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Optimal Material Selection for the Design and Fabrication of a Three Wheeled Electric Vehicle (TRIKES)

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Abstract: This research explores the application of material selection in the design and fabrication of a three wheeled electric vehicle. The material selection criteria considered up to sixty percent (60%) locally sourced materials, which is in consonance with the GREEN INITIATIVE, in a world already affected by the emissions of combustible fuel generated by automobiles which deplete the Ozone layer. The project employed the optimized design tools of Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM).The selected component parts are the DC brushed motor, the transmission, the steering mechanism, the suspension system, and wheels that were mounted upon square pipes that served as the chassis. The chassis, which carries the batteries, transmission, electric motor and other components is made of mild steel square pipes of 5.0cm cut into different shapes in order to meet the design specifications. The selected battery is a 38Ah-12V lead acid battery, With the designed torque of 9,5Nm, and having the voltage of 12V.The fabricated Electric tricycle vehicle (ETV) demonstrates improved performance, including increased range, reduced energy consumption and enhanced stability for sustainable transportation systems.

Keywords: Material selection, design, optimization, electric vehicle, transmission, Cad, Cam, components

Introduction

The introduction of the Electric Tricycle vehicle (ETV into the country is as a result of the nation's gasoline fuel prices which have risen significantly in recent years, as greenhouse gas issues keep escalating on a regular basis. There is prevalence of more cars on the road, which helps to make mobility simpler and more comfortable. The release of carbon dioxide, nitrogen oxide and methane has however, resulted in a sharp rise in air pollution levels in urban areas (Smith, J. 2017). Today, experts are looking for substitutes and dependable sources of energy for cars that won't send hazardous emissions to the environment because of the destructive impact that gasoline and other petroleum manufacturing have on the ozone layer. Among these superior energy options are hydrogen, ethanol, natural gas, biodiesel and electricity. The advantages of some of these alternative energy sources include the reduction of various air pollution due to the production of energy that emits no greenhouse gases, the reduction of over-dependence on fossil fuels and the diversification of the energy supply, the promotion of economic development, as well as the creation of much needed jobs in manufacturing and installations for the teeming youths. A car that is propelled by one or more electric motors using energy stored in rechargeable batteries is referred to as an electric powered vehicle and is a recent breakthrough in the automotive industry.

In addition to not emitting harmful hydrocarbons, electric-powered cars are also incredibly simple, effective, and more dependable because they only have one moving part, the rotor. Other advantages of electric cars include ease of maintenance, low maintenance requirements, economic effectiveness, reduced pollution, use of renewable energy, and increased safety. A go-kart is a compact, four-wheeled vehicle that is produced in a variety of forms and designs, from unpowered models to super-powered racing vehicles. It is a good example of an electric powered car. The automotive sector has grown to be one of the most significant in the world, both economically and in terms of research and development. More and more sophisticated components are being added to automobiles for the future enhancement of pedestrian and passenger safety. Electric cars are powered by installed electrical energy sources and are propelled by electric motors. Compared to gasoline-powered vehicles, electric cars are frequently more reliable and simple mechanically. Due to a built-in flaw in current battery technology, the automotive industry is not yet fully transitioning to all-electric vehicles. The battery is the most frequent form of energy storage utilized in electric cars. It has huge energy storage capacity for its light weight and compact volume. According to a recent research, more automobiles were using gasoline in the previous year, but the statistic has since changed due to an increase in the use of hybrid and electric vehicles. Electric vehicles are becoming more and more significant because, in addition to reducing noise and pollution, they may also be used to lessen the reliance of transportation on oil, provided that power is produced from sources other than oil. Carbon emissions can be decreased by using electric automobiles. The energy for electric vehicles must be produced from non-fossil fuel sources, such as nuclear and alternative energy, in order to produce zero carbon dioxide emissions. Concerns about global warming are continuing to grow. When fossil fuels, carbon dioxide is released into the atmosphere, which is blamed for global warming. This phenomenon is thought to cause a variety of issues, such as climate change and rising sea levels that could wipe out many coastal towns around the world (Gallagher, K.S., Muehlegger. E. and Lutsey. N. P. 2018). Each components material selection or rating is a challenging process because the specifications of one component influence the power level of another. Therefore, there is a chance that one component will be improperly rated, increasing the likelihood that the car would be overpriced or underpowered. Mechanical Engineers have been developing mechanical components for a while now. Material selection is an essential step in the design of an electric vehicle since it impacts the reliability of the vehicle in terms of industrial and economic considerations. According to Cebeci. H and Dincer (2013), each of these physical components we can see is a result of thorough design process and careful material selection strategy that mad the mechanism function effectively.

A three-wheeled electric vehicle’s design and construction is a complex and revolutionary project that spans the fields of Mechanical Engineering, Electrical Engineering, Material Science and sustainability. Electric vehicles (EVs) have become a crucial component of the automotive industry’s answer to the need to cut greenhouse gas emissions and the global push for a greener future. Electric trikes, which are three-wheeled electric vehicles that combine the benefits of electric propulsion with the naturalqualities of trikes including higher maneuverability, lower weight and increased energy economy, offer a novel approach to sustainable mobility.

The vehicles architecture and layout are at the center of the design process. For best performance and efficiency, engineers carefully balance weight distribution with aerodynamics and structural integrity. The vehicles body is expertly engineered to reduce air resistance and increase range, which adds to its eco-friendliness. The battery pack, a crucial part of electric vehicles (EVs), is carefully integrated to maintain a low center of gravity, improving stability and overall safety while turning and navigating. Electric vehicle design must take into account battery technology. Longer ranges and quicker charge periods are now possible thanks to recent improvements in lithium-ion and solid state battery technologies’ energy density and charging capabilities.

A delicate balancing act must be performed when choosing the right battery type and capacity to manage both the weight of the vehicle as a whole and the driving range. Engineers must also take thermal management systems into account to maintain ideal battery operating temperatures and guarantee battery longevity. The location of the electric motor is a crucial factor as well. As the engine of the car, the electric motor transforms electrical energy into mechanical power. Engineers evaluate alternative motor designs, including hub motors or centrally mounted motors, depending on their advantages in terms of weight distribution, energy efficiency, and overall design viability. Increasing energy efficiency is largely dependent on regenerative braking technology. This function enable the car to gather and hold energy during braking and acceleration, which is later used to replenish the battery. The vehicle’s operating range in increased by this regenerative braking system, which also saves wear on the mechanical braking system and lowers maintenance expenses.

Modern manufacturing processes and materials are used in the construction of three-wheeled electric vehicles. To reduce vehicle weight while retaining structural integrity, high strength and lightweight materials like aluminum alloys or carbon fiber composites are preferred. Rapid prototyping and the fabrication of delicate components can be accomplished using cutting-edge 3D printing and additive manufacturing processes, expediting the production process and encouraging design innovation. Throughout the design and fabrication process, safety considerations are of the utmost importance. In the event of a collision, occupant’s protection is ensured through strict crash testing processes and adherence to safety requirements. Additional safety measures including air bags, seat belt pretensions, and sophisticated driver assistant systems, may be added to increase safety. The chassis design is built to withstand impact forces.

