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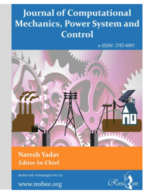

Design and Production of an Electrically Powered Tricycle

Toroabasi Jeremiah Etim
Department of Mechanical Engineering, University of Uyo, Nigeria
etimtoroabasi@gmail.com

Godwin Monday Abia
Department of Mechanical Engineering, University of Uyo, Nigeria
godwinabia03@gmail.com

Michael Emmanuel
Department of Mechanical Engineering, University of Uyo, Nigeria
enmichael234@gmail.com

Oghenemena Yvonne Akpobor-Okoro
Department of Mechanical Engineering University of Uyo, Nigeria
Oakpoborokoro@gmail.com

Godspower Godwin Micheal
Department of Mechanical Engineering University of Uyo, Nigeria
gmicheal36@gmail.com

Lawrence Ifeanyi Chinaka
Department of Mechanical Engineering, University of Uyo, Nigeria
Lawrencechinakaa@gmail.com

Abstract: An Electric Bike Is Essential For Promoting Sustainable Transportation By Reducing Reliance On Fossil Fuels, Minimizing Air Pollution, And Lowering Greenhouse Gas Emissions. It Provides A Cost-Effective And Efficient Alternative For Short Commutes, Making It Ideal For Urban Environments Where Traffic Congestion And Air Quality Are Major Concerns. This Project Outlines The Design, Production, And Analysis Of An Electrically Powered Tricycle. The Project Was Designed Using Computer-Aided Design (CAD) Software (Solidworks). Production And Assembly Of Various Components Like The Chassis, Front Fork, Frame, Leather Seats, Electric Motor, And Chain Drive As Well As Detailed Analysis On Various Parameters Like Battery Capacity, Efficiency, And Power Rating Of The Electric Motor Was Carried Out. The Findings Show That The Electric Motor Had To Work On An Independent Brake And Not In Conjunction With The Mechanical Brake Added To The Front Fork To Avoid Disharmony In The Brake System. The Resulting Tricycle Is Expected To Address Urban Congestion, Provide A Cost-Effective Transportation Option, And Contribute To A Greener Environment.

Keywords: Tricycle, electrical vehicle, Design and production, CAD, Battery

Nomenclature

Abbreviation	Expansion
EVs	Electric Vehicles
PEV	Pure Electrical Vehicle
HEV	Hybrid Electrical Vehicle
FCEV	Fuel Cell Electrical Vehicle
BEV	Battery Electric Vehicle
ICEV	Internal Combustion Engine Vehicles
DC	Direct Current
FC	Fuel cell
PHEV	Plug-in Hybrid Electric Vehicle
REV	Range-extended Electric Vehicle
AC	Alternating Current
CAD	Computer Aided Design
BMS	Battery Management System

1. Introduction

1.1 Background of Study

The issues of climate change and the impact of global warming have been rigorously discussed by many researchers since the early 21st century. The research revealed that the negative impact of climate change is dominantly driven by human activities such as the combustion of fossil fuels for energy and transportation. With the increase in civilization and industrialization, a significant proportion of greenhouse emissions due to the combustion of fossil fuels is also responsible for the uptick in acute respiratory illnesses (Wee, 2010). Vehicular emissions, which mainly include greenhouse gases such as

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CO_2, CO, NOx, and particulate matter (PM10 and PM2.5), have been considered as the major contributors to the impact of the greenhouse effects, and it is also a contributor to the increase in different forms of cancers and other respiratory diseases [24] [23].

Currently, the transportation sector consumes about 49% of crude oil resources and following the current trends of oil consumption and crude oil sources, the world's oil resources are predicted to be depleted by 2038 [22]. Similarly, the transportation sector accounts for 29% of greenhouse emissions and is projected to increase by about 50% by 2050 if policies to address greenhouse emissions from fossil fuels are not introduced and the move to an eco-friendly alternative in this sector is not implemented. Therefore, replacing non-renewable energy resources with renewable energy sources and the migrating to sustainable energy technologies is imperative. Thus, EVs have been presented as a reliable alternative for curbing the issues posed by the combustion of fossil fuels, and the gains are being extensively studied [18] [26] [43].

1.2 Statement of Problem

The need to alleviate the suffering of the masses occasioned by the inadequate means of public transportation has led to a lot of innovations in the transportation sector. This project "Design, Production and Analysis of an Electrically Powered Tricycle" is an attempt to reduce the sufferingencountered by many people in daily transportation. The project is further necessitated by the fact that it is going to be electrically powered which is a welcome development because it will not contribute to the consequences of global warming and its effects on climate change. The operationof the tricycle will not generate greenhouse emissions and an eco-friendlier alternative in contemporary society.

1.3 Objective of the Study

1.3.1 Main Objective

To design, produce, and analyze an electrically powered tricycle.

1.3.2 Specific Objectives

The specific objectives of this work are;

1. To Design each component using CAD software.
2. To Produce and assemble component parts.
3. To test-run and analyze the operation of the electrically powered tricycle.

1.4 Significance of Study

The global transition towards renewable energy and alternative energy resources to curb the issues associated with climate change is underway. Research and efforts are made in this regard and this work is an instance of that. Thus, this work produces an electrically operated tricycle that has a net zero emission and generates no noise pollution. Aside from the meeting set environmental sustainability goals, this work serves as a template for a simplified electricallyoperated tricycle.

1.5 Scope of Study

This work is focused on the design and production of an electrically powered tricycle with a 3-person seating capacity, to make it aesthetically suitable and test-run it.

The rest of the paper is aligned as follows: Section 2 covers the literature review, Section 3 details materials and methods, Section 4 explains the result and discussion, and Section 5 concludes the paper with recommendations.

2. Literature Review

An EV is a vehicle that uses one or more electric motors for propulsion. It can be powered by a battery. Electric cars have no vibrations from the engine and are extremely quiet compared to their competitors. They do not emit smoke or backfire as frequently as gas-powered cars. An electric motor on the other hand is an electrical machine that converts electrical energy to mechanical energy. This section presents a review of the existing literature on EV and electric motors focusing on their types, components, and differences.

2.1 Classifications of EV

Taking the power supplement and propulsion devices into account, EVs could be classified into three different types: PEV, HEV, and FCEV (Chan and Chau, 2001; Chau, 2010, 2014).

1. PEV

The PEV commonly named BEV is purely fed by electricity from the power storage unit, while the propulsion is solely provided by an electric motor. Zero discharge emission of PEV is a significant advantage because the electrical energy is solely supplied from the vehicle-mounted battery.

On the other hand, the limitations on the present status of the onboard battery technology of PEV make it less attractive than ICEV under the same economic and driving requirements. Batteries with high power densities but low energy densities result in longer charging time – even with fast charging technologies, one hour to several hours for full charging is necessary. Thus, the main challenges of the PEV are limits to the driving range, high initial cost, and lack of charging infrastructures [27]. For practical

implementation, the size and location of the battery inside the PEV should also be standardized (Chau and Li, 2014).

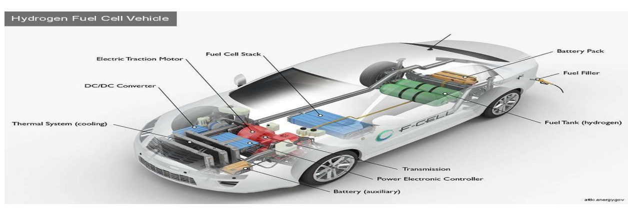
Source: (Chau and Li, 2014).

