

**ELECTRIC BICYCLE UPGRADE: ENHANCING BATTERY LIFE, LIGHTING
SYSTEM, AND CABLE INFRASTRUCTURE FOR OPTIMAL
PERFORMANCE**

BY

NWABUDIKE SAMUEL AYOMIKUN

ENG1805189

UNIVERSITY OF BENIN

BENIN CITY

APRIL, 2024

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**A PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF
INDUSTRIAL ENGINEERING, FACULTY OF ENGINEERING, UNIVERSITY
OF BENIN, BENIN CITY**

**IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD
OF BACHELOR OF ENGINEERING (B.Eng) DEGREE IN INDUSTRIAL
ENGINEERING**

APRIL, 2024

CERTIFICATION

This is to certify that this project was carried out by **NWABUDIKE SAMUEL AYOMIKUN** with matriculation number **ENG1805189** of the department of Industrial Engineering, Faculty of Engineering, University of Benin, Edo state, Nigeria.

Engr. (Dr.) Collins. E. Etin-Osa

Project Supervisor

Date

Engr. (Dr.) M. Etuk

Project Co-ordinator

Date

Prof. R.O Edokpia

Head of Department

Date

DEDICATION

This project is dedicated to the Giver of life and the Source of infinite wisdom, Jehovah God who has imparted wisdom, knowledge and understanding to me all these years.

ACKNOWLEDGEMENT

My utmost appreciation goes to God, for seeing me through all my years in school.

I am thankful and immensely grateful to my project supervisor, Engr.(Dr.) C.E. Etin-Osa for your patience, motivation, guidance, and immense support throughout my time at the University of Benin.

To my project group members, you've been instrumental in this journey. And to the many others whose names time will fail me to recount, you have all played a significant part in making this project a reality. I am deeply appreciative of your contributions and support.

ABSTRACT

This project focuses on the upgrade of an electric bicycle to enhance its performance and range. The objective is to improve the distance travelled and charging power of the bicycle through technical enhancements and component upgrades. Methods include the integration of advanced battery technology, indication upgrade, and enhancements to the control systems. Results demonstrate significant improvements in speed, range, and overall user experience. The findings of this project contribute to the advancement of electric bicycle technology, offering insights into potential upgrades for future models."

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CHAPTER ONE

1.0. INTRODUCTION

1.1 RESEARCH BACKGROUND

The global pursuit of the United Nations Sustainable Development Goals (SDGs) has underscored the need for a radical shift towards sustainable transportation systems. In Nigeria, the recent elimination of fuel subsidies marks a significant economic reform that has substantially influenced transportation dynamics (Inegbedion et al, 2020). The resulting surge in commuting expenses has driven individuals to explore alternative transportation solutions that are both sustainable and affordable.

One such innovative approach is converting traditional pedal bicycles into electric bicycles (Matey, 2017; Lemire-elmor, 2020; Schneider, 2021). Given the lack of immediate government support, this conversion method not only addresses pressing transportation needs but also contributes to the reduction of carbon emissions on Nigerian roads.

Electric bicycles typically fall into one of three categories: pedal-assist (pedelec), throttle-on-demand, or speed pedelec (Cherry & Cervero, 2007). Pedal-assist electric bicycles provide electric assistance only when the rider is pedaling, while throttle-on-demand electric bicycles can be propelled without pedaling. Speed pedelecs offer electric assistance up to higher speeds but often require special licensing and regulations (Gan et al., 2020).

However, one significant limitation of electric bicycles is their range, which determines the distance they can cover on a single battery charge. This limitation can hinder their widespread adoption, particularly for users who require longer travel distances (Cherry & Cervero, 2007).

Therefore, it is crucial to explore potential solutions to extend the range of the bicycles, promoting their viability as a sustainable transportation option.

Amidst Nigeria's evolving landscape, the lack of immediate government actions necessitates individual creativity and adaptability (Khalid et al, 2014). The conversion of traditional bicycles into electric bikes signifies a grassroots initiative that tackles current challenges while supporting global sustainability goals. By embracing this transformation, individuals can maintain mobility without relying on conventional fuel-based vehicles (Brand & Thompson, 2019). Consequently, the conversion exemplifies the potential for individuals to drive change and influence the future of transportation.

Generally, it's mostly used in small and less populated urban environment in order to avoid congestions and traffic. Also, due to their ease of riding, the electric bicycle has become very popular across some individuals and used as a form of recreational activities, exercising and as light transportation between places or rural businesses.

1.2 STATEMENT PROBLEM

Upon consideration of the working systems and environment in which the electric bicycle thrives and comparing it to the Nigerian environment, we have been able to identify a series of problems which might affect its operation.

Nigeria has not yet been able to attain a stable and uninterrupted power supply and additionally, there are still very few charging stations in Nigeria so the Electric Bicycle won't be able to be charged regularly.

To combat this problem, we provided an upgrade to the version of an electric bicycle which will be outlined in the proposal before you.

1.3 AIMS AND OBJECTIVES

The Aims and Objectives of this study are as stated below;

1.3.1. AIMS

Our aim is the upgradement of an electric bicycle designed by Dr. Collins Etin-nosa

1.3.2 OBJECTIVES:

Our primary objectives are to guide us throughout this project:

1. Increasement of the range of the Electric Bicycle.
2. Replacement of the lightning system (headlight, indicators).
3. Replacement of the alarm systems

1.4 PROJECT SCOPE

The scope of this project is the upgrading of an Electric Bicycle. The project will include the working on the battery system, lightning system and the synchronisation of needed components or accessories.

1.5 SIGNIFICANCE OF THE PROJECT

- Addressing immediate transportation needs
- Contribution to environmental sustainability
- Promotion of physical activity and health

- Encouragement of grassroots innovation and self-sufficiency.
- Supporting of the Global Sustainability Goals

CHAPTER TWO

2.0 HISTORY OF ELECTRIC BICYCLES

Electric bicycles have undergone significant evolution over the years, transforming from basic pedal-assist bicycles to sophisticated electrically powered vehicles that offer a viable alternative to traditional modes of transportation (Brand & Thompson, 2019).

