turning the throttle handle. Current drawn by DC motor was measured by using ammeter, Voltage supplied to DC motor from controller was measured by using volt meter and wheel speed (rpm) was measured by using digital type tachometer while wheel was rotating freely and the required rpm was obtained by turning throttle handle.

5.2 Conclusions

As per the objectives set the modification has been completed and necessary test performed have proved the functionality of the improved solar assisted passenger tricycle. We can say our project can be a success considering the changes we had to make in the spring once we actually found out how the solar tricycle was for. We can achieve our aims, and we believe that we have a system that will be effective in providing mobility for one driver and two passenger persons who have lower economy. One of the major lessons we have learned is that designing an appropriate technology is a huge challenge. Appropriate is more than just availability for replication, it considers long life, reliability, and efficiency.

The dissemination of this work to end users will provide the benefits listed below:

- Utilization of alternative energy such as solar energy for three wheeled vehicles.
- Fulfillment of transportation needs in rural and urban areas of our country at the low cost.
- Transfer of new technology in transportation system which is environmentally friendly
- Inspiring small and micro-enterprise (SME) for production of SAT.

From the modification done and tests performed, the following conclusions are drawn:

i. As the test result of this project show that the SAT efficiency is greater than man powered tricycle. The top speed is almost similar and the battery life time is good and lead acid battery technology makes the SAT light in weight

ii. DC motor specifications were discussed by comparing different types and it was found that BLDC motor is selected for our project because of its more efficient and has better performance than other motors.

iii. Different types of batteries that are used for SAT were discussed and among them lead acid battery type is found appropriate for our project due to its efficiency and less in weight.

iv. SAT speed control has been designed. DC motor controller, fuse, switch, relay, and potentiometer were used in the control design.

v. The power transmission parts of the SAT (i.e. shaft, sprocket and chain) were designed by choosing appropriate drive mechanism and calculations are done.

vi. Since in most cities of our country the solar energy is so sufficient, while it is attractive to use SAT than using man powered tricycle due to its advantages was discussed in the project.

vii. Estimation of the SAT weight and the motor done. Accordingly, estimated value of SAT weights about 276 kg including driver and two passengers and the motor power is 0.627 kW to obtain maximum velocity of 30km/hr at the level road, while using modified SAT is so better than other single person solar tricycle and man powered tricycle.

Therefore, the conclusion given is that improved solar assisted passenger tricycle has a great deal to offer and it is going to be a big part of our future prospective, and we were taken the following points in account:

- We should effort to realize the solar assisted tricycle that has been performed on paper work and prototype into the actual in TVET College with MSE and with other stakeholder
- We should perform advance modification and improvement of solar tricycle rather than the existence in order to give better transportation service in our country
- We should try to establish way of promotion and expansion the manufacturing result and transportation service of the SAT as a part of income

5.2. Recommendations

The project forms the foundation for various works in the area of SAT propulsion especially in the solar application technology in Ethiopia, which is the current worldwide issue.

Still in Ethiopia there is no supplier of SAT or its spare parts, so we recommend that:

- Having this project work as one input, Adama Science and Technology University (ASTU) shall effort toward transfer this technology to micro enterprises and TVET in order to accelerate our countries development. We sincerely wish that investigations in SAT technology in Ethiopia that began here to continue and get improved by schools, students and other concerned bodies.
- The government should create awareness, make promotion and persuade about SAT for higher institution especially TVET, micro enterprise, industries, investors and stakeholder to participate in the field.
- The higher institution like universities and TVET colleges shall provide skilled and knowledgeable man powers that are capable of modifying man powered bicycle into improved Solar Assisted passenger Tricycle and maintaining SAT as per maintenance procedure and its manual.
- The small and micro enterprise should take part of mass fabrication and supply of SAT to the users as per demand, there will be beneficiary since there is a high demand in the most cities of our country.