Fig. 1. *A Diagrammatic Representation of a BEV*

2. FCEV

The FCEV is an electrochemical device that produces DC electrical energy through a chemical reaction. There are five main components in FCEV: an anode, an anode layer, an electrolyte, a cathode, and a cathode catalyst layer. With suitable parallel/series connections of FCEV sources, the required amount of power can be produced to drive the car. In terms of driving range, it is comparable to an ICEV, thus resulting in a wide range of applications of FCs from small-scale plants of the order of 200 W to small power plants of the order of 500 kW.

FCEVs are attractive because of zero roadside emissions. Even taking the overall emissions into account, which include the emissions from chemical plants and on-road reformers, the FCEV seems still competitive. FC is the main power supplier and the critical technology. However, the high initial cost and lack of refueling stations are still regarded as significant challenges to the success of FCEV (Rao and Wang, 2011). Also, the supply electricity continuity of FCs is less reliable than conventional batteries used in EVs. The crucial advantage of BEV and FCEV is the ‘zero emission’ and hence reduced air pollution. However, the ‘zero emission’ of BEV and FCEV is not absolute considering the emissions during the whole processing. However, “what is critical as the main pollution-contributor and how” are the topics that are hardly discussed. For example, the pollution contributors include chemical contamination when producing the fuel cell and the battery (or the electrochemical plant for FCs), emissions during vehicle manufacture, pollution from scrap battery processing, etc.

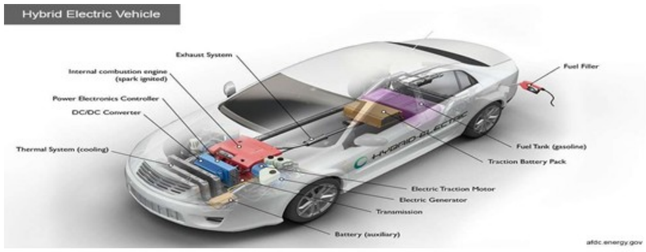


Source: (Chau and Li, 2014).

Fig. 2. *A Diagram of a Hydrogen Fuel Cell Vehicle*

3. HEV

The HEV combines the properties of ICEV and BEV. Driving power sources of HEV include both gasoline/diesel and electricity; the propulsion relies on the engine and electric motor. According to different refueling or recharging measures, HEVs can be classified as either conventional HEVs or grid-able HEVs. Based on levels of the combination, the conventional HEV could be further developed into three types: micro, mild, and full HEV. The grid-able HEV could be either a PHEV or a REV (Chau and Li, 2014).



Source: (Chau and Li, 2014).

Fig. 3. *A Diagram of a Hybrid Electric Vehicle*

Table 1. *Categories of EVs Based on the Energy Source and Propulsion Device*

Energy Source	Vehicle Type	Propulsion Device
Gasoline	ICEN	
	Micro HEV	**Engine**
	Mild HEV	
	Full HEV	
	PHEV	
	REV	
Electricity	PEV	**ElecricMotor**
Hydrogen	**FCEV**	

Source: (Chau and Li, 2014).

2.2 Components of an Electric Motor

1. Rotor

The rotor is the moving part that delivers the mechanical power. The rotor typically holds conductors that carry currents, which the magnetic field of the stator exerts force on to turn theshaft. Alternatively, some rotors carry permanent magnets, and the stator holds the conductors.Permanent magnets offer high efficiency over a larger operating speed and power range (MJH,2015).

An air gap between the stator and rotor allows it to turn. The width of the gap has a significant effect on the motor's electrical characteristics. It is generally made as small as possible, as a large gap weakens performance. It is the main source of the low power factor at which motors operate. The magnetizing current increases and the power factor decreases with the air gap, so narrow gaps are better. Conversely, gaps that are too small may pose mechanical problems in addition to noise and losses.

The motor shaft extends through the bearings to the outside of the motor, where the load is applied. Because the forces of the load are exerted beyond the outermost bearing, the load is said to be overhung.

2. Stator

The stator surrounds the rotor and usually holds field magnets, which are either electromagnets consisting of wire windings around a ferromagnetic iron coreor permanent magnets. These create a magnetic field that passes through the rotor armature, exerting force on the windings. The stator core is made up of many thin metal sheets that are insulated from each other, called laminations. These laminations are made using electrical steel which has a specified magnetic permeability, hysteresis, and saturation. Laminations are used to reduce losses that would result from induced circulating eddy currents that would flow if a solid core were used.

Source: https://en.wikipedia.org/wiki/Electric_motor

Fig. 4. *A Rotor (left) and Stator (right)*

3. Commutator

A commutator is a rotary electrical switch that supplies current to the rotor. It periodically reverses the flow of current in the rotor windings as the shaft rotates. It consists of a cylinder composed of multiple metal contact segments on the armature. Two or more electrical contactscalled "brushes" made of a soft conductive material like carbon press against the commutator. The brushes make sliding contact with successive commutator segments as they rotate, supplyingcurrent to the rotor. The windings on the rotor are connected to the commutator segments. The commutator periodically reverses the current direction in the rotor windings with each half-turn(180°), so the torque applied to the rotor is always in the same direction (Hameyer, 2001).

4. Armature

The armature consists of wire windings on a ferromagnetic core. Electric current passing through the wire causes the magnetic field from the field magnet to exert a force (Lorentz force) on it, turning the rotor, which delivers the mechanical output. Windings are wires that are laid in coils, usually wrapped around a laminated, soft, iron, ferromagnetic core to form magnetic poles when energized with current.

5. Bearings

The rotor is supported by bearings, which allow the rotor to turn on its axis by transferring the force of axial and radial loads from the shaft to the motor housing through an interface that has a low coefficient of friction.

2.3 Types of Electric Motor

1. DC Motors

A DC motor is an electric motor that runs on direct current power. In an electric motor, the operation is dependent upon simple electromagnetism. A current-carrying conductor generatesa magnetic field, when this is then placed in an external magnetic field, it will encounter a forceproportional to the current in the conductor and to the strength of the external magnetic field.It is a device that converts electrical energy to mechanical energy. It works on the fact that a current-carrying conductor placed in a magnetic field experiences a force that causes it to rotateto its original position.

2. AC Motor

An AC motor is a kind of electric motor that uses an electromagnetic induction phenomenon. An alternating current drives this electric motor. It is a type of electric current that periodicallyreverses direction and changes its magnitude continuously with time. This current contrasts with direct current, or 'DC,' which flows only in one direction. An AC motor can offer a comparablyefficient method of producing mechanical energy from a simple electrical input signal.

3. Materials and Methods

3.1 Materials

When designing this electrically powered tricycle, the choice of materials played a crucial role in determining the overall functionality and durability of the tricycle. The selection of appropriate materials depended on various factors such as weight, strength, cost, manufacturability, and other characteristics.
By carefully considering the characteristics of different materials and their suitability for various tricycle components, engineers can create a balanced and efficient tricycle that meets specific performance requirements while ensuring reliability and longevity.
Below is a table of the components, selection criteria as well as the equipment and utilization.