The concept of electric bicycles dates back to the late 19th century, with early attempts to incorporate electric motors into bicycles for propulsion (Matey, 2017). However, it wasn't until the late 20th century that they gained traction, particularly in regions where environmental concerns and urban congestion necessitated alternative transportation solutions (United Nations, 2015). The development of lightweight and efficient electric motors, coupled with advancements in battery technology, played a significant role in the proliferation of the bicycles in the modern era.

Over the years, electric bicycle have seen considerable technological advancements aimed at enhancing performance, comfort, and usability. Early electric bicycles were characterized by heavy and bulky designs, limited range, and relatively low power output (Khalid et al., 2014). However, advancements in battery technology, particularly the widespread adoption of lithium-ion batteries, have led to lighter and more energy-dense power sources, significantly improving their range and efficiency (Battery University, 2023). Additionally, advancements in motor technology, such as the development of brushless hub motors, have contributed to smoother and more efficient propulsion systems (L-faster, 2023).

In recent years, electric bicycle have witnessed a surge in popularity, driven by a combination of factors including environmental awareness, urbanization, and changing consumer preferences (World Bank, 2022). They offer a convenient and eco-friendly alternative to traditional vehicles, particularly for short-distance commuting and recreational purposes (Al Jazeera, 2023). Moreover, the COVID-19 pandemic has further accelerated their adoption as people seek safer and more socially distant modes of transportation (Schneider, 2021). As a result, sales have soared in various markets around the world, underscoring the growing importance of electric bicycles in the global transportation landscape.

2.1 BENEFITS OF ELECTRIC BICYCLE

2.1.1 Environmental Advantages of Electric Bicycles

Electric bicycles offer several environmental advantages, making them a sustainable alternative to traditional gasoline-powered vehicles. The reduction in emissions contributes to mitigating the impact of transportation-related pollution on climate change and improves air quality in urban areas (Raynolds, 2023).

One of their key environmental benefits lies in the fact that they have lower manufacturing emissions and require fewer resources to produce compared to cars, further reducing their environmental footprint over their lifecycle (Raynolds, 2023).

Furthermore, this bicycles facilitate a shift towards more sustainable transportation modes, reducing dependence on fossil fuels and promoting active mobility (Brand et al., 2022). By encouraging cycling as a viable means of transportation, they contribute to creating healthier and more environmentally friendly cities (United Nations, 2015).

Overall, the environmental advantages of electric bicycle make them a valuable tool for addressing climate change, reducing air pollution, and promoting sustainable urban development. By embracing e-bikes as a mode of transportation, individuals and communities can play an active role in building a more sustainable and resilient future.

2.1.2 Health and Fitness Benefits of Electric Bicycles

Electric bicycles offer a range of health and fitness benefits, combining the convenience of motorized transportation with the physical activity associated with cycling. While electric bicycles provide electric assistance for propulsion, riders still engage in pedaling, which contributes to improved cardiovascular health, muscle strength, and overall fitness (Brand et al., 2022).

Research has shown that their riders tend to cycle longer distances and more frequently compared to traditional cyclists, leading to greater levels of physical activity and potential health benefits (Brand & Thompson, 2019). Moreover, electric bicycle enable individuals with varying fitness levels and physical abilities to enjoy cycling and reap the health benefits associated with active transportation (Raynolds, 2023).

One of the key advantages of electric bicycles is their ability to encourage physical activity among populations who may not engage in regular exercise otherwise. For individuals who find traditional cycling challenging due to factors such as age, fitness level, or physical limitations, electric bicycle offer a more accessible and enjoyable alternative (Matey, 2017).

Additionally, electric bicycles can serve as a mode of active transportation for commuting, errands, and recreational purposes, providing opportunities for individuals to incorporate physical activity into their daily routines (United Nations, 2015). By promoting cycling as a

means of transportation, electric bicycles contribute to improving public health outcomes, reducing sedentary behavior, and combating lifestyle-related diseases such as obesity and diabetes (Kim et al., 2014).

2.1.3 Economic Advantages of Electric Bicycles

Electric bicycles offer significant economic advantages over traditional gasoline-powered vehicles, making them an attractive option for both individuals and communities.

1. **Lower Operating Costs:** Electric bicycles are significantly cheaper to maintain compared to automobiles. Unlike cars, they do not require regular trips to the gas station or expensive repairs, resulting in lower ongoing expenses for users.

2. **Affordable Initial Investment:** Electric bicycles are often more affordable to purchase initially compared to cars or motorcycles. The cost of entry is typically lower, making them accessible to a broader range of individuals, including those from lower-income backgrounds (World Bank, 2022).

3. **Reduced Reliance on Public Transportation:** Electric bicycles can help reduce reliance on expensive public transportation systems, particularly in areas with limited access to affordable transportation options. By providing a convenient and cost-effective mode of personal transportation, they empower individuals to travel independently and avoid the high costs associated with public transit fares (Khalid et al., 2014). This increased autonomy and flexibility can lead to significant savings for commuters over time.

2.2 BATTERY USED IN AN ELECTRIC BICYCLE

A battery is a device that stores energy and then discharges it by converting chemical energy into electricity. Typical batteries most often produce electricity by chemical means through the use of one or more electrochemical cells. Many different materials can and have been used in batteries, but the common battery types are alkaline, lithium-ion, lithium-polymer, and nickel-metal hydride. Batteries can be connected to each other in a series circuit or a parallel circuit.

Batteries provided the primary source of electricity before the development of electric generators and electrical grids around the end of the 19th century. Successive improvements in battery technology facilitated major electrical advances, from early scientific studies to the rise of telegraphs and telephones, eventually leading to portable computers, mobile phones, electric cars, and many other electrical devices.

2.2.1. CLASSIFICATION OF BATTERIES

Batteries are classified as either primary or secondary.

1. Primary Batteries

A primary battery or primary cell is a battery (a galvanic cell) that is designed to be used once and discarded, and not recharged with electricity and reused like a secondary cell (rechargeable battery). In general, the electrochemical reaction occurring in the cell is not reversible, rendering the cell unchargeable. As a primary cell is used, chemical reactions in the battery cell use up the chemicals that generate the power; when they are gone, the battery stops producing electricity. Primary cells are made in a range of standard sizes to power small household appliances such as flashlights and portable

radios. Primary batteries come in various types, like alkaline, lithium, zinc carbon, mercury, normally with a voltage range of between 1.5v-2v.