In the design and development of electric cars, computer aided designs (CAD) and simulation tools are indispensable. Before actual prototyping, engineers can use these tools to construct virtual models, run simulations, and evaluate various design iterations. With less time and money spent on development, this iterative procedure permits optimization of vehicle performance, efficiency and safety. After the design and prototyping stages are over, the vehicle goes through a number of demanding testing and validation procedures.

Acceleration, highest speed, and driving range are evaluated during performance testing, while regulatory standards are met during safety testing.

Real world road tests are conducted to assess the vehicle's handling, ride comfort, and general user experience. These tests offer priceless insight for future improvements. A cooperative and interdisciplinary strategy is necessary for the effective design and construction of a three-wheeled electric vehicle, the specialists from diverse sectors cooperating to achieve a common objective. The development of three-wheeled electric cars offers enormous promise in transforming urban mobility, lowering carbon emissions and ensuring a better and cleaner future for future generations as the globe quickens its shift to sustainable transportation options. The development of three-wheeled electric vehicles marks the union of innovation, technology and sustainability, paving the way for a paradigm change in transportation and igniting a global movement towards a more environmentally friendly and sustainable future.

In the automotive sector, electric vehicles (EVs) have emerged as an advancement in technology that offers a cleaner and more environmentally friendly alternative to conventional internal combustion engine automobiles. Early prototypes of electric vehicles were developed in the early 19th century by inventors including Robert Anderson and Thomas Davenport. However, due to environmental concerns and breakthroughs in battery technology, EVs didn't start gaining considerable attention and interest until the late 20th century (Lemke & Kong, 2015). Battery electric cars (BEVs), hybrid electric cars (HEVs), plug-in hybrid electric vehicles (PHEVs), and fuel cell electric vehicles (FCEVs) are only a few of the different types of electric vehicles available today (U.S. Department of Energy, 2020).

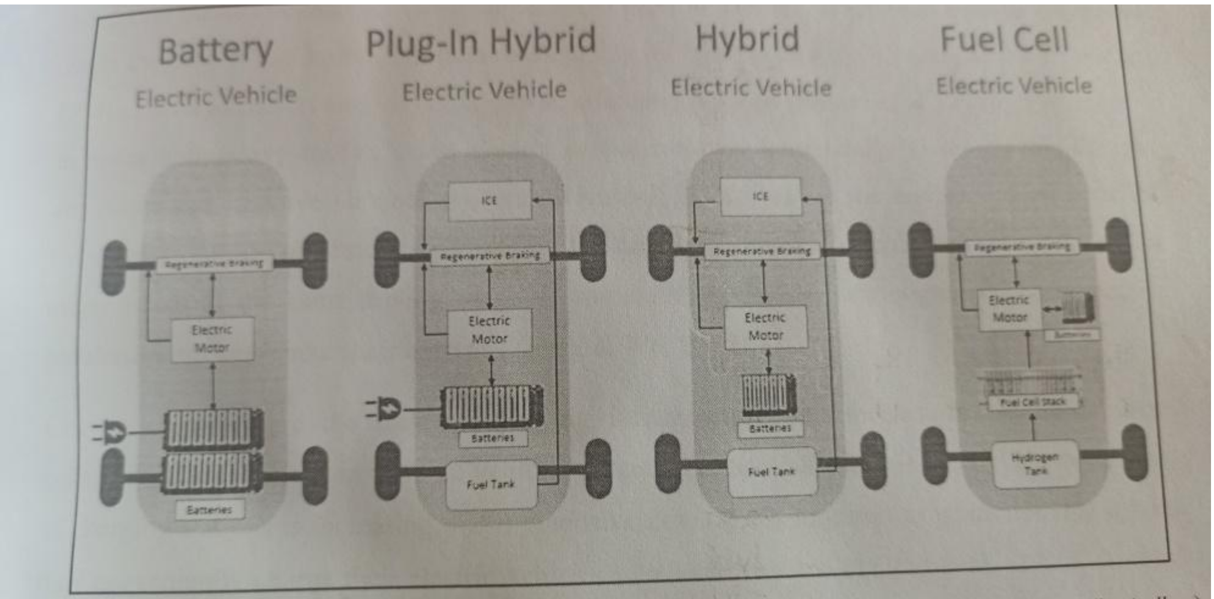

Fig 2.1 Illustration of Electric Vehicles (*https://www.linkedin.com/pulse/overview-electric-vehicles-shradha-jadhav*)

Different propulsion technologies are used by different types of EVs, resulting in varying levels of electrification. The electric motor, battery pack, power electronics and charging system re important elements of the electric cars (Toyota & Campbell, 2015). The electric motor, which transforms electrical energy into mechanical energy to move the vehicle forward, is the engine of an electric vehicle. Battery packs are an essential part of electric cars since they store and supply energy to the electric motor (Lu & Yang, 2019), Power electronics govern the flow of electrical energy by serving as an interface between the battery pack and the electric motor (Fang, 2015). Last but not least, the charging system is necessary to recharge the battery pack and maintain the operation of the vehicle (Tuffner & Kitner-Meyer, 2015).

The development of electric vehicles has been significantly influenced by advancements in battery technology. Due to its high energy density, efficiency, and relatively low self-discharge rates, lithium-ion batteries have supplanted other types of batteries (Scrosati & Garche, 2010). They are commonly utilized both in BEVs and PHEVs and provide significant performance and weight savings over conventional lead acid batteries. Research is still being done on solid-state batteries and lithium-sulfur batteries, as well as on ways to make batteries more affordable and perform better overall (Nitta et al., 2015).

One of the main factors influencing the broad adoption of electric vehicles is their positive effects on the environment. Due to the fact that electric cars (EVs) have no tailpipe emissions while they are in use, harmful pollutants including nitrogen oxides (NOx) and particulate matter (PM) as well as carbon dioxide (CO2) are significantly reduced (Ehsani et al., 2010). Particularly in cities with heavy traffic, using electric propulsions can dramatically lower greenhouse gas emissions and improve air quality (Axsen & Kurani, 2018). Despite the environmental benefits, there are a number of obstacles preventing the adoption of electric vehicles. One of the major issue is the short driving range of some EV models, which might make prospective purchasers anxious about their options (Zhang & Wu, 2015).

Critical obstacles are the lack of charging infrastructure and the lengthy charging times compared to refueling conventional vehicles (Stephen &Sullivan, 2016). While the availability of charging stations is increasing, more extensive coverage is required to guarantee that drivers may conveniently charge their electric vehicles while they travel (Jiao et al., 2020). Another obstacle to adoption is thee high initial cost of electric vehicles in comparison to conventional vehicles (Vocke & Joskow, 2019). In addition, consumer's decision to migrate to electric vehicles may be influenced by concerns about battery longevity and total cost of ownership (Jarvi et al., 2020). The widespread use of electric vehicles depends on the infrastructure for charging being accessible and available.