3.1.1 Raw Materials

The following materials were used in the fabrication processes. They include;

1. Metal sheets
2. Square pipes
3. Bolts and nuts
4. Welding electrodes
5. Angle irons
6. Wires
7. Light bulbs
8. Leather
9. Spray paints

3.1.2 Table 2. Materials and Selection Criteria

S/N	Components	Materials	Selection Criteria
1	Chassis	High Carbon steel	Strong and durable with high wear and tear resistance
2	Axles	Carbon steel	For a higher tensile and yield strength
3	Electric Motor Casing	Aluminium	Weight savings and excellent conductor of heat.
4	Battery	Lithium	Rechargeability and good energy density
5	Seat	Leather/foam	Durability, water resistance, and softness.
6	Drive Sprocket	Stainless steel	High strength and corrosion resistance
7	Charge Controller	Resistors and insulators	Power rating and dielectric strength
8	Brake Pedal	Aluminium	Good yield strength
9	Constant velocity shafts	Carbon steel	For good tensile strength
10	Drive Chain	Harden steel	High mechanical strength and toughness
11	Upright	Carbon steel	Corrosion resistance and high tensile stress
12	**Handlebar pedal**	**Aluminium alloy**	Good yield strength

3.1.3 Table 3. Equipment and Utilization

S/N	Equipment	Utilization
1	Wrenches	Fastening, gripping, tightening
2	Allen key	Installation and removal of fasteners with hexagonal head
3	Screwdrivers	Turning screws and slotted heads
4	Multimeter	Measure two or more electrical values like voltage and current
5	Tape measure	Used for taking measurement
6	Spirit Level	Use to check how parallel or perpendicular a surface is relative to the earth.
7	Grease or lubricant	Used to reduce friction, prevent wear and tear
8	Soldering iron	Used to solder electric components together
9	Safety equipment (safety glasses, gloves)	To minimize exposure to hazards
10	Workbench	Use to clamp work pieces together
11	Welding machine	Use to weld metal pieces together
12	Angle grinder	Use for cutting and grinding metal surfaces together
13	Bench vice	Use to clamp metal together
14	**Hacksaw**	Use for grinding and cutting metal

3.2 Methods

The following methods would be adopted for this project:

- Design drawings with CAD Software (Solid Works)
- Production and assembly of components
- Analysis

3.2.1 Design Drawings with Cad Software (Solid Works)

Below are the 2&3-dimensional drawings of the electrically powered tricycle designed fromSolidWorks CAD software.

Fig. 5. *Isometric Side view of the Electrically Powered Tricycle*

Fig. 6. *Isometric Back view of the Electrically Powered Tricycle*

Fig. 7. *Isometric Top view of the Electrically Powered Tricycle*

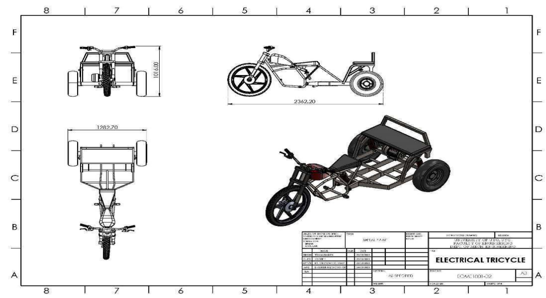


Fig. 8. *Orthographic views of the Electrically Powered Tricycle*

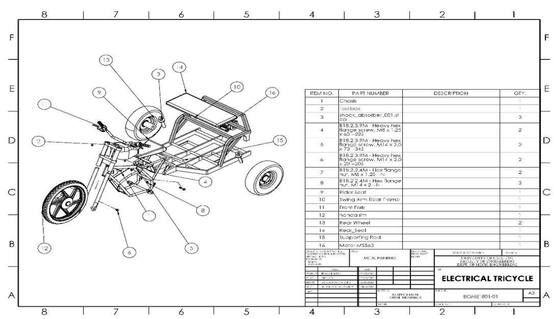
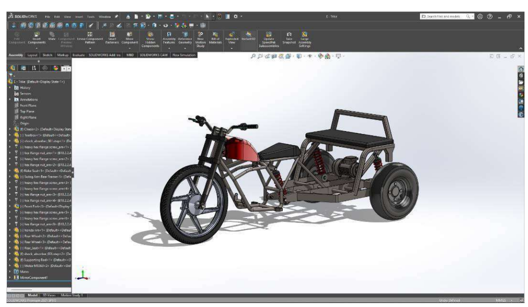


Fig. 9. *Exploded View of the Electrically Powered Tricycle*



Source: Field Work, 2023.

Fig. 10. *General Isometric View of the Electrically Powered Tricycle*

3.2.2 Key Components

1. Chassis

A chassis is the structural framework of a vehicle or machine. It provides support and servesas the foundation for various components such as the engine, transmission, suspension, and body. It contributes to the vehicle's stability, handling, and overall performance. It can be madefrom materials like steel, aluminum, and carbon fiber depending on factors such as strength, weight,and cost. The chassis of this electrically powered tricycle was specifically made with high carbon steel due to its high strength to withstand the weight of those who sit on it. The design and engineering of a chassis are critical in determining the vehicle's safety, durability, and functionality.

Source: Field Work, 2023

Fig. 11. *A Pictorial Representation of the Chassis*

2. Axles

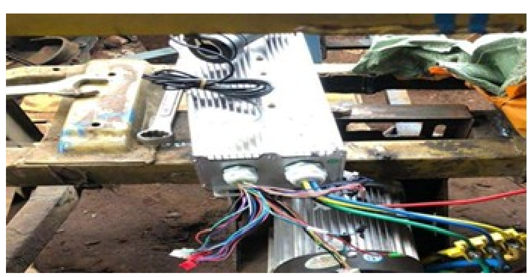
An axle is a crucial component in many vehicles and machines, responsible for connecting andsupporting the wheels. It serves as a central shaft that rotates with the wheels, enabling themto turn and transmit power from the engine to the wheels. There are two primary types of axles:live axles and dead axles. Live axles are capable of transmitting both power and supporting theweight of the vehicle. They are commonly used in rear-wheel-drive vehicles where the axle provides power to the wheels. Dead axles, on the other hand, do not deliver power and are mainly used for the supporting weight of the vehicle. Axles are designed to withstand the forcesand stresses associated with vehicle movement. They are made from materials like steel or other alloys, which provide the necessary strength and durability. In some cases, axles mightbe equipped with differentials to allow wheels on the same axle to rotate at different speeds, crucial for smooth cornering.

Source: Field Work, 2023

Fig. 12. *A Pictorial Representation of an Axle*

3. Charge Controller

A charge controller also known as a charge regulator, is a crucial component in renewable energy systems that involve batteries, such as solar power systems and wind turbine setups. Itsmain function is to regulate the charging process of batteries by controlling the amount of current and voltage delivered from the energy source, be it solar panels or wind turbines. The primary purpose of a charge controller is to prevent overcharging and over-discharging of batteries. Overcharging can lead to excessive heat generation, electrolyte loss, and reduced battery lifespan. On the other hand, over-discharging can damage batteries and decrease the capacity over time. A charge controller ensures that the battery is charged optimally, extendingits life and maintaining its efficiency.



Source: Field Work, 2023.