2. Secondary Batteries

A rechargeable battery, storage battery, or secondary cell (formally a type of energy accumulator), is a type of electrical battery which can be charged, discharged into a load, and recharged many times, as opposed to a disposable or primary battery, which is supplied fully charged and discarded after use. It is composed of one or more electrochemical cells. The term “accumulator” is used as it accumulates and stores energy through a reversible electrochemical reaction. Rechargeable batteries are produced in many different shapes and sizes, ranging from button cells to megawatt systems connected to stabilize an electrical distribution network. Several different combinations of electrode materials and electrolytes are used, including lead–acid, zinc–air, nickel–cadmium (NiCd), nickel–metal hydride (NiMH), lithium-ion (Li-ion), lithium iron phosphate (LiFePO₄), and lithium-ion polymer (Li-ion polymer).

Rechargeable batteries typically initially cost more than disposable batteries but have a much lower total cost of ownership and environmental impact, as they can be recharged inexpensively many times before they need replacing. Some rechargeable battery types are available in the same sizes and voltages as disposable types, and can be used interchangeably with them. Some characteristics of rechargeable battery are given below: hi

- In rechargeable batteries, energy is induced by applying an external source to the chemical substances.
- The chemical reaction that occurs in them is reversible.
- Internal resistance is comparatively low.

- They have a high self-discharge rate comparatively.
- They have a bulky and complex design.
- They have high resell value.

2.2.2 BATTERY FOR ELECTRIC BICYCLES

Batteries for electric bicycles and other vehicles are secondary batteries which can be recharged after been used up.

Energy storage systems, usually batteries, are essential for all-electric vehicles, plug-in hybrid electric vehicles (PHEVs), and hybrid electric vehicles (HEVs).

2.2.3 TYPES OF ENERGY STORAGE SYSTEMS

The following energy storage systems are used in all-electric vehicles, PHEVs, and HEVs

1. Lithium-Ion Batteries

Lithium-ion batteries are currently used in most portable consumer electronics such as cell phones and laptops because of their high energy per unit mass and volume relative to other electrical energy storage systems. They also have a high power-to-weight ratio, high energy efficiency, good high-temperature performance, long life, and low self-discharge. Most components of lithium-ion batteries can be recycled, but the cost of material recovery remains a challenge for the industry. Most of today's all-electric vehicles and PHEVs use lithium-ion batteries, though the exact chemistry often varies from that of consumer electronics batteries.

2. Nickel-Metal Hydride Batteries

Nickel-metal hydride batteries, used routinely in computer and medical equipment, offer reasonable specific energy and specific power capabilities. Nickel-metal hydride batteries have a much longer life cycle than lead-acid batteries and are safe and abuse tolerant. These batteries have been widely used in HEVs. The main challenges with nickel-metal hydride batteries are their high cost, high self-discharge rate, heat generation at high temperatures, and the need to control hydrogen loss.

3. Lead-Acid Batteries

Lead-acid batteries can be designed to be high power and are inexpensive, safe, recyclable, and reliable. However, low specific energy, poor cold-temperature performance, and short calendar and lifecycle impede their use. Advanced high-power lead-acid batteries are being developed, but these batteries are only used in commercially available electric-drive vehicles for ancillary loads. They are also used for stop-start functionality in internal combustion engine vehicles to eliminate idling during stops and reduce fuel consumption.

4. Ultra capacitors

They store energy in the interface between an electrode and an electrolyte when voltage is applied. Energy storage capacity increases as the electrolyte-electrode surface area increases. Although ultra capacitors have low energy density, they have very high power density, which means they can deliver high amounts of power in a short time. Ultra capacitors can provide vehicles additional power during acceleration and hill climbing and help recover braking energy. They may also be useful as secondary energy-storage

devices in electric-drive vehicles because they help electrochemical batteries level load power.

2.3 INTRODUCTION OF MOTOR CONTROLLERS

Motor controllers play a crucial role in regulating the power supplied to the electric motor, thereby determining the performance and efficiency of an electric bicycle (Gan, Dai, Liu, Zhu, Zou & Li, 2020). By processing input signals from various sensors and rider commands, the controller ensures optimal energy usage and manages the motor's speed, torque, and direction of rotation (Khalid, Devotta, Golub & Wohar, 2014). As the brain of the electric bicycle, the motor controller contributes to the overall riding experience and safety.

2.3.1 ROLE OF MOTOR CONTROLLERS

Motor controllers serve as the central nervous system of electric quadracycles, controlling the speed, torque, and direction of electric motors to achieve optimal performance (Chowdhury et al., 2019). By modulating power delivery to the motors, motor controllers enable smooth acceleration, deceleration, and speed regulation, enhancing the overall driving experience and efficiency of electric quadracycles.

2.3.2 TYPE OF MOTOR CONTROLLERS

Various types of motor controllers are utilized, each offering distinct advantages and capabilities:

1. Pulse-Width Modulation (PWM) Controllers:

- PWM controllers are commonly employed to regulate the voltage supplied to electric motors by modulating the width of pulse signals (Chowdhury et al., 2019).

- This technique enables precise control over motor speed and torque, contributing to smoother acceleration and improved efficiency.

2. Field-Oriented Control (FOC) Systems:

- FOC systems utilize sophisticated algorithms to control the magnetic field orientation of motors, enabling precise torque control and improved efficiency (Wang et al., 2021)
- By aligning the magnetic field with the rotor position, FOC systems minimize losses and optimize motor performance across a wide range of operating conditions.

3. Sensorless Control Algorithms:

- Sensorless control algorithms eliminate the need for position sensors by utilizing motor phase currents and voltages to estimate rotor position and speed (Zhang et al., 2018).
- This approach reduces system complexity and cost while maintaining accurate control over motor operation.