In order to give users convenient and accessible charging alternatives, a dependable and extensive charging network is required (Neaimeh et al., 2017). This can increase users trust in choosing an electric vehicle. There are many charging choices, including office charging, home charging solutions and public charging stations (Kipourous et al., 2018). Vehicle to grid (V2G) systems and other smart charging technologies can be integrated to improve grid stability and maximize the usage of renewable energy sources (Ma & Lu, 2019). Government all across the world have put in place regulations and incentives to encourage the use of electric vehicles and overcome the difficulties. Some of the strategies used to lower carbon emissions and encourage the market of electric vehicles include financial incentives, tax credits, subsidies, and regulations (Sierzchula et al., 2014). These regionally specific regulatory initiatives have a big impact on the market penetration and sales of electric vehicles. With continued technological and infrastructure developments, the prospect of electric vehicles are bright. Improvements in energy density, faster charging rates and longer battery life are still the main goals of battery technology research and development (Zhang et al., 2018). The electric car industry may a revolution as a result of developments in solid-state batteries and other alternative chemistries (Manthiram et al., 2017). EV consumers now have more accessible and convenient charging alternatives because of the fast growing charging infrastructure (Kluschke et al., 2021).

Three-Wheeled Electric Vehicle Concepts

Concepts for three-wheeled electric vehicles are all about original ideas that could revolutionize how we move around cities. These suggestions are meant to make city travel simpler and more environmentally friendly. As an illustration, some concepts can tilt to the side and have three wheels, which helps them maintain stability when turning (Smith et al., 2019). Others are extremely compact electric vehicles designed for short city excursions, which are better for the environment and save energy (Jones and Brown, 2020). Even specific vehicles exist to distribute items like packages without polluting the environment (Johnson & White, 2021). To make urban transportation both economical and environmentally friendly, some concepts emphasize sharing these vehicles (Chen et al., 2018). Additionally, there are cars made specifically for the elderly that are simple to use and aid in transportation (Davis & Wilson, 2022). All these fresh concepts are altering the way we think about urban mobility, making it simpler, more environmentally friendly, and better for everyone.

Previous Designs and Innovations of Three Wheeled Electric Vehicles

Three wheeled electric vehicles have existed since the beginning of the automobile industry, and the performance, efficiency and usability of three wheeled electric vehicles have been improved over time by novel designs. In particular, the Aptera 2 series displayed a cutting edge aerodynamic design for energy optimization (Aptera Motors, 2006).

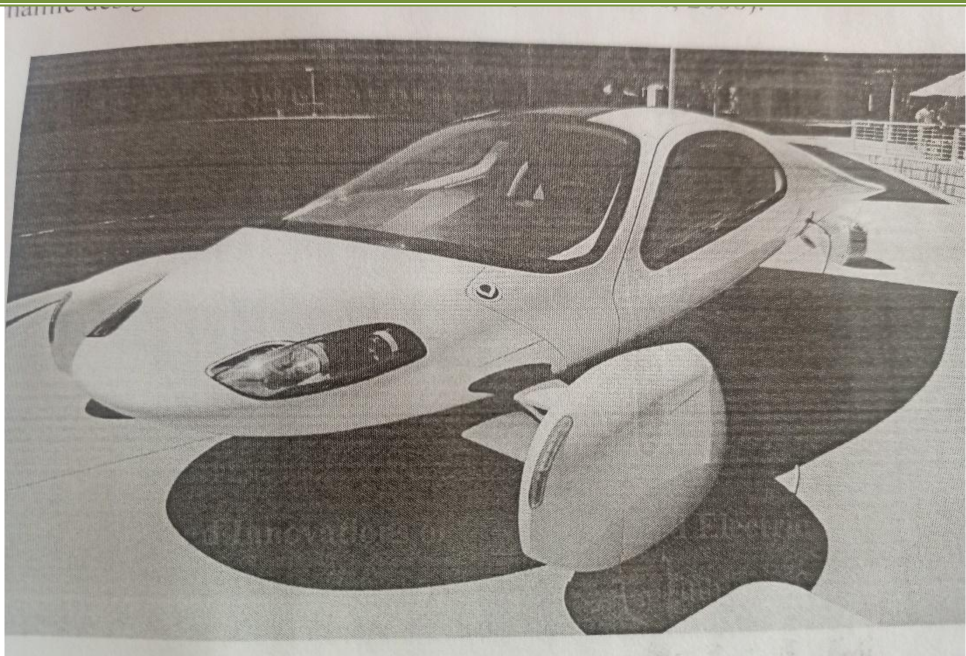

Fig 2.2 Aptera 2 series EV (*https://en.wikipedia.org/wiki/Aptera_2_Series*)

The performance and design of three wheeled electric vehicles have been greatly influenced by developments in the field of electric vehicle engineering. Power electronics and electric motor system have been optimized by scientists and Engineers to increase the overall effectiveness and range of vehicles. While exploring various methods to improve stability during cornering and maneuvering, safety and stability have been key considerations (Carroll & White, 2009; Haddadi et al., 2018).The development of three wheeled electric cars has also been significantly influenced by user-centric designs, which place a strong emphasis on ergonomics, accessibility, and user interface design to enhance the entire user experience (Ma et al., 2019).

In addition to providing last mile connection and lowering carbon footprints, these vehicles have the potential to provide solutions to urban mobility issues, especially in packed streets and congested urban regions (MohdMokhtar et al., 2015).Technological breakthroughs in autonomous driving, lightweight construction, and vehicle-to-grid integration will shape the direction of three wheeled electric vehicles in the future (Kockelman, 2019; Tan & Yang, 2021). But there are still problems, such as those related to market adoption, infrastructure development, and charging issues (Zhang & Wu, 2015). For three wheeled electric cars to be successfully incorporated into the transportation sector, it will be crucial to address these issues.

Comparative Analysis between Existing models of Three-Wheeled Electric Vehicles and Internal Combustion Engine Three-Wheeled Vehicles

Innovative three-wheeled electric cars (EVs) have emerged as possible competitors in the automobile industry as a result of the rapid improvements in electric vehicle (EV) technology. In this study, three wheeled electric vehicle (EV) models that are now available are compared to their ICE-powered counterparts in-depth. It is possible to gain important knowledge about the advantages and drawbacks of each technology by looking at the design aspects, performance traits, environmental effects, and user experiences of the two vehicle kinds. This analysis helps to clarify the possible function of three-wheeled electric vehicles (EVs) in the development of sustainable urban transportation.

Design Features and Configuration

Electric three-wheelers and ICE three-wheelers have different design elements and layouts. When accelerating and turning, electric trikes, like the Acrimoto FUV, frequently assume a delta trike layout with two wheels in front and one in back (Acrimoto, 2021). While giving agile mobility and distinctive throwback aesthetic, ICE three-wheelers like the Morgan 3 wheeler typically adopt a tadpole trike shape, with two wheels up front and one behind (Morgan Motor Company, 2021). There are differences in design between the two vehicle types due to the varied power train requirements and combustion engine integration issues.

Performance Characteristics

Electric trikes are known for their quiet operation, instant torque delivery, and smooth acceleration, offering a more enjoyable driving experience for urban environments (Toliyat & Campbell, 2015).The absence of internal combustion engines will eventually eliminate tailpipe emissions, contributing to reduced air pollution and improved air quality (Li & Gao, 2020).