Fig. 13. *A Pictorial Representation of a Charge Controller*

4. Shafts

Shafts are essential mechanical components used in a wide range of applications, from machines and vehicles to industrial equipment and consumer products. A shaft is a long, slender, and usually cylindrical object that rotates to transmit power or motion between different parts of a mechanism. One of the primary functions of a shaft is to transfer rotational motion from a power source, such as an engine or motor, to various components like gears, pulleys, or wheels. The design and material of the shafts are critical, as they must withstand theforces, torque, and stresses generated during operation. Shafts can be classified into different types based on their applications and features. Some common types include:

- **Transmission Shafts:** Found in vehicles, these shafts transmit power from the engine tothe wheels, enabling movement.
- **Drive Shafts:** These shafts transfer torque from the engine to the wheels in vehicleswith front, rear, or all-wheel drive configurations.
- **Pump Shafts:** Used in pumps and fluid handling systems, these shafts transfer rotationalenergy to create fluid flow.
- **Rotary Shafts:** Found in machinery and devices, they transmit rotary motion to various components.
- **Crankshafts:** Common in engines, these shafts convert the linear motion of pistons into rotational motion.
- **Propeller shaft:** Used in boats and ships, these shafts transmit power from the engine tothe propeller.
- **Shaft Couplings:** These connect two shafts to transmit motion between them, compensating for misalignment.

Source: Field Work, 2023.

Fig. 14. *A Pictorial Representation of Shafts*

5. Drive Chain

A drive chain is a mechanical system consisting of interconnected links that transmit power from one place to another. It's a common method for transferring rotational motion and force, often used in various applications such as bicycles, motorcycles, industrial machinery, and evensome types of vehicles. The basic components of a drive chain include:

- **Sprockets:** These are toothed wheels that are connected to the source of power (such as an engine or pedals) and the driven component (such as a wheel or conveyor belt). The sprockets engage with the links of the chain, causing it to move.
- **Chain Links:** The chain is made up of individual links, which can be of various shapes and designs depending on the type of chain.
- **Rollers**: Many drive chains, especially those used in vehicles, have rollers within the links.These rollers help reduce friction between the chain and sprockets, allowing for smoother motion and longevity of the chain.

Drive chains play a crucial role in numerous mechanical systems, enabling the transfer of power and motion over distances. Proper maintenance, lubrication, and occasional replacement are essential to ensure the longevity and efficient operation of drive chains.

Source: Field Work, 2023.

Fig. 15. *A Pictorial Representation of the Drive Chain*

6. Battery

Batteries are electrochemical devices that store and release electrical energy through a reversible chemical reaction. The basic structure of a battery includes:

- **Anode:** The electrode where oxidation occurs. It releases electrons during the chemicalreaction.
- **Cathode:** The electrode where reduction occurs. It accepts the electrons released nearthe anode.
- **Electrolyte:** A substance that allows ions to move between the anode and cathode,completing the electrical circuit.
- **Separator:** A material that prevents direct contact between the anode and cathode, whileallowing the movement of ions.

Various types of batteries exist, each with its chemistry and characteristics:

- **Lithium-ion (Li-ion) Batteries:** Widely used in portable electronics and EV, Li-ion batteries offer a high energy density and a relatively low self-discharge rate.
- **Lead-Acid Batteries:** Common in automotive applications, lead-acid batteries are robust and cost-effective but have a lower energy density compared to newer technologies.
- **Nickel-Cadmium (NiCd) Batteries:** Used less frequently due to environmental concerns, NiCd batteries have a higher self-discharge rate but can handle high discharge currents.
- **Nickel-Metal Hydride (NiMH) Batteries:** These have replaced NiCd batteries in many applications, offering a higher energy density and reduced environmental impact.
- **Solid-State Batteries:** Emerging as a future technology, these batteries use solid electrolytes instead of liquid ones, offering potential benefits in terms of safety, energydensity, and longevity.

Source: Field Work, 2023.

Fig. 16. *A Pictorial Representation of a Lithium-ion (Li-ion) battery*

7. Seats

Seats are integral components of furniture, vehicles, and various settings, providing a comfortable and supportive surface for people to sit on. They come in various designs, materials, and configurations, catering to different needs, aesthetics, and functions.

Key aspects of seats include:

Design and Style: The seats were designed to match the overall aesthetic of a space or vehicle, ranging from classic to modern, minimalistic to ornate.

Materials: The seats were made from a variety of materials, including wood, metal, and leather.

Construction: The construction of a seat involves the frame, padding, and covering. The frame provides structural support, while padding enhances comfort.

Ergonomics: The seats were designed with the human body in mind, ensuring proper support and comfort.

Functionality: Seats serve different functions based on their context. They can range from office chairs with adjustable features for working long hours to stadium seats designed for short-term comfort duringevents.

Source: Field Work, 2023.

Fig. 17. *A Pictorial Representation of the Tricycle Seat*

8. Shock Absorber

The shock absorber that was used was a coil-over shock absorber that consists of a damper with a coil spring encircling it. Two shock absorbers were used at the rear end of the framework. It controls the oscillation of the suspension springs, preventing excessive bouncing and ensuring the tires remain in contact with the road.

Source: Field Work, 2023.

Fig. 18. *A Pictorial Representation of the Shock Absorber*

3.2.3 Production/Assembly Process

A. Mechanical Section Frame Construction:

- We began by cutting the steel pipes to the desired measurement, with the use of measuringtape and an angle grinder. After cutting, the steel pipe was then placed on the working table.
- The Frame/chassis was constructed according to the information or measurements obtainedfrom solid works.
- Tack welding was made to hold the steel together. Try-square was then used to make sureall the angles were correct.
- The front fork/tire was then attached and set at an angle of 70 degrees to the horizontalbase. A spirit level was used to make sure both sides of the fork were aligned properly.
- After the front fork/tire was attached, we started building the framework up to the rear end.
- We then added the rear wheels to the chassis.
- We then started attaching steel pipes to form the rear structure.
- After all the steel construction work was completed, proper measurement of the frame wascarried out to make sure it was perfect and the frame was fully welded together.

Braking System Construction

- We installed the braking system which includes the drum brake for the front wheel and thedisc brake for the back.
- We also connected the brakes to the handlebar and ensured proper functionality.
- The brakes were bled and the cables were properly checked to make sure it's in good condition.

B. Electrical Section

- The electric motor, charge controller, battery, and BMS were attached to the frame.
- The battery was mounted securely on the tricycle frame to ensure proper weight distribution.
- We then connected the motor and battery using appropriate wiring and connectors.
- We installed the motor controller which regulates the power flow from the battery to the motor.
- The controller was then connected to the throttle and other control mechanism.
- We ensured proper insulation and protection against water and other elements.

3.2.4 Tricycle Test Run

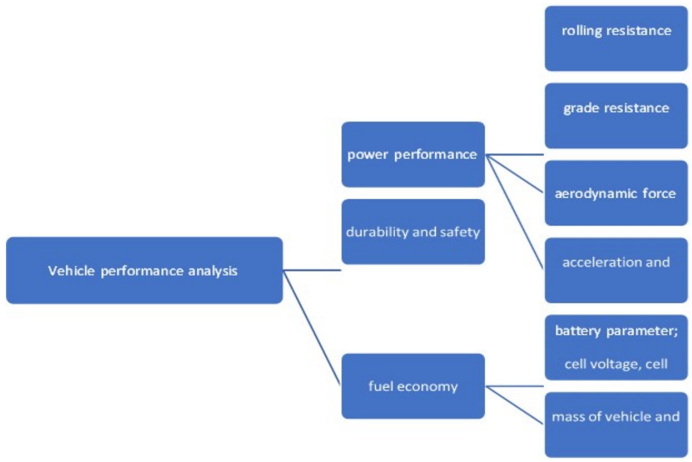
- We conducted a proper inspection of the tricycle by creating a list of all the necessary checks, double checking all connections and components; welding joints, bolts, and nuts were properly tightened. All this is to ensure the tricycle is safe for testing.
- We conducted a test on the electrical system, motor, throttle, and brakes for proper functionality.
- We made necessary adjustments where necessary.
- We took the tricycle on a road test to ensure all systems were working properly.
- We tested to check the speed, durability, and how long the battery will last.
- We did a proper inspection after the test drive to ensure the tricycle was perfect and safe for use.