2.3.3 DESIGN CONSIDERATION

The design and implementation of motor controllers require careful consideration of various factors:

1. Voltage and Current Ratings:
 - Voltage and current ratings dictate the maximum power output of the motor controller, ensuring compatibility with the DC brushed motors used (Chowdhury et al., 2019).
2. Switching Frequency:
 - Switching frequency affects efficiency and electromagnetic interference (EMI) performance, with higher frequencies enabling faster response times but potentially increasing power losses (Chowdhury et al., 2019).
3. Thermal Management:
 - Efficient thermal management is essential to dissipate heat generated during operation and prevent overheating of electronic components (Luo et al., 2020).
 - Proper heat sinking, cooling systems, and thermal interface materials are employed to manage heat dissipation and maintain component reliability.

CHAPTER THREE

3.0 METHODS AND MATERIALS

3.1 MATERIALS

3.1.1 MODIFIED BICYCLE SELECTION

The bicycle chosen for the upgrade had undergone prior modifications, with several areas identified for further enhancement.



Figure 3.1: The Electric Bicycle before modifications

Notably, the bicycle's battery capacity was inadequate, which limited its range — a constraint that necessitated immediate attention to extend its usability and performance. Other modifications included:

- **Burned Wires:** Significant sections of the electrical wiring had suffered damage due to overheating, resulting in burned wires and compromised connectivity.

- **Mechanical Bell:** An outdated mechanical bell was integrated into the bicycle's signaling system, offering limited functionality and reliability. Upgrading to an electrical bell system promised enhanced performance and convenience for the rider.
- **Manual Charging for Indicator:** The indicator system, crucial for signaling intentions during rides, relied on manual charging for power replenishment. This manual intervention introduced inefficiencies and inconveniences, underscoring the need for automatic charging capabilities.
- **Inadequate Headlight Illumination:** The existing headlight provided insufficient illumination, especially during nighttime rides or low-light conditions. Improving the brightness and efficacy of the headlight was paramount to enhance visibility and safety for the rider.

3.1.2 UPGRADED COMPONENTS OF THE ELECTRIC BICYCLE

The existing electric bicycle underwent an upgrade process involving various components to enhance its performance and functionality. These components included:

- **Battery Fabrication and Enhancement:** The battery system was meticulously fabricated to extend the bike's range and improve overall battery life. High-quality lithium-ion batteries were carefully selected and assembled to form a custom battery pack tailored to the specific requirements of the electric bicycle upgrade project. This involved connecting individual lithium-ion batteries in series, tack welding them securely using a custom tack weld machine, and integrating them with a Battery Management System (BMS) for monitoring and management. The fabricated battery pack featured a capacity of 4.8Ah and a voltage of approximately 37 volts, providing seamless power delivery.

- Headlight
- Wiring
- Bike Indicator
- Electrical Bell

3.1.3 TOOLS AND EQUIPMENT NEEDED FOR THE UPGRADE.

The upgrade process required various tools and equipment to ensure the safe and effective enhancement of the electric bicycle. These included:

1. Pliers: Essential for gripping, bending, and cutting wires during the installation and modification of electrical components.
2. Wire cutter/stripper: Used to cut wires to the desired length and strip insulation for proper connection.
3. Adjustable wrench: Allows for tightening and loosening nuts and bolts of various sizes, ensuring secure attachment of components.
4. Multimeter: Essential for measuring voltage, current, and resistance, helping troubleshoot electrical issues and ensure proper functioning of components.
5. Heat gun: Used for heat shrinking tubing and components, providing insulation and protection for electrical connections.
6. Hot glue gun: Enables the secure attachment of components and wiring in place, offering flexibility and ease of use.
7. Safety gloves: Essential for personal protection during work, safeguarding against potential hazards such as sharp edges and electrical shocks.

8. Cable ties: Useful for bundling and organizing wires, helping to maintain a tidy and organized workspace.
9. Electrical tape: Provides insulation for electrical connections and protects against moisture, ensuring long-term reliability.
10. Tack weld machine: Utilized for securely tack welding the terminals of adjacent batteries together during the fabrication of the custom battery pack.

3.2 METHODS

3.2.1 DESIGN CALCULATIONS FOR FRONT WHEEL ELECTRIC BICYCLE

The bicycle been used is a converted conventional bicycle into an electric bicycle. The design considerations required to ensure optimal performance and safety are taken into view [Electric bike report, 2021]. The power output of the motor (P_{motor}) was calculated using equation 1.

$$P_{\text{motor}} = V_{\text{battery}} * I_{\text{motor}} \quad (1)$$

Where V_{battery} is the battery voltage (36V), and is the current drawn by the motor. Since P_{motor} is rated at 350W, $I_{\text{motor}} = 9.72\text{amps}$. the salvaged speed controller would work just fine since it has the amp rating of 16amps.

Torque (T_{motor}) generated by the motor can be determined from equation 2:

$$T_{\text{motor}} = P_{\text{motor}} / \omega_{\text{motor}} \quad (2)$$

The angular velocity (ω) in radians per second of a 36v 350w scooter hub motor depends on the speed and the radius of the wheel. According to L-faster, [2023], the speed of a 36v 350w

scooter hub motor can range from 600 to 1100 rpm, which is equivalent to 62.8 to 115.7 rad/s. Using the lower bound of 62.8 rad/s, $T_{\text{motor}} = 5.57\text{Nm}$.

In the context of front wheel conversion, the torque applied to the wheel (T_{wheel}) is estimated as:

$$T_{\text{wheel}} = T_{\text{motor}} / G \quad (3)$$

where G represents the gear ratio between the motor and the wheel. For this scenario, no gear exists so $G = 1$. Front wheel torque $T_{\text{wheel}} = 5.57\text{Nm}$.