Environmental Impact and Sustainability

Three-wheeled ICE vehicles and three-wheeled electric vehicles have quite different environmental effects and sustainability levels. Particularly when powered by renewable energy sources, electric trikes exhibit a smaller carbon footprint and fewer greenhouse gas emissions (Manthiram et al., 2017). These automobiles support the worldwide movement toward a greener future and lessen overall transportation emissions (Brown et al., 2018). In contrast, the use of fossil fuels by ICE three-wheelers results in increased emissions of particulate matter (PM), nitrogen oxides (NOx), and carbon dioxide (CO2) (Jiao et al., 2020). Three-wheeled electric cars have higher environmental performance, which makes them desirable solutions in the fight against climate change and for sustainable transportation.

Cost Consideration and Affordability

The adoption of both vehicle types on the market is heavily influenced by cost factors. Due to the pricey battery technology, three-wheeled electric vehicles may have greater upfront expenditures (Lu & Yang, 2019). However, because electricity is typically less expensive than gasoline, they offer lower operating and maintenance costs (Zhang & Wu, 2015). Although ICE three-wheelers may have a lower initial investment, their ongoing costs, such as gasoline and maintenance, can be somewhat greater (Chau et al., 2015). Additionally, the long-term cost barrier for three-wheeled EVs is anticipated to be lowered by continued improvements in battery technology and mass production of electric cars (Sierzchula et al., 2014).

User Experience and Convenience

Various factors impact the comfort and user experience of ICE and electric wheelers. Electric trikes provide a quiet, smooth ride, enhancing comfort and reducing noise (Lee et al., 2021). Electric motors deliver quick torque for snappy acceleration and urban agility (Polidori et al., 2017). Charging station expansion and vehicle-to-grid connection enhance convenience for electric trike owners (Wang & Wang, 2018). On the other hand, ICE three-wheelers offer traditional refueling and longer ranges for distant trips (Jarvi et al., 2020),but their combustion engines create more vibration and require frequent maintenance (Chen et al., 2018).

Safety and Regulation

In the automotive sector, safety is the first priority. Strict safety requirements and criteria must be met by ICE three-wheelers as well as three-wheeled electric vehicles. Due to the positioning of the battery pack, electric trikes have lower centers of gravity, which improves stability when turning and reduces the chances of rollover (Haddadi et al., 2018). Additionally, mechanical problems are less likely to occur in electric vehicles than in ICE vehicles since they typically have fewer mechanical components (Ehsani et al., 2010). ICE three-wheelers, on the other hand, are covered by proven safety features like seat belts and airbags and are subject to conventional vehicle safety rules and regulations (Nagayoshi et al., 2017)

Aim and objectives of the study

The aim of this project is to provide optimal material selection criteria in the design and fabrication of a prototype three-wheeled electric vehicle..

The objectives include:

- To develop a conceptual design for the three-wheeled electric vehicle, considering factors such as weight distribution, and energy efficiency.
- Select suitable and cost effective components such as the electric motor, battery, etc, to ensure optimal performance and range for the vehicle.
- To develop a sustainable mobility solution that reduces greenhouse gas emissions and contributes to a greener and more environmentally friendly transport system.

Scope of the Study

This contemporary study employed an in-depth study of various aspects of design that relates to the creation of a three-wheeled electric vehicle. Comprehensive technical and design concerns are covered, including motor location, battery technologies, and important elements affecting performance. The best integration is made possible by multidisciplinary collaboration. The study carefully evaluates the environmental impact, paying close attention to improvements in air quality and emission reduction for sustainable transportation. Cost analysis and expected benefits are used to thoroughly assess the project's economic viability, while user experience and societal ramifications, such as noise reduction and urban enhancement are also taken into account. The study encourages innovation in electric mobility technologies, placing the initiative at the fore of developments in environmentally friendly transportation. This study also acts as an educational resource, including scholars, researchers, and business experts in an effort to spread information and advance electric mobility. This study affords a comprehensive material selection that provides, environmentally friendly, and user friendly electric car that will benefit society, the economy and the environment.

Significance of the study

The relevance of this study is anchored on promoting the sustainability of a mobile system that can lower greenhouse gas emission and reduce dependence on fossil fuels. The project is focused on designing and creating a three-wheeled electric vehicle. With enhanced material selection, the vehicle can address the problems associated with urban mobility and offer urban commuters an effective mode of transportation. Exploring improvements in electric vehicle technology, energy efficiency, and conservation might encourage industrial innovation. Additionally, it has economic ramifications that could result in job development and expansion of the electric vehicle industry. The results of the project can be used as teaching materials and to help shape regulations that encourage the use of electric vehicles. A three wheeled electric vehicle's successful demonstration of its viability promotes additional investment in environmentally friendly transportation, resulting in advantages for the environment like decreased carbon emissions and improved air quality. Overall the study's importance resides in its potential to promote advancements in better and more sustainable transportation, environmental preservation and technology innovation.

Limitations

There were various restrictions that had an impact on the scope and outcomes of the study. Firstly, there were financial limitations that prevented the utilization of cutting-edge materials and technology. Secondly, time constraints made it more difficult to conduct in-depth analysis and extensive testing. Thirdly, certain parts of the design of the electric vehicle may be imported.

Methodology

In order to optimize the drive train and use the best locally available materials, the concept for this design and construction of this electric cycle were created from scratch as part of this project report**.** Fabrication, assembly, installation, and analysis were the main processes used in this project. The main design goals were to keep the chassis sturdy while keeping it lightweight, and to optimize the design by avoiding over designing, which would also help with cost reductions. As a result, it is essential that we design the electric tricycle differently from other vehicles in order to get a completely original concept.

This conceptual design primarily focuses on the power train, chassis design, suspension and steering system, braking system, electrical systems, fabrication, and assembly procedures. We also used AutoCAD models to design the electric vehicle. The conceptual designs main objective is to utilize electric propulsions potential to build a straightforward, versatile, and emission free tricycle. This electric tricycle attempts to maximize efficiency, maneuverability, and sustainability by fusing the advantages of an electric power train with the versatility of a three-wheeled layout.

The design methodology outlines the project workflow and how concepts were put into practice to get the required design. The flowchart demonstrates how the project was conceptualized and how it was carried out. This effective design approach ultimately distinguishes the project.