3.2.5 Finishing Section

- After the testing is completed, the tricycle will be dismantled and proper finishing processes will be carried out.
- The welded joints were properly grinded to a fine smooth surface using the angle grindingmachine.

- Sandpaper was used to give a nice smooth finish surface.
- The frame would then be properly washed down with detergents and water to remove allforms of grease and oil from it.
- After drying, we then sprayed it with a primer coat to prepare it for the paint job.
- Thereafter, the frame was properly painted to its desired color.
- After the paint dries up, the tricycle will be assembled.
- After assembling, we conducted another test drive to make sure everything was in good condition and all systems were working properly.

3.2.6 Analysis



Traction Force (Positive force)

- The amount of force that is developed by the power-producing unit of the vehicle. Inthis case; the electric motor with a battery pack

Net Force

- Net force (used for vehicle propulsion) = Traction force - Resistive force

Forces

Grade Resistance	Aerodynamic force	Acceleration force	Rolling resistance
• when a vehicle goes up or down a slope, its weight produces a component, which is always directed to the downward direction • Grade resistance = GVW*Sin(Θ) • Θ is the inclination angle • GVW= Gross Vehicle Weight	• vehicle travelling at a particular speed in air encounters a force resisiting its motion • aerodynamic force= $0.5*\rho*C_D*A*V^2$ • ρ- air density, C_D-drag coefficient, A-frontal area, V-vehicle speed	• force that the vehicle has to overcome due to acceleration of the vehicle. • Acceleration Force = M*a • M- mass of the vehicle • a-acceleration of the vehicle.	• force that a vehicle must overcome due to the rollibg motion between the wheels and the surface of motion of the vehicle • rolling resisitance = GVW * C_{rr} • C_{rr}- Coefficient of rolling resistance

Table 4. *% Contribution to Total Running Resistance*

Running Resistance	
Components	% Contribution to Total RunningResistance
Aerodynamic resistance	45-55
Tyre rolling resistance	35-45
Drivetrain Components	5-10
Brake pads	4-5
Wheel hub	2-4

Source: https://www.researchgate.net/figure/runningresistance

Rolling Resistance

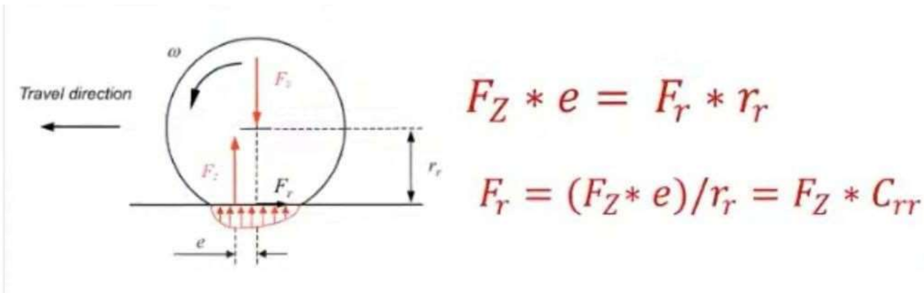


Fig. 19. *Schematics of the Rolling Resistance of the Tyres*

Where F_Z= the gross weight of the tricycle F_r= the rolling resistance force
C_{rr}= the coefficient of rolling resistance of the tire to the road

Table 5. *Rolling Resistance Data for Tricycles*

Parameters	Mean rolling resistance coefficient	SD rolling resistance coefficient	Coefficient of Variation [%]
Surfacing			
Bituminous	0.002	0.001	29%
Grass	0.007	0.002	23%
Gravel	0.006	0.002	33%
Sand	0.030	0.006	18%
Tyre inflation pressure			
180kPa	0.012	0.011	91%
250kPa	0.012	0.011	94%
500kPa	0.011	0.012	114%
Cyclist mass			
70kg	0.011	0.012	107%
80kg	0.012	0.011	98%
90kg	0.012	0.011	93%
Wheel diameter			
26in.	0.013	0.013	100%
29in.	0.010	0.009	93%
Suspension type			
Hardtail	0.011	0.012	103%
Full suspension	0.012	0.011	95%

Source:https://www.researchgate.net/figure/MEAN-AND-STANDARD-DEVIATION-OF-ROLLING-RESISTANCE-COEFFICIENTS-FOR-ALL-PARAMETERS_tb

Aerodynamic Force

Aerodynamic force, $F_a = 0.5*\rho*C_D*A*V^2$

Where ρ= air density, C_D= Coefficient of drag, A= Frontal area of the tricycle, V= velocity

The frontal area of a vehicle is what the air sees as you propel the tricycle forward while thecoefficient of drag is how aerodynamic the basic shape is through air.

Table 6. *Data for Coefficient of Drag of Vehicles*

Vehicle Description	Coefficient of Drag
Experimental	**0.17**
Sports	**0.27**
Performance	**0.32**
Sedan	**0.34**
Motor cycle	**0.50**
Truck	**0.60**
Tractor	**0.60**

Source: http://www.bgsoflex.com/airdragchart.html

Calculations

Mass of Tricycle= 118kg Average weight of driver = 80kg

Gross Vehicle Weight (GVW) = 118 +80 =198kg

Wheel revolution per minute(rpm)

V= ωr; where V- velocity of the wheels, ω= angular speed, r= radius of the wheelsV= 30kmph=9.72m/s, r=0.1185m

8.33=ω*0.1185 $\longrightarrow$ ω=70.32 rad/s

ω= 2πN/60 $\Longrightarrow$ 70.32= 2πN/60; N_{wheel}= 672 rpm

Calculation for TorqueRolling Resistance

Rolling resistance, Fr= GVW*C_{rr}= (118+80) *9.81 * 0.006= 11.65Nthe value of C_{rr} is gotten from table 5 from that of gravel.

Grade Resistance

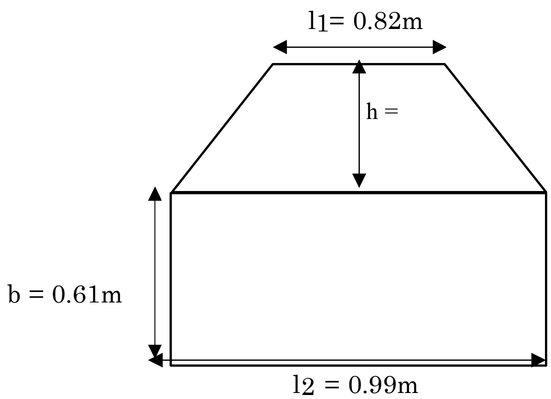
Grade Resistance, F_{grade}= GVW*Sin(Θ); Θ= 0; assuming movement on a flat road.Therefore, F_{grade}= 0N

Aerodynamic Force

Aerodynamic Force, F_{aero}= 0.5*ρ*C_D*A*V^2

ρ = 1.225 kg/m3, C_d=0.5 from table 6 (i.e data for motorcycle), V= 11.11m/s

A= frontal area. In the case of our project, the frontal shape is a composite shape of a trapeziumand a rectangle.