More than a few recommendations and ideas related with future research meeting point can be given. This project did not cover the different mechanism to recharge the battery pack during driving at night time and cloud condition when the solar energy is unavailable. In general, the following are recommended to be investigated further:

- Mechanism to recharge the battery pack during drive at night and cloud condition
- Modifying a superior suspension system for modified improved SAT

- Designing high efficiency electromagnetic brake system

5.3 Educational implications

The objective of the national TVET strategy is to create a competent, motivated, adaptable and innovative man power in Ethiopia contributing to poverty reduction, social and economic development through facilitating demand driven, high quality technical and vocational education and training, relevant to all sectors of the economy, at all levels and to all people in need of skill development transferring new technologies.

Technical and vocational education is of great relevance to the technological and economic status of nation. Such as:

- Technological advance and series, which naturally lead to economic release and independence that evaluate new instructional program and draw lessons for further improvement.
- To get better and build up the teaching and learning process. Effective handling the issue of transfer of technology and its employee problems. Reduction of over dependence on imported products by making import substitution. Conservations of the resource that could have spent in engaging the service of foreign experts

The objective of this project is to show how education can play a great role in introducing and transferring SAT technologies to the country; and also to enrich understanding and create ability of higher institutes such as University and TVET trainees through education. Accordingly, the findings of this project could have an impact in TVET education, and training in the following area:

- It can help to transfer SAT technology into TVET training
- It can commence TVET experts to introduce new instructional programs
- It can develop the potential of TVET trainees to create new application solar powered tricycle technology in automotive fields.

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APPENDIXES

Appendix A- Improved solar assisted passenger tricycle description

1. Solar assisted passenger tricycle:

A solar assisted passenger tricycle is operated by solar power which stored in the battery pack. Solar panel charge the battery pack and then the electric current is supplied to DC motor from the battery pack that has been charged by solar energy, the DC motor convert chemical reaction of battery into mechanical energy that moves wheels through tensioned chain. This implies the conversion of energy from one form to another. But there is a loss of energy in the conversion process.

2. Bill of materials:

Materials used in this project to modify pedal bicycle to solar assisted passenger tricycle are listed below in the table:

Table 3.1 Material to be required

№	Name of materials	Specification
1	Bicycle	Conventional
2	Solar panel	24volt,700W
3	Motor	24V, DC 0. 627kW, 1390 rpm
4	Throttle/Accelerator/	Variable Resister
5	Different type switch	Two-way & Single way 12v
6	Side view mirror	Assembly L & R Convex
7	Turn signal	Case lens & Lamp 12v
8	Battery	12v 60Ah Lead acid
9	Head light	sealed
10	Horn	12 volt
11	Sheet metal	0.8mm thickness (mild steel)
12	Square pipe(RHS)	20x20mm
13	Round bar	6mm in diameter
14	Driver sprocket	36 teeth diameter 16cm
15	Round pipe	20mm diameter
16	Flasher	12 volt

3. Consumable materials

In this project consumable materials that used to perform the required task are listed below in the table:

№	Name of materials	Specification
1	Washer	0.8-12mm thickness
2	Rivet	5mm
3	Cloth	Hard nylon
4	Glue	For attaching
5	Ply wood	16mm thickness
6	Paint	White & Red for iron& anti rust
7	Wire	appropriate color & diameters
8	Body filler	Wet for finishing work
9	Electrode	Arc welding 300mm*3mm
10	Sponge	12mm thickness
11	plastic cover	Hard plastic
12	Bolts & nuts	M-6mm

In this project tools, equipment's and machines used to perform the required task are listed below in the table:

3. Tools and equipment's

- Screw driver
- Clamp meter
- Wrenches
- Hack saw
- Gripper
- Vernier caliper
- Soldering gun
- Center punch
- Millimeter
- Pier
- Mater

Machines

1. Drilling machine
2. Arc welding machine
3. Lathe machine
4. Grinder machine

4. Characteristics and efficiency of solar panel

There are three type of solar panel that available in commercial, these solar panel classified by their characteristics and working efficiency as shown in the figure 3.3(1, 2 and 3)

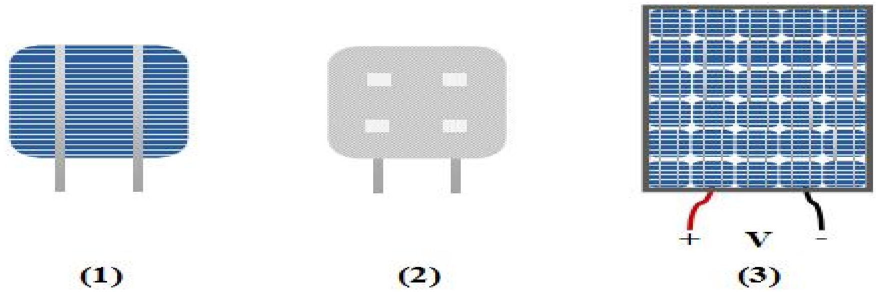


Figure 3.3: Example of mc Si or sc Si cell and panel.