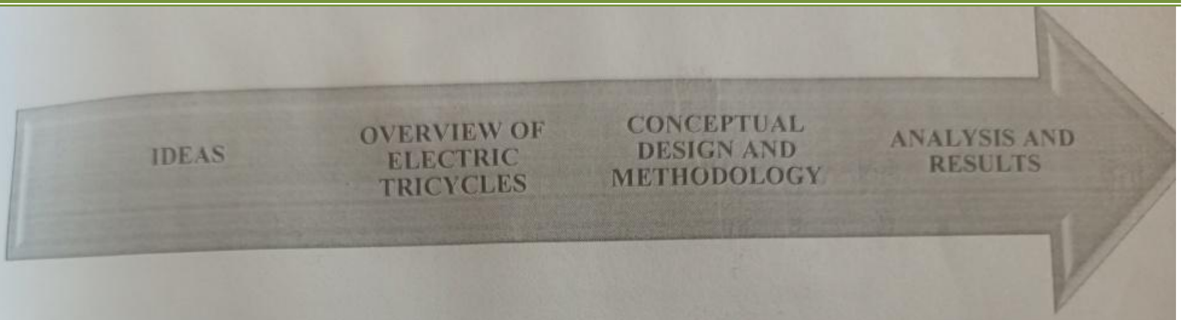

Fig 3.1 Diagram Illustrating the Design Process for the Three-Wheeled Electric Vehicle

Project subsystem and components design methodology

There are a number of subsystems and components that were employed to design the structure and produce the functioning of this three wheeled electric vehicle. Some of these include:

Chassis design and material selection

The vehicles primary skeleton is the chassis frame. It supports the car body, power train, and engine. The suspension system supports the frames. The frame supports all the weight of the automobile and the driver while also withstanding external stresses. The operators comfort and safety were taken into consideration when designing the chassis. The frame was made to be sturdy and solid so that it could support weight without compromising the structure's integrity. This chassis design was completed in AutoCAD before it was constructed utilizing square tubular space frame pipes.

The benefits of square tubular space frame chassis are its lightweight, ease of manufacture, structural strength, simplicity in component mounting, aesthetics, vibration damping, and material savings. A portion of the chassis also included the use of angle irons.

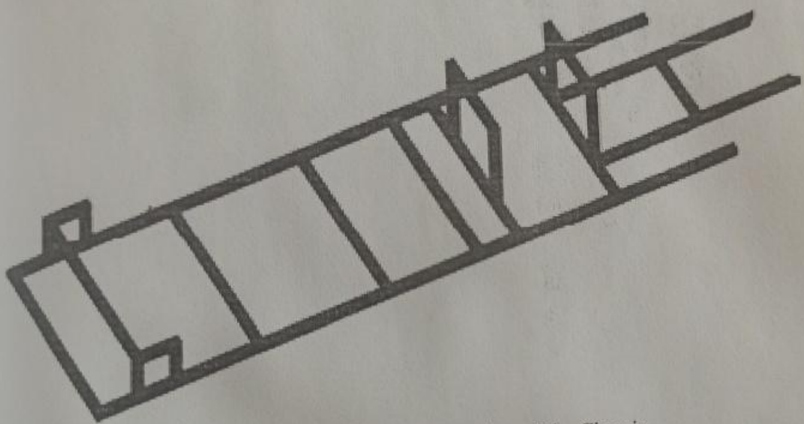

Fig 3.2 AutoCAD Design of the Chassis.

The selection of materials for the chassis was made with the following considerations in mind: weight and structure, compatibility, manufacturing, and cost analysis.

Suspension and steering system

The suspension connects the frame or the chassis of the vehicle to the wheel and then to the road surface for smooth motion. This system absorbs the impact of vibration on the body of the vehicle and in addition, it enhances vehicle stability, braking performance, load bearing, increases handling and cornering. The main components of the suspension system are: springs, shock absorbers (dampers), brushings, struts, ball joints, wheel bearings, control arms. These components work together to create a proper suspension system. On the other hand, the steering system is the system responsible for providing directional control to the vehicle. This

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system is normally attached to the front wheel and it consist of the steering linkage, a steering column and a steering wheel. This system allows to rotate the steering wheel 45^o left and 45^o right which produce minimum wheel angle and minimum turning radius.

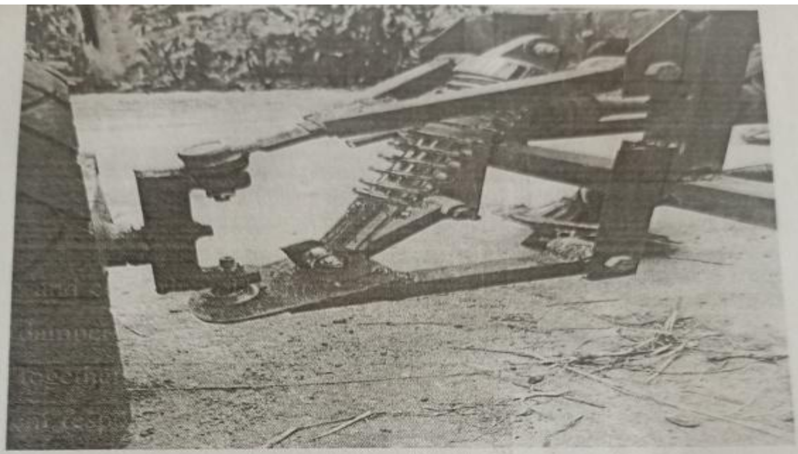

Fig 3.3 Suspension Unit

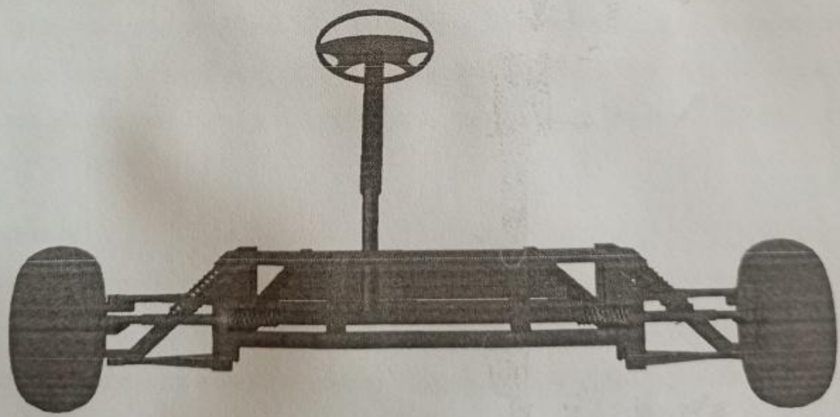

Fig 3.4 Suspension and Steering System Assembly (CAD representation)

Braking system

This is a system responsible for the speed retardation of the vehicle. In the design of the braking system, we made use of Drum brakes which is one of the traditional brakes or the conventional braking systems which slows the tricycle down due to the friction between brake pads/shoes and rotors. This method is generally known as friction braking. Friction brakes are typically located on the wheels and use pads or shoes to grip the rotor or drum of the wheel and slow it down. The figure below shows a drum brake with the positions of the brake shoe, springs, brake drum, fulcrum and expander.