Furthermore, the maximum speed (S_{max}) achievable by the electric bicycle can be estimated using the relationship between speed, wheel diameter (D_{wheel}), and motor angular velocity of equation 4:

$$S_{\text{max}} = \omega_{\text{motor}} * (D_{\text{wheel}} / 2) \quad (4)$$

For wheel size of 0.6604m, $S_{\text{max}} = 20.74\text{m/s}$ or 74.66km/h

3.2.2 METHODS FOR BATTERY LIFE UPGRADE

3.2.2.1 Battery Pack Fabrication process

The battery pack fabrication process commenced with the assembly of individual lithium-ion batteries to form a custom battery pack tailored to the specific requirements of the electric bicycle upgrade project. Here's a breakdown of the process:

1. Selection of Lithium-ion Batteries: High-quality lithium-ion batteries with a voltage rating of approximately 3.7 volts each were chosen for the fabrication process.
2. Connection in Series: The selected lithium-ion batteries were connected in series to increase the overall voltage of the battery pack. This involved connecting the positive

terminal of one battery to the negative terminal of the next battery, creating a continuous circuit. By connecting 10 lithium-ion batteries in series, the total voltage of the battery pack was increased to approximately 37 volts ($10 * 3.7$ volts).

3. Tack Welding: To secure the connections between the lithium-ion batteries, a tack weld machine fabricated specifically for this purpose was utilized. Tack welding involves briefly welding the terminals of adjacent batteries together, ensuring a strong and reliable connection. This process was carefully executed to prevent overheating and damage to the batteries while creating a secure bond between them.
4. Integration with Battery Management System (BMS): Once the batteries were securely connected in series, the fabricated battery pack was integrated with a Battery Management System (BMS). The BMS plays a crucial role in monitoring, managing the charging and discharging of the batteries, ensuring safe and efficient operation. The tacked batteries were connected to the BMS, allowing for real-time monitoring and protection against overcharging, over-discharging, and thermal runaway.



Figure 3.2: The Batteries been arranged

3.2.2.2 Battery Enhancement:

In this phase of the project, the focus was on enhancing the electric bicycle's battery capacity to extend its range. The fabricated batteries were integrated to ensure seamless operation within the existing electrical system.

The first step involved the connection of the fabricated batteries in parallel with the original battery of the bicycle. This parallel configuration was chosen to increase the overall capacity of the battery pack while maintaining a compatible voltage level with the bike's motor and controllers.

To determine the total battery capacity after integration, the following calculation was carried out:

Total Battery Capacity = Original Battery Capacity + fabricated Battery Capacity

Next, the compatibility of the batteries with the existing charge controller and motor controller was evaluated. This included verifying the voltage and current ratings of the controllers to ensure they could handle the combined load of the new battery pack.

Throughout this phase, monitoring of the temperature and performance of the batteries during charging and discharging cycles was crucial to prevent damages to the system.

3.2.3 METHODS FOR LIGHTING SYSTEM UPGRADE:

During this process, the focus shifted towards enhancing the electric bicycle's lighting system to improve visibility and safety during nighttime rides.

The first step involved the fabrication of a new headlight using a salvaged LED torch. This approach was chosen for its energy efficiency and durability compared to traditional

incandescent bulbs. The LED torch provided a bright and focused light output, ensuring enhanced visibility for the rider while minimizing power consumption.



Figure 3.3: LED Torch

To ensure compatibility between the LED torch and the electrical system of the electric bicycle, a buck converter was utilized. The buck converter played a crucial role in regulating the voltage supplied to the LED torch, ensuring optimal performance and longevity. By stepping down the voltage from the battery which had approximately 37V to match the requirements of the LED torch which is 5V, the buck converter helped to prevent overloading and overheating of the lighting system.

Once the LED torch was successfully integrated into the headlight assembly, it was installed by mounting the headlight securely onto the bicycle frame and routing the necessary wiring connections to the electrical system.



Figure 3.4: The Headlight

In addition to the headlight upgrade, an alarm system was installed into the electric bicycle. This alarm system was designed to provide audible alerts to the rider in case of emergencies or potential hazards on the road.



Figure 3.5: The Alarm System

3.2.4 CABLE INFRASTRUCTURE IMPROVEMENT

Work was done to streamline the wiring connections and integrate automatic charging capabilities for certain components, namely the bike indicator and alarm system.

Assessment of the existing wiring layout and identifying areas for improvement were done by inspecting the routing of cables, ensuring proper insulation, and addressing any potential issues such as fraying or damage. This helps to minimize clutter and reduce the risk of electrical faults or malfunctions.

Once the wiring connections were established, proper routing of the cables to the appropriate components, such as the bike indicator and alarm system, and securing them in place to prevent interference or damage during operation was done.

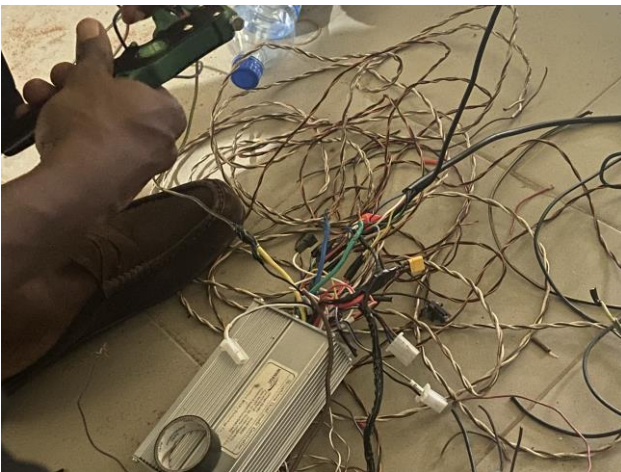


Figure 3.6: Sorting and Replacement of Damaged Wires

3.2.5 BIKE INDICATOR INTEGRATION AND FIX

During the upgrade process, we integrated the bike indicator system into the electric bicycle's framework while addressing existing functionality issues. The endeavor encompassed a series of steps to ensure seamless operation and optimal performance of the indicator system. Below is an overview of the specific measures undertaken:

- **Initial Wiring Configuration:** At the outset, the bike indicator system, alongside the headlight and alarm components, was connected to a wire originating from the motor controller. This wire supplied a voltage of approximately 37 volts, which surpassed the operational requirements of the indicator system. Recognizing the disparity in voltage levels, it was rectified to facilitate a harmonious integration.
- **Voltage Regulation with Buck Converter:** To reconcile the difference in voltage between the motor controller output and the indicator system's operational requirements, a buck converter was used. This device played a pivotal role in stepping down the voltage from the motor controller to a compatible level for the indicator system, approximately 5 volts. The buck converter ensures that the power supplied to the indicator system was precisely tailored to its specifications, thereby mitigating any potential malfunctions.