4) **Front of solar cell:** Horizontal stripes collect the current and minimizes the resistance and are connected to bus bars (vertical), used for connection to other cells.
5) **Back of cell:** Square contact points are used to connect bus bars from previous cell.
6) **Panel layout:** All cells connected in series [8][16].

Table ap 1. Typical efficiency of commercial solar panels

Solar cell technology	Typical range of commercial panel efficiency (%)
Single-crystalline Silicon (sc-Si)	14-22
Multi-crystalline Silicon (mc-Si)	12-19
Thin films	4-19

5. Characteristic of DC motor

- It is highly efficient and the flux density does not decrease with time.
- It's performance characteristics suite very well to the requirement of our solar three-wheeler. At standard load condition, the motor needs 627Watts.
- This power will cover the required power needed to run the solar three-wheeler at a speed of 30 km/hr.
- If the load increases or the three-wheeler climbs up-ward slope, then the current will also increase and power output of the motor will also increase. However,
- The PMDC (permanent magnet direct current motor) was chosen for its power rating and cost. A 0.627 kW motor is chosen for the ideal electric power for a tricycle which is smooth in minute sound than other motor
- The motor runs on 24 volts DC, with a rated speed of 1390 rpm and a rated current 32.6 amps

Appendix B - Work plan

This project was performed according to the following schedule listed in the table below.

Table C.1 Time breakdown in project work performed

Activities	**Time line**																			
	February				**March**				**April**				**May**				**June**			
	Weeks				Weeks				Weeks				Weeks				Weeks			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Preparation of project proposal																				
Submission of project proposal																				
Preparing and collecting of material and equipment required																				
Preparing pedal bicycle for modification																				
Implement modification of bicycle to tricycle																				
Implementation of powering tricycle with solar assist																				
install lighting system of solar tricycle																				
Finishing and varnishing of tricycle with colored paint																				
Overall checkup and on road performance test																				
Paper writing																				
Final presentation																				
Submission of completed document																				

Appendix -C Picture captured during practical work

In this project during practical work pictures were captured at each stage of improved SAT modification process.