Area of trapezium = 0.5 * (l_1 + l_2) h = 0.5 * (0.82 + 0.99) 0.4= 0.362m^2

Area of rectangle = l_2*b= 0.99*0.61= 0.6039m^2

Frontal Area = Area of Trapezium + Area of rectangle = 0.362 + 0.6039 = 0.9659m^2

Aerodynamic Force, F_{aero}= 0.5*1.225*0.17*0.9659*8.33^2

=6.98N

Acceleration Force

Acceleration force, Fa = Mass of vehicle * acceleration

= 198*1=198N

F_{net} = $F_{traction}$- (F_{roll} + F_{grade} + F_{aero})$F_{traction}$ = F_{net} + F_{roll} + F_{grade} + F_{aero}

= 198 + 11.65 + 0 + 6.98

= 216.63N

Wheel torque and rpm calculationTorque = Force * radius of wheel

= 216.63* 0.1185 = 25.67Nm

Wheel torque = 25.67Nm

N_{Motor}/N_{wheel} = P; where P is the gear ratio.N_{Motor} / 672 = 5

N_{Motor} = 3360 rpm

T_{wheel}/T_{motor} = P; where T is the torque.T_{motor} = T_{wheel}/N

T_{motor}= 25.67/5 = 5.13Nm

Using an efficiency of 0.84; T_{motor} = 5.13/0.84 = 6.11Nm Power of electric motor = T_{motor} * (2π*N_{Motor})/60

= 6.11 * 2π*3360 / 60

= 2149.85W= 2.15kW

4. Results

4.1.1 Different Views of the Electrically Powered Tricycle

Fig. 20. *Realistic View of the Electrically Powered Tricycle*

Fig. 21. *Realistic Side View of the Electrically Powered Tricycle*

Fig. 22. *Realistic Front View of the Electrically Powered Tricycle*

4.1.2 Results Gotten from the Analysis

From the calculations obtained from the analysis, we arrived at the power and other parameters ofthe electric motor that would smooth the design of our electrically powered tricycle. The parameters are as follows;

Table 7. *Electric Motor Specifications*

Parameters	Values
Power rating	**2200W**
Voltage	**60/72V DC**
Current	**<= 46.0/38.0A**
Minimum Revolution PerMinute (RPM)	**2850RPM**
Torque	**7.2 Nm**
Efficiency	**>= 84%**
Maximum RPM	**4800RPM**

Source: Field Work, 2023.

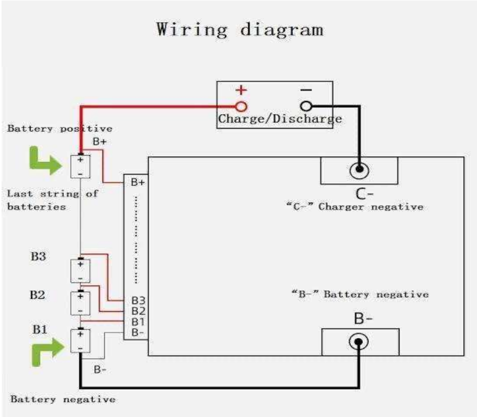
Table 8. *Battery Specifications*

Parameters	Values
Voltage	**72V**
Current	**50A**
Charging Time	**1hour**

Source: Field Work, 2023.

The battery is a combination of parallel and series connections. Parallel to Increase the currentand Series to increase the voltage.
Series (17 cells) = 12v
6 (series cells) connected in parallel= 72v
The charger is an 8A charger that charges in less than 2 hours.

Lithium battery lifetime can be counted in cycles. Brand new has 500 cycles. Each charge anddrain is a cycle. Then to calculate the cycle, is 500/365.



Source: Field work, 2023.

Fig. 23. *Wiring Diagram*

4.1.3 Estimated Mass properties of E-Trike

Configuration: Default Coordinate system: -- Default –
Mass = 118270.80 grams Volume = 49710314.39 cubic millimetersSurface area = 11199928.18 square millimeters
Center of mass: (millimeters)X = 372.61
Y = 371.79
Z = 202.66

Principal axes of inertia and principal moments of inertia: (grams * square millimeters)Taken at the center of mass.

Ix = (0.00, 0.16, 0.99) Px = 9155096789.66
Iy = (1.00, 0.01, 0.00) Py = 24992243698.60
Iz = (-0.01, 0.99, -0.16) Pz = 27571084213.78
Moments of inertia: (grams * square millimeters)

Taken at the center of mass and aligned with the output coordinate system.

Lxx = 24991993781.10	Lxy = 2396507.86	Lxz = -72854649.50
Lyx = 2396507.86	Lyy = 27119234248.38	Lyz = 2848793839.23
Lzx = -72854649.50	Lzy = 2848793839.23	Lzz = 9607196672.56

Moments of inertia: (grams * square millimeters)Taken at the output coordinate system.

Ixx = 46198120580.73	Ixy = 16386729654.58	Ixz = 8858297295.67
Iyx = 16386729654.58	Iyy = 48397299147.94	Iyz = 11760360462.96
Izx = 8858297295.67	Izy = 11760360462.96	Izz = 42375941929.90

4.1 Discussion

The electrically powered tricycle was first designed using CAD software i.e. SolidWorks, where the various dimensions were incorporated. We were able to incorporate some features like the horn, trafficator, headlight, and rear light for a good driving experience and safety.

The duration for the production of the tricycle lasted for fourteen weeks. We had some setbacks during the production stage such as;

Technical issues on the electric motor where the mechanical brake and electric brake were working against each other causing a continuous breakage. We then had to uncouple the electric motor and controller with the supervision of an electrician and we had to bypass the sensors of the electrical brake to make way for the mechanical brake to work.

Another challenge we encountered was when the electric motor developed a fault. Days after thorough analysis, it was discovered that the motor controller was the problem. We went as far as rechecking the battery voltage and testing all the MOSFETs in the controller system. It was then discovered that the 12 NDP 1991 MOSFET supplying current to the electric motor was opened. The reason why this happened was not known but with the help of an electrician, he assisted us repulsed the faulty MOSFET. The electric motor came without an instruction wiring manual. This was one of the biggest challenges we faced. With the help of the internet (Google, YouTube) and consulting electricians, we were able to solve this problem and make all the connections perfectly.

Another problem we faced was the choice of transmitting the power from the electric motor to the driving wheel. We thought of using a direct axle where the power would be transmitted directly from the electric motor to the drive shaft but because of the chances of chain spillage, the idea was not applicable. Another setback that hindered us from using the direct axle was it posed a challenge when making a turn at a corner. To solve this, we chose to use a differential from a 1900 Mercedes.The differential solved our turning problem but another issue we had is that differentials are made to reduce the high speed of the transmission. The speed of our electric motor did not match up with what the usually ought to produce. This affected the overall speed of our tricycle.In the process of solving the speed problem, the speed control switch we ordered from an e-commerce website (Alibaba) did not match the power of the controller so it burnt.