Figure 3.7: LM2596 DC-DC Buck Converter Step-Down Power Module

- **Resolution of Connectivity Issues:** In addition to voltage regulation, the upgrade initiative addressed a persistent issue pertaining to the bike indicator's Bluetooth connectivity. Despite its inherent functionality, the indicator system exhibited intermittent disconnections in bluetooth connectivity, particularly when the electric bicycle was

powered off. To solve this challenge, a solution was devised. A 3.5-volt battery, harvested from the indicator system, was strategically integrated into the setup. This auxiliary battery, when coupled with the buck converter, served to stabilize the voltage output, thereby ensuring uninterrupted bluetooth connectivity even during periods of inactivity or power-off states.



Figure 3.8: Bike Indicators/Trafficator

3.2.6 TESTING

Finally, rigorous testing procedures were conducted to ensure the proper functionality, safety, and reliability of all upgraded components of the electric bicycle. This phase served as a crucial step towards validating the effectiveness of the enhancements made throughout the project and ensuring that the electric bicycle was ready for optimal performance on various terrains and conditions.

The testing process began with a comprehensive evaluation of each upgraded component, including the battery system, lighting system, and cable infrastructure. This involved conducting

functional tests to verify that each component operated as intended and met the desired performance criteria. For the battery system, tests were conducted to assess charging and discharging capabilities, as well as overall energy efficiency and range. The lighting system underwent testing to evaluate its brightness, beam pattern, and visibility under different lighting conditions. Additionally, the cable infrastructure was tested to ensure proper wiring connections, insulation, and compatibility with the electrical system.

Data collection was done throughout the testing process to gather quantitative data on the performance of the electric bicycle. This included recording voltage, voltage drain, range to assess the efficiency and effectiveness of the upgrades.

With testing and adjustments complete, the electric bicycle underwent a final inspection to verify that all upgrades had been successfully implemented and that the bike was ready for use. This included a thorough visual inspection of all components, as well as a test ride to evaluate performance in real-world conditions.



Figure 3.9: Testing of the Taillight indicator



Figure 3.10: Testing of the Electric Bicycle after modifications are completed.

3.2.7 PROBLEMS ENCOUNTERED DURING TESTING AND SOLUTIONS:

During the testing phase of the project, several challenges arose that required resolution. The problems faced during testing and the corresponding solutions devised by the project team are outlined below:

3.2.7.1 Brake Interference with Bike Indicators:

During testing, it was observed that the bike indicators were inadvertently connected to a brake wire in the motor controller. As a result, activating the bike indicators triggered the brake in the motor, posing a safety concern for the rider.

Solution: The problem was rectified by identifying and rerouting the wiring connections for the bike indicators to a more suitable wire in the motor controller. Additionally, the voltage in the selected wire was found to be too high for the indicators, necessitating the use of a buck converter to step down the voltage to a safe level.

3.2.7.2 Bluetooth Disconnection of Bike Indicator:

Another challenge encountered during testing was the intermittent disconnection of the bike indicator due to its Bluetooth connectivity. Whenever the electric bicycle was turned off, the indicator would disconnect, requiring the user to reconnect it upon restarting the bike.

Solution: To address this issue, a 3.5V battery was integrated into the system. This battery served to maintain the Bluetooth connection even when the electric bicycle was turned off, ensuring that the indicator remained connected and ready for use at all times.

3.3. MATERIALS LIST

Here's the list of materials involved in the upgrade of the electric bicycle:

1. Lithium-ion Batteries: High-quality batteries with suitable voltage ratings for the custom battery pack fabrication.
2. Motor Controllers: Controllers for regulating power delivery from the batteries to the motor.
3. Battery Management System (BMS): A system for monitoring and managing battery charging and discharging.
4. LED Torch: Salvaged or custom-made LED torch for upgrading the headlight system.
5. Buck Converter: A device used for stepping down voltage from the motor controller to power the LED torch , Electric bell and Bike Indicator
6. Fabricated Battery Pack: Custom-made battery pack assembled from individual lithium-ion batteries for extending the electric bicycle's range.

7. 3.5V Battery: Additional battery component used for stabilizing voltage output in the electrical system, particularly for addressing Bluetooth connectivity issues in the indicator system.
8. Tack Welder: Machine for securing connections between lithium-ion batteries during the fabrication process.



Figure 3.11: Electric Bicycle on Completion

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1 Bicycle Test Performance

Prior to the electric bicycle upgrade, data was collected and presented in Table 1. This data includes battery usage in both percentage and voltage, as well as the distance traveled during a one-week bicycle usage test. The test was conducted at an average speed of 15 km/h and a maximum weight of 136 kg.

Battery percentage (%)	Battery Voltage drain(volts)	Distance Traveled (km)
100	42	1
88	40.56	2
76	39.12	3
64	37.68	4
52	36.24	5
40	34.8	6
28	33.36	7
16	31.92	8

4	30.48	8.33
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Table 4.1: Data of Battery Usage, Battery Percentage and Distance Travelled before the Upgrade

The data in the table below are those obtained after the upgrade of the electric bicycle was carried out. Table 2 below shows the battery usage in percentage, battery usage in volts and the distance traveled during a one-week bicycle usage test under the same conditions as above.