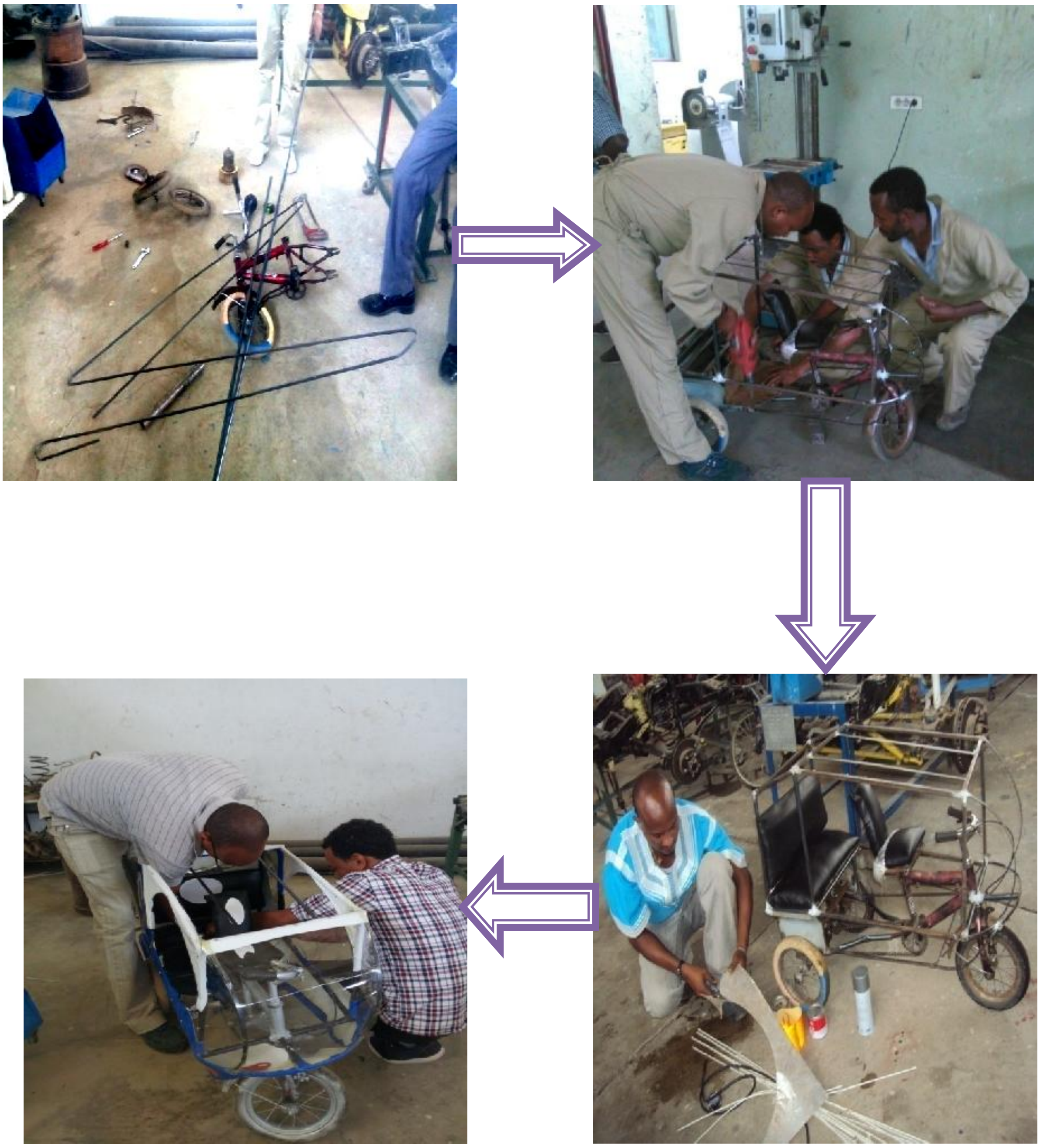


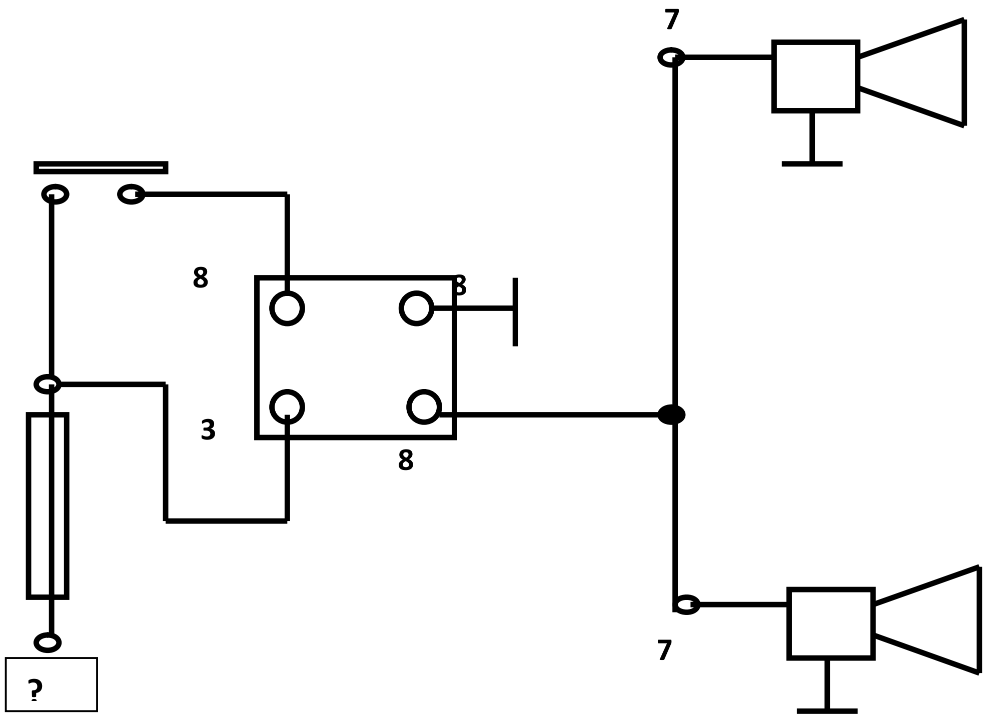
Figure C. 1 Modification process

Figure C.2 Components installation 1

Figure C. 3 Components installation 2

Figure C.5 No load test.