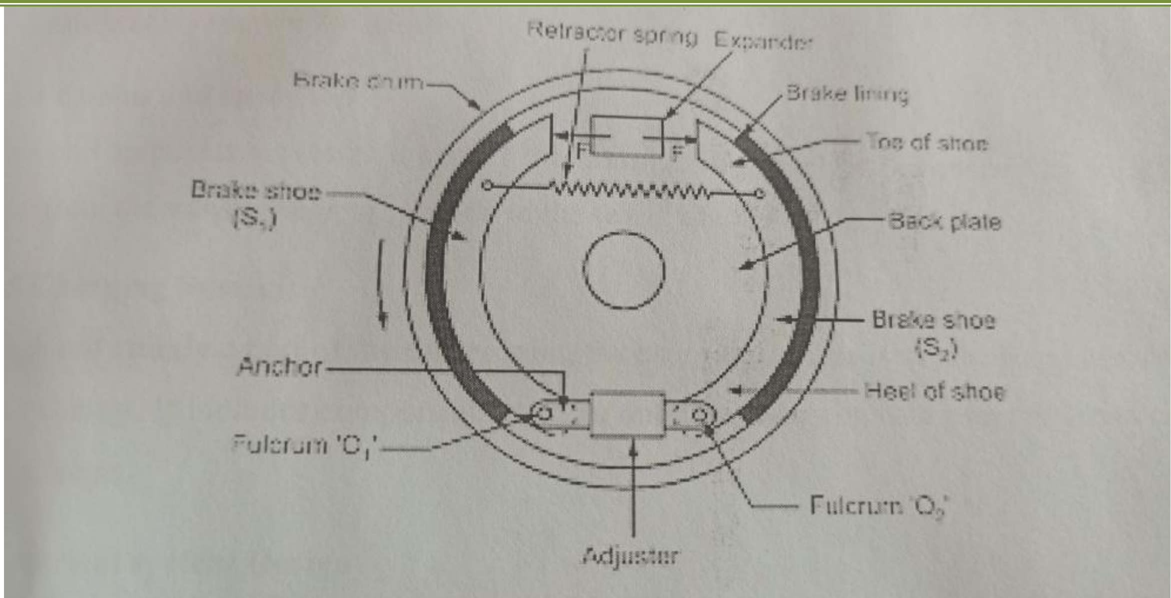

Fig 3.5 Diagram of a Brake Drum *(https://electricalworkbook.com/drum-brake/)*

Power train system design

The power train system is responsible for generating, controlling, and transmitting the electric power that drives the vehicles wheels. These power train consist of several key components that work together to convert electrical energy into mechanical motion. These systems typically consist of

Electric motor

An electric motor is considered the engine of and electric vehicle power train. It converts electrical energy from the battery into mechanical power. Based on the vehicle's design and configuration, we used just one electric motor (Brushed DC motor) which makes use of 13v dc current. The electric motor typically goes from 10-17 amps while running. This motor was connected to the transmission of the vehicle. Electric motors are highly efficient and provide instant torque, contributing to the quick acceleration of the electric vehicle.

Battery pack

The battery pack stores and supplies electrical energy to the electric motor. It consists of battery cells that are connected in series and parallel configuration to achieve desired voltage, capacity and energy density.

Transmission

The purpose of transmission or gearboxes is to transmit the motor's power to the wheels. In this project, we made use of the multi-speed transmission so as to attain high torque and maximum acceleration at constant motor speed.

Chains and sprockets

Chains and sprockets serves as a part of the transmission which is responsible for transferring motion from the transmission or gearbox o the wheel of the vehicle.

Charging system

Although not strictly a part of the power train, the charging system is crucial for replenishing the battery's energy. It includes components such as onboard charges, charging ports, charging control systems.

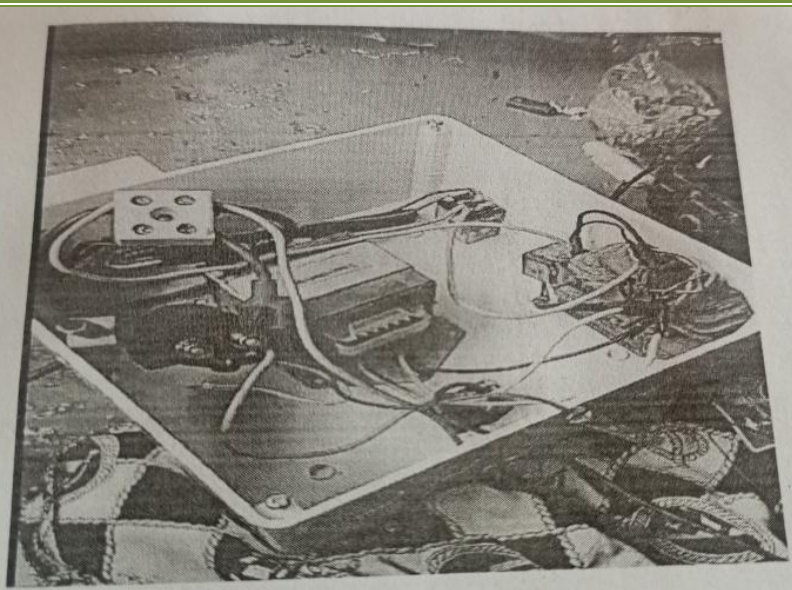

Fig 3.6 Picture of the Charging System

Electrical system design

The electrical system of an electric vehicle (EV) is a complex network of components responsible for maintaining various electrical functions, from powering the vehicle's systems to controlling its drive train and supporting auxiliary features. Here's an overview of the main components that make up the electrical system of an EV.

Battery pack

The central component of the electrical system, the battery pack, stores and supplies electrical energy to power the vehicle's motor and other electrical components. It consists of double battery cells connected in series and parallel configurations.

High-voltage wiring

High voltage wiring carries the electricity between the battery, power electronics, electric motor and other high voltage components. These wiring systems are designed to handle the higher voltages used in vehicle.

Charging systems

The charging system is a system designed to replenish the battery from an external power source after being used by the electrical components onboard. The system comprises of the following components: electrifiers, relay, transformer, cooling fan, solenoid, charging ports.

Fabrication and Assembly Process

The fabrication and assembly process in this project involved several stages, from designing and manufacturing components to final assembly and testing. Here's a brief general overview of the processes:

Stage 1: Design

The design of the three-wheeled electric vehicle's architecture, chassis, body and components was done with computer aided design (CAD) software (AutoCAD). The design includes the electric power train, battery system, suspension, electronics, and other critical components.

Stage 2: Components/Materials Purchasing

Purchasing of battery cells, modules, and packs. Purchasing of electric motors and power electronics components, chassis components, body panels, interior parts, transmission.

Stage 3: Chassis Fabrication

Fabrication of the chassis structure, including frame components and sub frames was done using various manufacturing processes like welding, forming and machining.

Stage 4: Mounting Suspension and Wheels

After the fabrication of the chassis, we installed the suspension components which are: shocks (struts), ball joints, brushing's, upper and lower arm, control arm, and then attached the wheels and tires. The installation of the wheels was carried out together with the installation of the steering system of the vehicle.

Stage 5: Installation of Braking Systems

Installments of braking components for the vehicle

Stage 6: Power train integration

Installed electric motors, power electronics, and transmission components and connected the wires.

Stage 7: Battery Integration

Installation of the battery pack into its designated location within the chassis.