The battery we used in powering the motor is lithium-ion. The battery was locally built here in Uyo. The battery was specifically built to match the power rating of the electric motor. The charging time for the battery spans from about 30 minutes to an hour. The battery lasts for about four (4) hours.

Additionally, user experience and safety were key considerations in the design and production of the tricycle. Factors such as ride comfort, ease of use, braking efficiency, stability, and control responsiveness were considered, ensuring that the tricycle offered a safe and enjoyable mode of transportation.

The results of the project demonstrated the success of the design, production, and analysis efforts. The electrically powered tricycle exhibited commendable power efficiency, extended range, and satisfactory performance across different road conditions. The positive user experience, enhanced safety features, and appealing design contribute to its overall appeal and market viability.

5. Conclusion

This project successfully achieved its objectives of developing an innovative and sustainable transportation solution. By utilizing electric power as the primary propulsion source, this tricycle showcases the potential for improved energy efficiency and reduced environmental impact compared to traditional gasoline-powered vehicles. Through careful design and integration of electrical components, the tricycle was manufactured to meet safety and performance standards. Various tests and analyses were conducted to evaluate its power efficiency, range, speed capabilities, maneuverability, ergonomics, stability, and user experience. The results demonstrated promising outcomes, showcasing efficient energy consumption, extended range, and satisfactory performance across different road conditions.

This project contributes to the growing field of sustainable transportation by providing a practical example of an electric-powered tricycle. The design, production, and analysis presented here serveas a foundation for further research and development in this area, inspiring the advancement of cleaner and more efficient modes of transportation. By promoting electric-powered vehicles like this tricycle, we can work towards reducing carbon emissions, minimizing our dependence on fossil fuels, and creating a greener future. This project encourages the adoption of eco-friendly transportation options that align with the goals of environmental sustainability. From the objectives of our project, we were able to design, produce, and analyze an electrically powered tricycle considering different factors such as cost, availability of local materials, noise, and air pollution so as not to pose health challenges to society. From the result, it is shown that the electric tricycle can carry about 3 people (including the driver) with an average weight of 80kg per person. In summary, the successful implementation of this project offers a compelling case for embracing EVs asa viable and environmentally friendly alternative. It demonstrates the potential for innovation and positive change within the realm of transportation.

5.1 Recommendation

Further work can be done on this project by incorporating smart devices like remote control, android systems that can be accessible using a mobile app, and security features like Face ID, fingerprint, etc. An external battery can be integrated into the Battery Management System to power the tricycle for about twelve hours.

Due to our research, we propose mass production of this electrically powered tricycle for efficient and effective transportation of people without fossil fuel as well as its environmentally friendly features; since it does not contribute to the greenhouse effect. It also operates without excessive noise.

Compliance with Ethical Standards

Conflicts of interest: Authors declared that they have no conflict of interest.

Human participants: The conducted research follows the ethical standards and the authors ensured that they have not conducted any studies with human participants or animals.

References

[1] Parab, A., Kamath, A., Rajpurohit, S. and Mulla, Z., "Urban Electric Bike", IJSRD-International Journal for Scientific Research & Development, Vol. 3(02), pp.2321-0613, 2015.

[2] Akshay, N. Khonde, Aditya R. Ughade, Kapil D. Warghane and Rajat R. Vidhale, "*Students, Performance Evaluation of Electric Bicycles"*, IARJSET ISSN (Online) 2393-8021 ISSN (Print) 2394-1588 International Advanced Research Journal in Science, Engineering and Technology, Agni-Pankh 16-Jawaharlal Darda Institute of Engineering and Technology, Yavatmal-Vol. 4, Special Issue 3, January 2017.

[3] American Century Investment., "ESG Focus - *The Acceleration of Electric Mobility", American Century,* July 2020.

[4] Black, A., Barnes, J., Makundi, B. and Ritter, T., "Electric two-wheelers in Africa? Markets, production and policy", In Proceedings of the Conference on Green Transformation and Competitive Advantage. Evidence from Developing Countries, Bonn, Germany (pp. 18-19), 2018, June.

[5] Arup., "The Electric Vehicle revolution: why it's already time to invest in the grid", 2021, January 01. Retrieved from https://www.arup.com/perspectives/the-electric-vehicle-revolution- why-its-already-time-to-invest-in-the-grid

[6] Beama., "*A Guide to Electric Vehicle Infrastructure",* 2015. Retrieved from www.beama.org.uk:https://www.beama.org.uk/static/uploaded/5e9d2696-bec8-4179- 956bedf5655a0272.pdf

[7] Dericioglu, C., YiriK, E., Unal, E., Cuma, M.U., Onur, B., and Tumay, M., "A review of charging technologies for commercial electric vehicles", International Journal of Advances on Automotive and Technology, Vol. 2(1), pp.61-70, 2018.

[8] Abagnale, C., Cardone, M., Iodice, P., Strano, S., Terzo, M. and Vorraro, G., "A dynamic model for the performance and environmental analysis of an innovative e-bike.", Energy Procedia, Vol. 81, pp.618-627, 2015.

[9] Smith, M. and Castellano, J., "Costs associated with non-residential electric vehicle supply equipment: Factors to consider in the implementation of electric vehicle charging stations" (No. DOE/EE-1289), 2015.

[10] Chan, C.C. and Chau, K.T., "Modern electric vehicle technology" (No. 47). Oxford University Press, USA, 2001.

[11] Chau, K.T., "Electric motor drives for battery, hybrid and fuel cell vehicles. Electric vehicles: technology", research and development, 2009.

[12] G.B. (Ed.): "Electric Vehicles: Technology, Research and Development", Nova Science, NewYork, pp.1–40, 2009.

[13] Chau, K.T., "Hybrid vehicles", Alternative Fuels for Transportation, pp.361, 2010.

[14] Chau, K.T., "Hybrid vehicles. Alternative Fuels for Transportation", pp.361, 2010.

[15] Chau, K.T. and Li, W., "*Overview of electric machines for electric and hybrid vehicles", (Invited Paper) International Journal of Vehicle Design,* Vol. 64, No. 1, pp.46–71, 2014).

[16] Mahindrakar, S. and Deka, J., "An Improved & Efficient Electric Bicycle system with the Power of Real-time Information Sharing".

[17] Outram, C., Ratti, C. and Biderman, A., "The Copenhagen Wheel: An innovative electric bicycle system that harnesses the power of real-time information and crowd sourcing", Exhibition & Conf. on Ecologic Vehicles & Renewable Energies, 2010.

[18] Clement, K., Haesen, E. and Driesen, J., "Coordinated charging of multiple plug-in hybrid electric vehicles in residential distribution grids", In 2009 IEEE/PES Power Systems Conference and Exposition (pp. 1-7). IEEE, 2009, March.

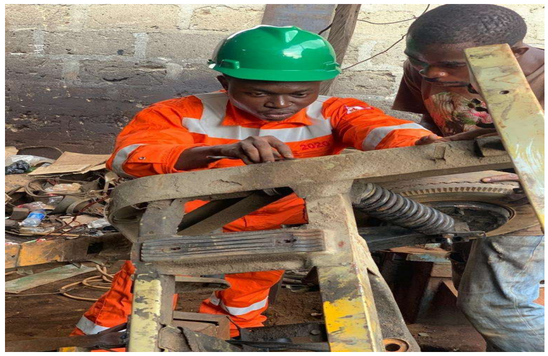
[19] Dekra., "*E-mobility Testing", 2018*. Retrieved from www.dekra-product-safety.com: https://www.dekraproduct-safety.com/en/solutions/testing-inspection/e-mobility-testing

[20] Covill, D., Blayden, A., Coren, D. and Begg, S., "Parametric finite element analysis of steel bicycle frames: the influence of tube selection on frame stiffness", Procedia Engineering, Vol. 112, pp.34-39, 2015.