Appendix –D Deferent type of electrical circuits' diagram



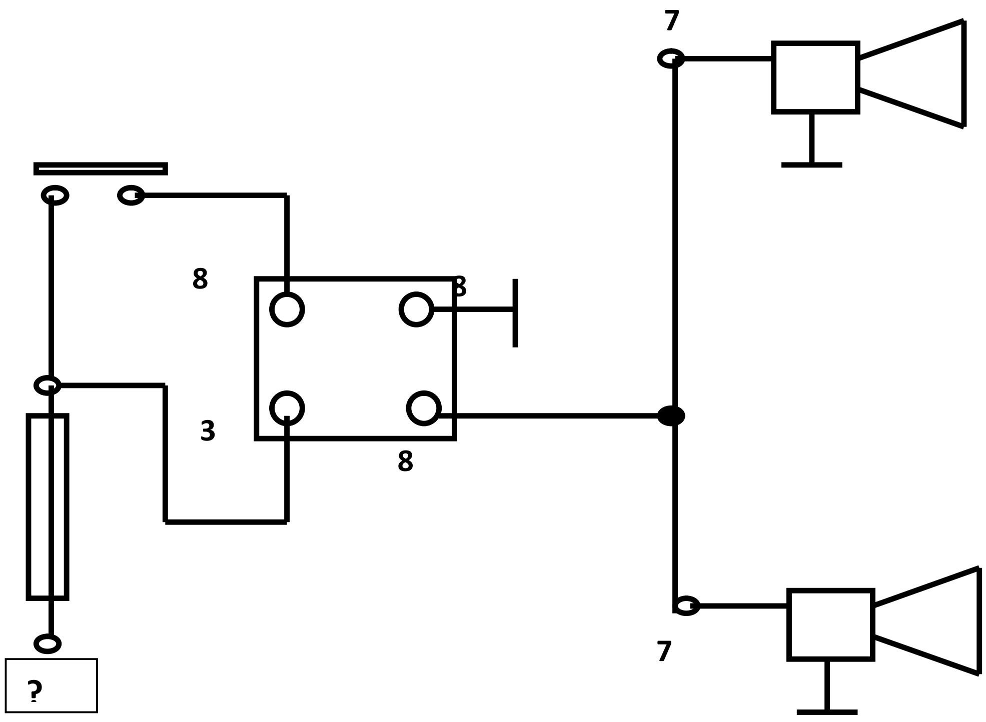


Fig: D-1 Horn circuit diagram