Stage 8: Final Assembly

Stage 9: Painting and finishing

Quality Control and Testing Procedures during Fabrication

The objective of carrying out quality control us to identify safety issues, defects or inefficiency in the vehicle. Quality control and testing are crucial stages in the fabrication to ensure that the vehicle meets safety, performance, and reliability standards. In this project, we conducted a functionality test on all the subsystem and components of the vehicle to ensure that all parameters are working properly. The type of quality control testing process that was carried out were: battery testing, power train testing, charging system testing, functionality testing, noise and vibration testing and range efficiency testing.

Budget and cost analysis

This budget and cost analysis provides a comprehensive overview of the financial considerations of fabricating a three wheeled vehicle by examining each price of the components used associating it with the maintenance, incentives and environmental benefits.

COMPONENTS	COST(₦)
Shock absorbers(Struts) (x4)	28,000
Steering rack	7,000
Back tire	5,000
Brushings	4,500
Transmission	58,000
1 and half inch Square pipe 18 ft (x2)	7,600
1 inch 1.5mm square pipe (x2)	6,000
2mm iron for chassis reinforcement	6,000
Sprockets (x3) and chains (x2)	18,000
Front tires (x2)	10,000
Drum brakes (x2)	7,000
Brushed motor	40,000
Ball joints (x4)	10,000
Size 19 bolts and nuts	2,000
Steering column	6,000
Lead acid Batteries 12v, 38Ah (x2)	64,000
Step down transformer	10,000
Electrifier	3,500
Tire rod extensions	6,000
Angle ion, rods and brushings	12,000
Flat metal plate of 2mm	5,000

Brake cables	10,000
Solenoid	5,000
Digital Display	3,000
Pedals for braking, clutch and acceleration	5,000
Gear cable	1,000
Clutch cable	3,000
Relay for charging (10A)	2,000
Sockets for charging and plugs	3,000
Wire for connecting motor	5,000
Change over	2,000
Cooling fan for charging system	3,000
Transportation	10,000
Workmanship	50,000
Miscellaneous	30,000
Total	447,600

Experimental Analysis

This experimental analysis aims to investigate the performance and efficiency of an electric vehicle under various driving conditions. The study includes a range of tests focusing on acceleration, range, energy consumption, and drum braking efficiency. The results supports the visibility of electric vehicles as a sustainable transportation solution, emphasizing their potential to reduce emissions. The following test were carried out for the experimental analysis

Efficiency and range testing

- Energy Consumption (3 wheel electric vehicle): The energy consumption of the electric vehicle was measured by fully charging the battery and discharging it under controlled conditions while monitoring the energy usage. Energy efficiency (kWh/mile or kWH/km): Energy consumed (kWh)/ distance traveled (miles or km)
- Range Calculation: The Electric vehicle range was evaluated by conducting a controlled drive on a standardized track at constant speeds. The distance covered and remaining battery charge were recorded to estimate the real-world range under different driving conditions. Range (miles or km): Available energy (kWh or gal)/ Energy consumption (kWh/mile or kWh/km)

Acceleration and Average Speed Testing

The following tests were conducted to evaluate the vehicle's acceleration and average speed performance:

- 0-60 mph Acceleration Test: The vehicle's acceleration from 0-60 mph was measured to assess its initial speed capabilities. The vehicle achieved a 0-60 mph time of 10 seconds, demonstrating high torque from the electric vehicles motor.
- 0-100 mph Acceleration Test: The vehicle's acceleration from 0-100 mph was measured to evaluate its high-speed performance.

Handling and Stability Assessment

The objective of this test was to assess the vehicle's performance in terms of handling characteristics and stability during various maneuvers, providing insights into its dynamic behavior and overall safety. The following maneuvers were performed to evaluate the handling and stability of the vehicle:

Lane Change Test: The vehicle was driven through a simulated sudden lane change maneuver to evaluate its stability and ability to maintain control during abrupt directional changes.

Emergency Braking Test: The vehicles braking system performance and stability were tested during sudden and hard braking cornering capabilities.
Skid Pad Test: The vehicle was driven in a circular path on a skid pad to determine its maximum lateral grip and cornering capabilities.

Battery Performance

The main objective of this test was to assess the performance and characteristics of the vehicle's battery under controlled conditions. This evaluation provides insights into battery's capacity, charging efficiency, and discharge capabilities, contributing to a better understanding of the vehicle's overall functionality and sustainability. The following assessments were carried out to determine the battery performance:

a) **Charging time of battery =** Battery rating (AH)/ Charging current (A)

Generally 10% of battery Ah is considered as battery charging current. Therefore if we have a battery of 12v and 38Ah, Battery charging current = 10% of 38Ah.

Charging current for a 12v, 38Ah battery = 38 x 10/100 = 3.8A

Also we need to consider 2A for charging loss because of the resistance in the cables,

So total charging current = 5.8A

Charging time of battery = 38/5.8 = 6hrs 30mins (ideal case).

- Practical case, but we need to consider battery losses 40%,
  Then 38 x (40/100) = 15.2
  So total battery Ah = 38+15.2 = 53.2Ah (38Ah + losses)
  Therefore, charging time of battery is Ah divided by charging current = 53.2/5.8 = 9 hours

b) **Battery range:** The battery capacity of the vehicle is 12v and 38Ah and we made use of 2 lead acid battery. We connected the batteries in parallel in order to maintain the same voltage and to increase the amp per hour. The total Ah needed by the electric motor is 17Ah so therefore considering the battery capacity, in an ideal case the battery should last for not less than 4 hours but considering the load involved (more load requires more amp per hour), the vehicle would not last up to the stipulated time. From practical analysis, the vehicle would last 30 minutes when fully charged.

c) **Battery discharge:** Battery discharging current formula is generally 10% of the actual battery Ah therefore considering the 12v 38Ah lead acid battery, the discharging current would be 10% of 38Ah which is 3.8Ah. Therefore a 38Ah battery can discharge their full current in about 3.8 hours depending on the load requirement from the components attached to it.

d) **Discharge rate test:** The battery's ability to provide power at different rates was evaluated by discharging it at various levels of current demand and observing its voltage and capacity response. The battery exhibited consistent voltage and capacity response across different discharge rates, indicating its ability to deliver power reliably under varying load conditions. Discharge rates (C) = discharge current/ battery capacity

Factor of safety

There is obviously a need for a very high value of factor of safety because the project deals with human (driver), so life and property need to be protected. To this regard, a minimum FOS value of 3.2 was adopted. The maximum load the vehicle can carry before failure is 124kg so we estimated a factor of safety of 3.2. In this case, we designed the structure to safely support 124kg x 3.2 = 396.8kg. This ensures that even if there are variations or uncertainties in the load or material properties, the structure will still be able to handle the expected conditions without failing. The material used for the chassis frame (square tubular steel pipe) has yield strength of 62Mpa. The point of maximum stress was found to be 16.25Mpa. The major loads that are acting on the chassis frame considered here include: electric motor, driver mass (average of 70kg), and the DC battery weights.