[21] Derek Covilla, Steven Begga, Eddy Eltona, Mark Milnea, Richard Morrisa and Tim Katza (2014). *Parametric Finite Element Analysis of Bicycle Frame Geometries*, Science Direct Ekseveir Procedia Engineering 72 pp. 441 – 445.

[22] Ehsani, M., Gao, Y. and Emadi, A. "*Modern Electric, Hybrid Electric, and Fuel Cell",* 2010.
[23] Fajri, P. and Asaei, B., "*Plug-in hybrid conversion of a series hybrid electric vehicle and simulation comparison"*, 11th International Conference on Optimization of Electrical andElectronic Equipment, 2008. OPTIM 2008, IEEE, May, pp.287–292, 2008.
[24] Fenton, J. and Hodkinson, R., "*Lightweight Electric/Hybrid Vehicle Design"*, Elsevier Gogoro, 2001.
[25] Green Policy Platform., "*Electric Two Wheelers in Africa".* 2011. https://www.greengrowthknowledge.org/sites/default/files/Electric%20two- wheelers%20in%20Africa.
[26] Hajimiragha, A., Canzares, C.A., Fowler, M.W. and Elkamel, *"Optimal transition to plug-in hybrid electric vehicles in Ontario, Canada, considering the electricity-gridlimitations*", IEEE Trans. Ind. Electron, Vol. 57, No. 2, pp.690–701, A. 2010.
[27] Hannan, M., Azidin, F. and Mohamed, A., "*Hybrid electric vehicles and their challenges:a review"*, Renewable and Sustainable Energy Reviews, Vol. 29, pp.135–150, 2014.
[28] Holmes, G. S (2012). *Electric Automobile. How Products are Made*. http://www.madehow.com/Volume- 5/ElectricAutomobile.html.
[29] https://www.elprocus.com/different-types-of-electric-motors/
https://www.todayifoundout.com/index.php/2011/04/in-1899-ninety-percent-of-new-york-citys-
[30] taxi-cabs-were-electric-vehicles/
[31] Ian Vince McLoughlin, Komang Narendra, Leong Hai Koh, Quang Huy Nguyen, Bharath Seshadri, Wei Zeng, Chang Yao, (2012). *Campus Mobility for the Future: The ElectricBicycle, Journal of Transportation Technologies,* pp. 1-12.
[32] ICCT. (January 24, 2019). *US Charging Gap*. ICCT
[33] IRENA. (2019, May). *Innovation Outlook. Retrieved from Smart Charging for Electric Vehicles:*https://www.irena.org//media/Files/IRENA/Agency/Publication/2019/May/IREN A_Innovation_Outlook_EV_smart_charging_2019.pdf
[34] Jasprit S Gill, P. B. (2014*). Infrastructure Cost Issues Related to Inductively Coupled PowerTransfer for Electric Vehicles*. South Carolina: Elsevier B.V.
[35] K. Schleinitz , T. Petzoldt , L. FrankeBartholdt , J. Krems , T. Gehlert, (2015). *The German*
[36] *Naturalistic Cycling Study – Comparing cycling speed of riders of different e-bikes andconventional bicycles,* Science Direct Ekseveir.
[37] M. Reddi Sankar, T. Pushpaveni, V. Bhanu Prakash Reddy (2013). *Design and Development of Solar Assisted Bicycle,* International Journal of Scientific and Research Publications, Volume3, Issue 3, March 2013 ISSN 2250-3153
[38] *Permanent magnet vs. induction motors*. Turbomachinery International. United States: MJH lifesciences. March 7, 2015. Retrieved November 8, 2021.
[39] Rahul Sindhwani, Punj L. Singh, Anjum Badar and Ankur Rathi (2014*). Design Of Electric Bike with Higher Efficiency, International Journal of Advance Research and Innovation* Volume2, Issue 1 (2014) 247-251 ISSN 2347 – 3258
[40] Rajendra Beedu, Ankit, Mohmed Asif Shaik and Sushant Jain (2014). *Design, Fabrication and Performance Analysis Of Solar Power Bicycle,* International Journal of Renewable Energyand Environmental Engineering ISSN 2348-0157, Vol. 02, No. 03, July, 2014
[41] Rajendra Beedu (2015). *Performance Evaluation of Electric Bicycles*, IJRET: International Journal of Research in Engineering and Technology ISSN: 2319-1163 | ISSN: 2321-7308July-2015.
[42] Rao, Z. and Wang, S. (2011) *'A review of power battery thermal energy management', Renewableand Sustainable Energy Reviews,* Vol. 15, No. 9, pp.4554–4571.
[43] R.S Jadoun, Sushil Kumar Choudhary, (2014). *Design And Fabrication of Dual Chargeable Bicycle, Innovative Systems Design and Engineering*, www.iiste.org ISSN2222-1727 (Paper)ISSN 2222-2871 (Online) Vol.5, No.8.
[44] Stephan, C.H. and Sullivan, J., "*Environmental and energy implications of plug-in hybridelectric vehicles"*, Environ. Sci. Technol., Vol. 42, No. 4, pp.1185–1190, 2008.
[45] V. Sarath Teja, D.V.S.S.S.V. Prasad, K.S.B.S.V.S. Sastry (2011). *Numerical Study on Materialsand Design Optimization of a Bicycle Frame.*
[46] Wee, J.H. (2010*) 'Contribution of fuel cell systems to CO2 emission reduction in their applicationfields'*, Renewable and Sustainable Energy Reviews, Vol. 14, No. 2, pp.735–744.
[46] F (2012). The SmarterWay Forward: Swap & Go. Retrieved from www.gogoro.com: https://www.gogoro.com/

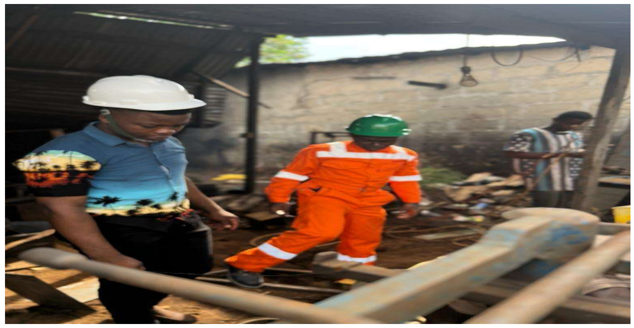
APPENDICES



Appendix 1. *Tightening of Bolts and Nuts of Various Parts of the Tricycle*

Appendix 2. *Cutting and Welding Operation*

Appendix 3. *Alignment of Various Parts of the Tricycle*



Appendix 4. *Inspecting the Equipment*

Appendix 5. *Taking the Measurements Accurately*

Appendix 6. *Assembly of Components*

Appendix 7. *Welding of the Metals*

Appendix 8. *Installation of the Rear Lights*

Appendix 9. Spray Painting the Tricycle

Appendix 10. *Sand Papering the Metal sheets*