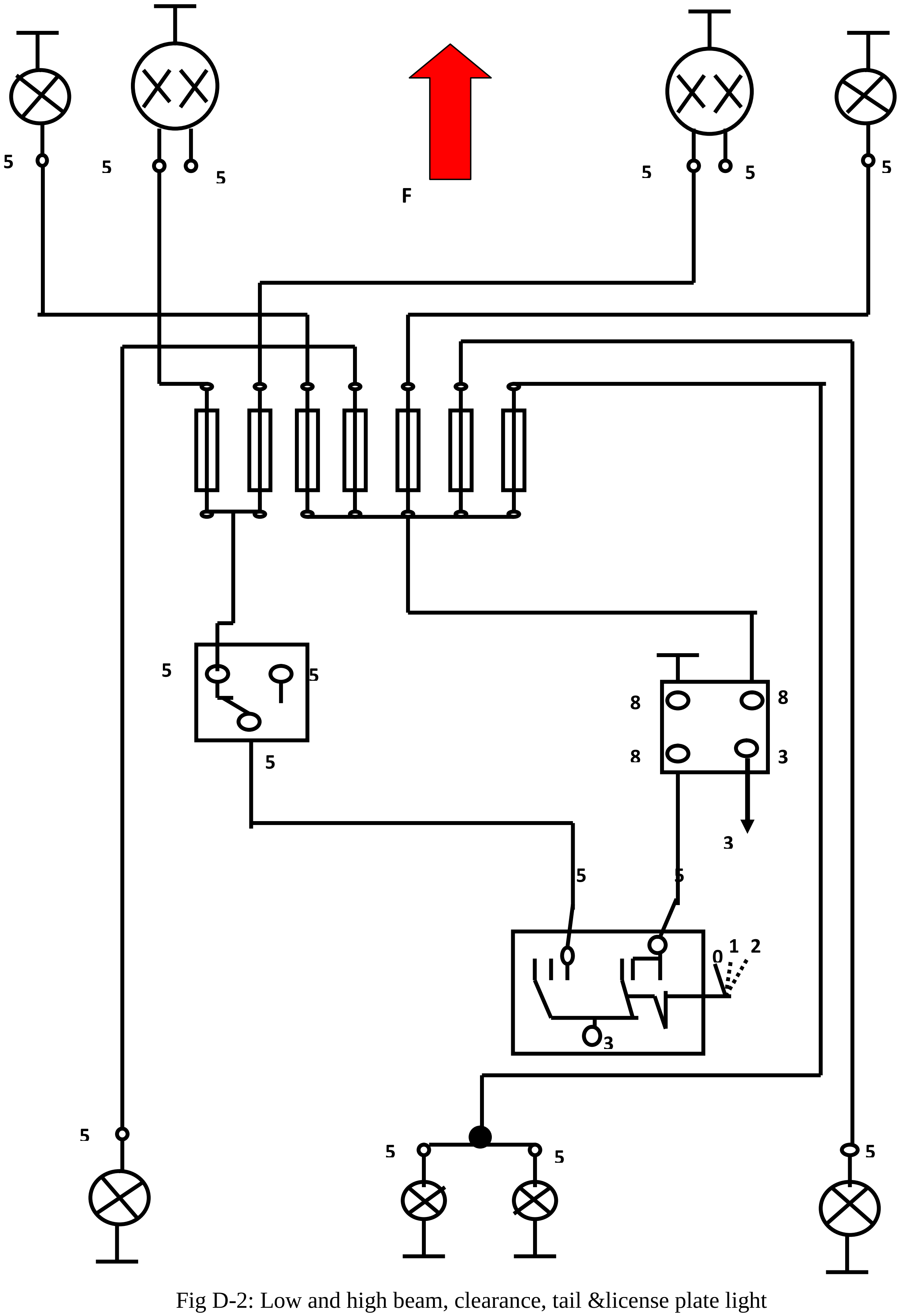


Fig D-2: Low and high beam, clearance, tail &license plate light

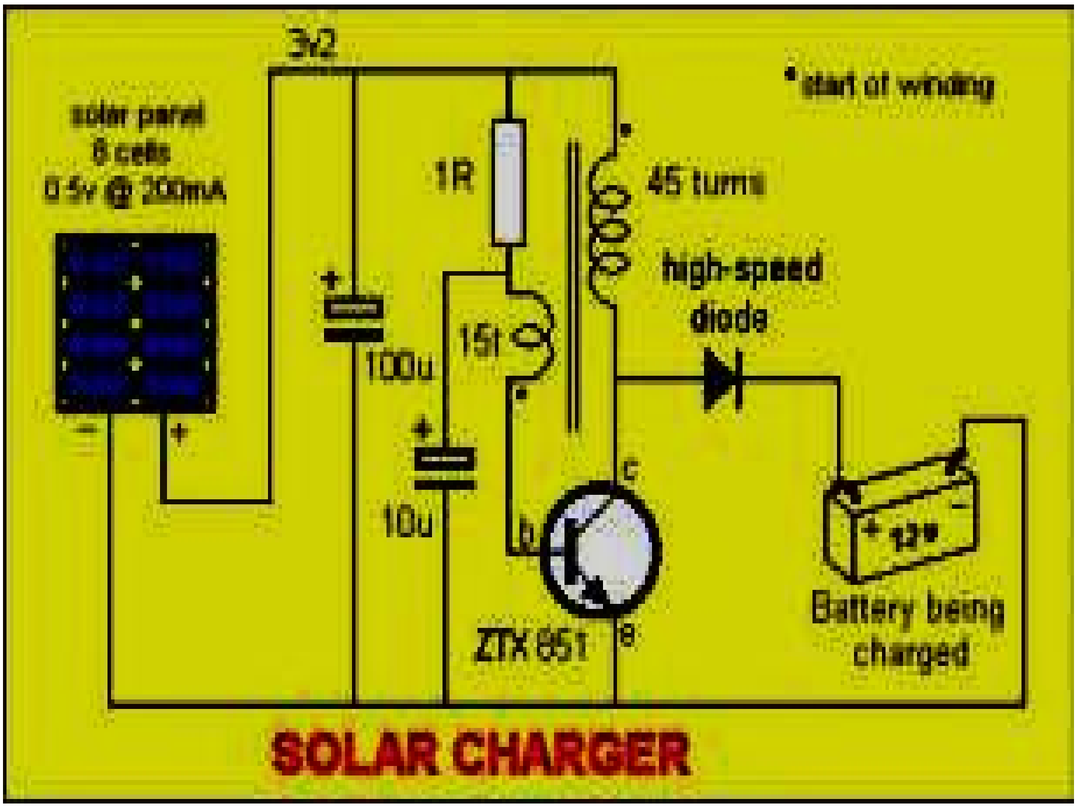