Battery percentage (%)	Battery Voltage drain(volts)	Distance Traveled (km)
100	42	1.87
88	40.56	3.74
76	39.12	5.61
64	37.68	7.48
52	36.24	9.35
40	34.8	11.22
28	33.36	13.09
16	31.92	14.96
4	30.48	15.58

Table 4.2: Data of Battery Usage, Battery Percentage and Distance Travelled after the Upgrade

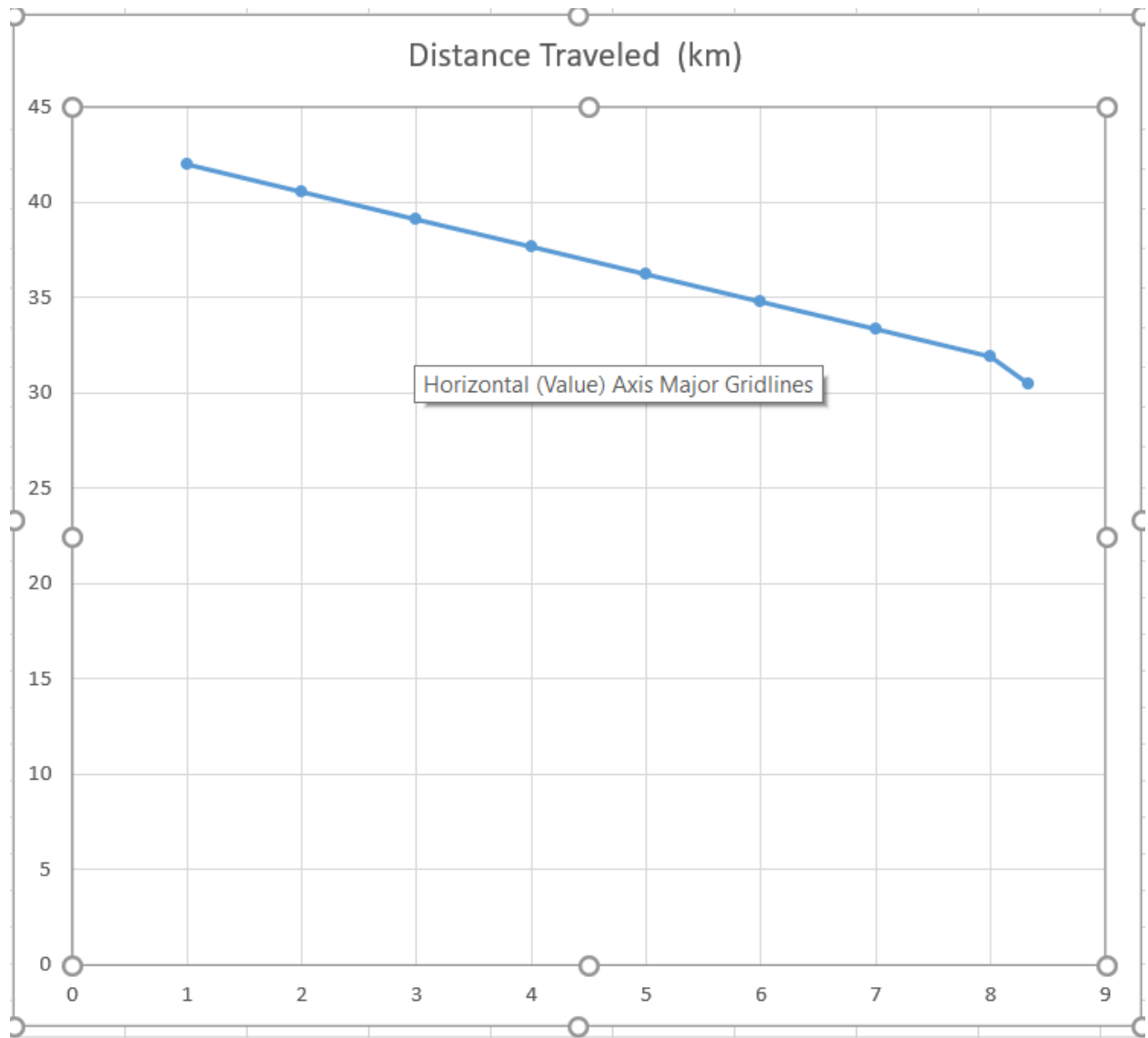


Figure 4.1: Fitted Line Plot Of Volt/Km Performance Of The Electric Bicycle before Modifications