Figure D- 3: Circuit diagram for solar charger[6][15][21].

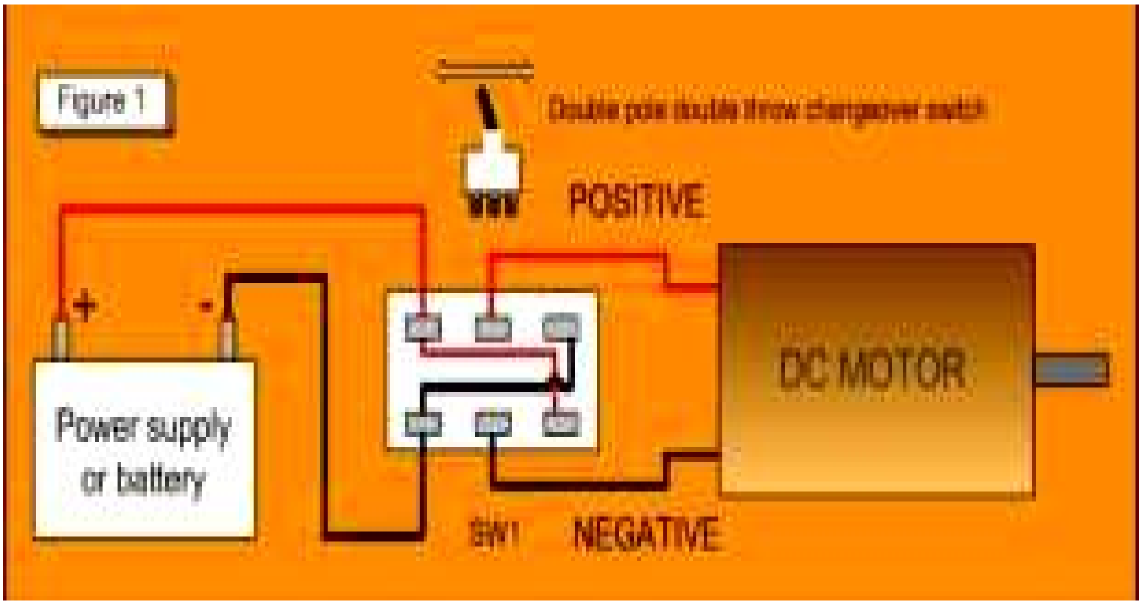


Fig D-4:working diagram of solar assisted tricycle[1][10].