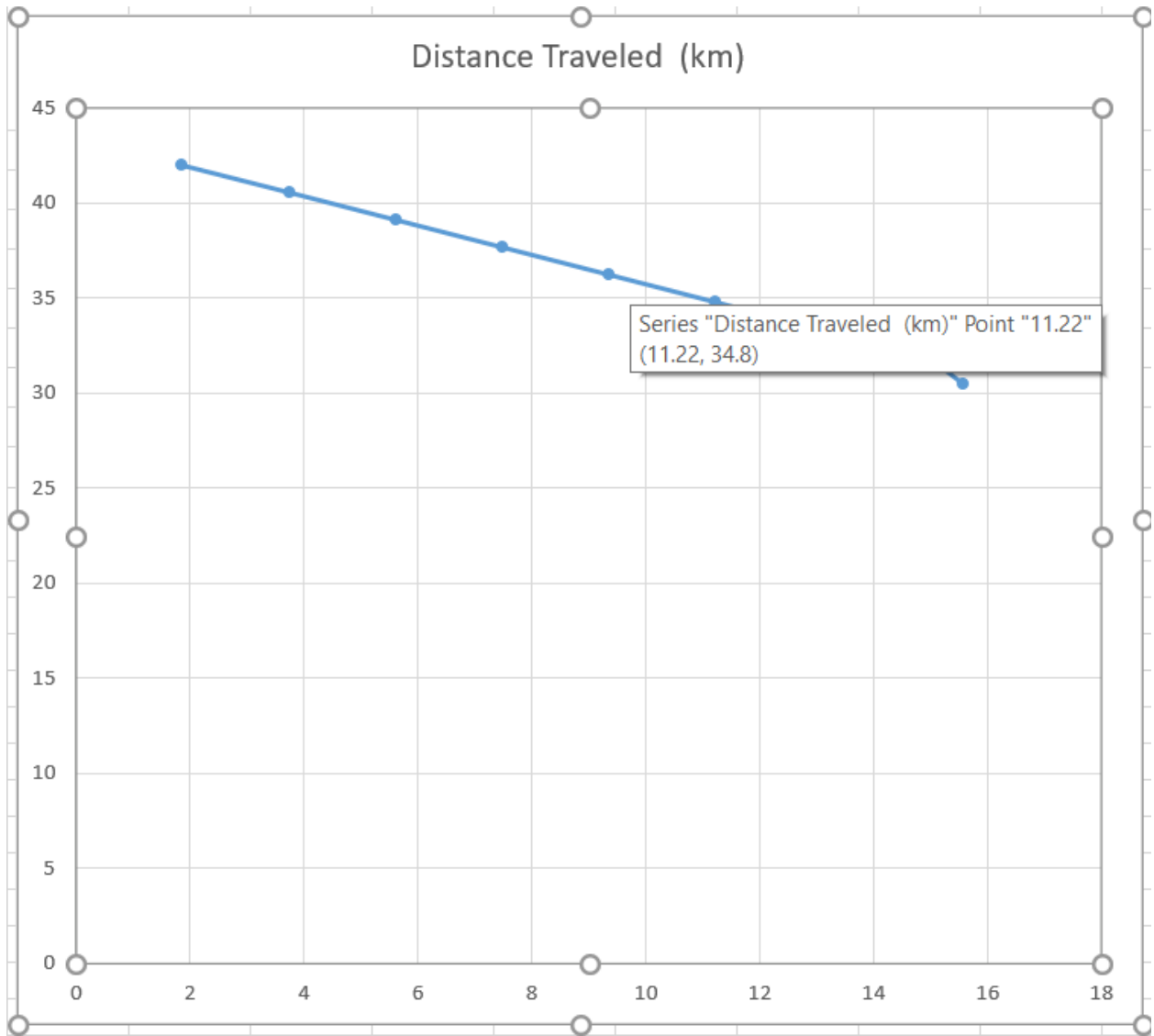


Figure 4.2: Fitted Line Plot Of Volt/Km Performance Of The Electric Bicycle after Modifications

4.2 DISCUSSION

The results of the two test above depicts some information. The original electric bicycle setup was equipped with a standard lithium-ion battery pack, which was replaced with a higher-capacity pack. The higher-capacity battery pack includes the addition of new batteries in parallel to the original batteries in the battery pack, the electric bicycle's range increased by

approximately 87% compared to the original configuration. This enhancement enables users to ride longer distances which reduces the frequency of charging, thereby minimizing electricity consumption.

The extended range also enables electric bicycles to better compete with traditional vehicles, making them more appealing for long-distance commuting and various applications. While the results are promising, it is important to note that factors such as riding conditions, user behavior, and ambient temperature may influence battery life and range.

With respect to the upgraded LED headlights, they provided a significant improvement in visibility compared to the original lighting system. The increased brightness offered enhanced illumination of the road ahead, enabling riders to better detect potential hazards and react accordingly. Additionally, the upgraded headlights featured the proximity of the headlight switch to be very close to the bicycle handle. The LED technology utilized in the headlights consumed less power while delivering light output, resulting in extended battery life and increased e-bike range.

Furthermore, the addition of integrated turn signals in the upgraded taillights facilitated clearer communication of the rider's intentions, enhancing overall safety.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSIONS

The exploration of the various aspects of upgrading an electric bicycle's battery life, lighting system, and cable infrastructure was to achieve optimal performance. The findings of this study have demonstrated that these strategic modifications can enhance an electric bicycles overall performance and functionality.

The battery upgrade, which involved replacing the original battery pack with a higher capacity one, resulted in a notable increase in the electric bicycles range and battery life. This improvement not only allows for longer rides but also contributes to a more reliable and efficient mode of transportation.

The installation of an enhanced lighting system, consisting of LED headlights, taillights, and indicators, has led to improved visibility and safety during low-light conditions. The use of energy-efficient lighting technologies ensures that these enhancements do not compromise the electric bicycles battery life.

Also, the optimization of cable infrastructure has resulted in better organization, protection, and management of the electric bicycles electrical components. This upgrade not only improves the electric bicycles maintainability but also contributes to the safety and overall user experience.

These improvements which were made with locally sourced materials and expertise solidifies the electric bicycles position as a sustainable and reliable mode of transportation, thereby contributing to a greener and more accessible future.

5.2. RECOMMENDATIONS

The following recommendations are also made for further study and optimisation of the electric bicycle:

- Upgrading the electric bicycles battery pack to a higher-capacity model to extend the range and battery life. Integrate an advanced battery management system to ensure safe operation, monitor battery health, and optimize power distribution.
- Consider incorporating smart lighting systems that adjust brightness based on ambient light conditions to optimize energy consumption.
- Continuation in advancements of electric bicycle technology through research and development efforts. Stay informed about emerging technologies, such as advanced battery chemistries, efficient motor controllers, and smart connectivity features, to further optimize e-bike performance and functionality.

REFERENCES

- Brand, J., & Thompson, L. (2019). Grassroots Innovation in Sustainable Transportation: A Case Study of Electric Bicycle Adoption in Nigeria. *Journal of Cleaner Production*, 239, 118053.
- Cherry, C. R., & Cervero, R. (2007). Use Characteristics and Mode Choice Behavior of Electric Bike Users in China. *Transport Policy*, 14(3), 247-257.
- Gan, Y., Huang, Y., & Xue, D. (2020). Current Status and Development Trend of Electric Bicycles in China. *Advances in Mechanical Engineering*, 12(6), 1-13.
- Inegbedion, E., Olowe, T., & Ayo, C. K. (2020). Transportation Pricing and Sustainable Urban Transport in Nigeria. *Journal of Urban Management*, 9(1), 62-71.
- Khalid, H., Ahmad, N., & Rashid, Y. (2014). An Assessment of Sustainable Transportation Initiatives in Nigeria: A Case Study of Lagos State. *Transportation Research Procedia*, 4, 107-119.
- Lemire-elmor, L. (2020). Electric Bicycles: A Sustainable Transportation Solution for Nigerian Cities. *Journal of Sustainable Development*, 13(2), 49-58.
- Matey, K. (2017). Towards Sustainable Transportation in Nigeria: An Investigation into the Feasibility of Electric Bicycle Adoption. *International Journal of Sustainable Transportation*, 11(9), 641-652.
- Schneider, P. (2021). The Role of Electric Bicycles in Sustainable Urban Mobility: Case Study of Lagos, Nigeria. *Sustainable Cities and Society*, 71, 102933.