Vehicle specifications

- General information:
  - Manufacturer: CUA Mechanical Engineers
  - Year: 2023
  - Type: 3 wheeled electric vehicle
- Performance:
  - Acceleration (0-60 mph/ 0-100 mph): the vehicle achieved a 0-60mph time of 10 seconds
- Battery and range:
  - Battery specification: 12v, 38Ah
  - Battery type: Lead acid
  - Standard charging time: 9hrs
- Interior:
  - Seating capacity: 1
  - Cargo space: Nil
- Exterior:

- Body type: Metal steel
- Exterior features: Fine paint
- Wheels: 100/90/10 45j

➢ Dimensions:
- Length: 7ft = 2133.6mm
- Width of chassis: 2ft = 610mm
- Distance from chassis to tire: 400mm
- Distance between upper and lower arm: 210mm
- Pole height: 580mm
- Pole size: 228.6mm
- Estimated weight: 200kg = 441 lbs
- Cambers (upand down): 7 inch each for the front
- Back camber: 27 and half inches (length)
- Back camber width: 254mm
- Height of the driver seat: 700mm
- Tire width: 100mm

Design Drawings

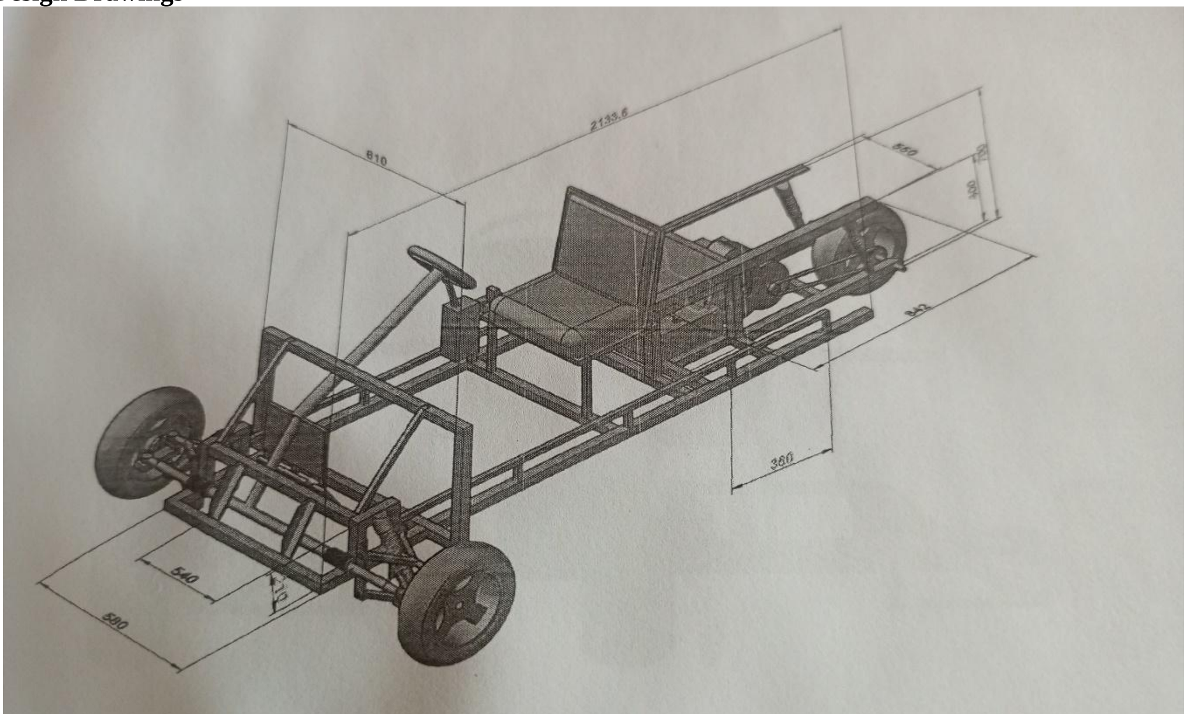

Fig 4.1 Dimensioned View

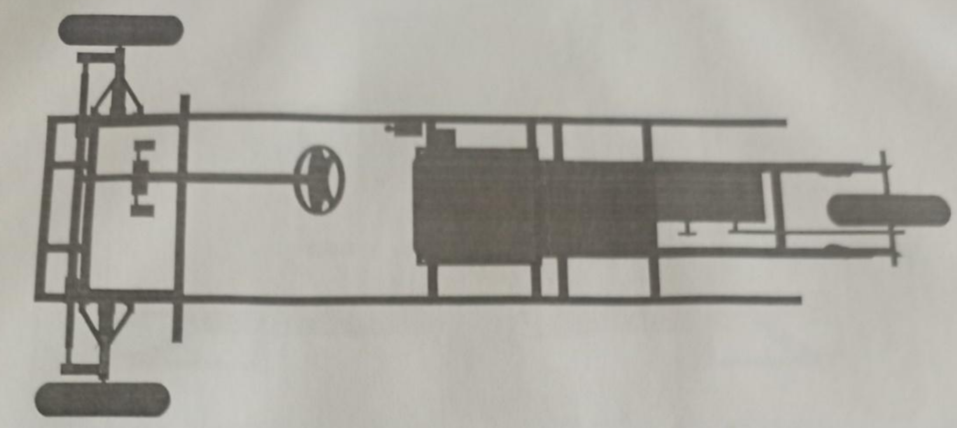

Fig 4.2Top View

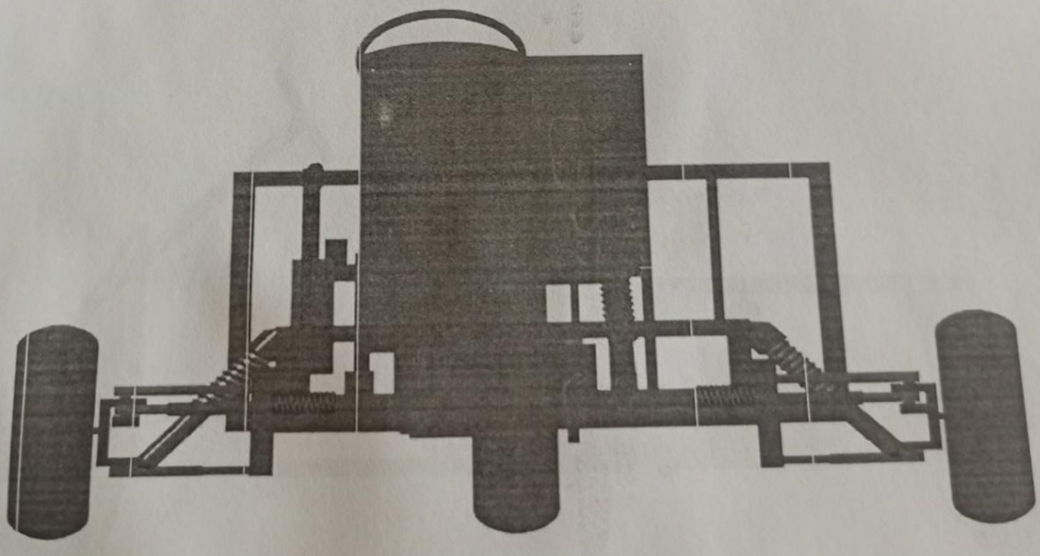

Fig 4.3 Left View

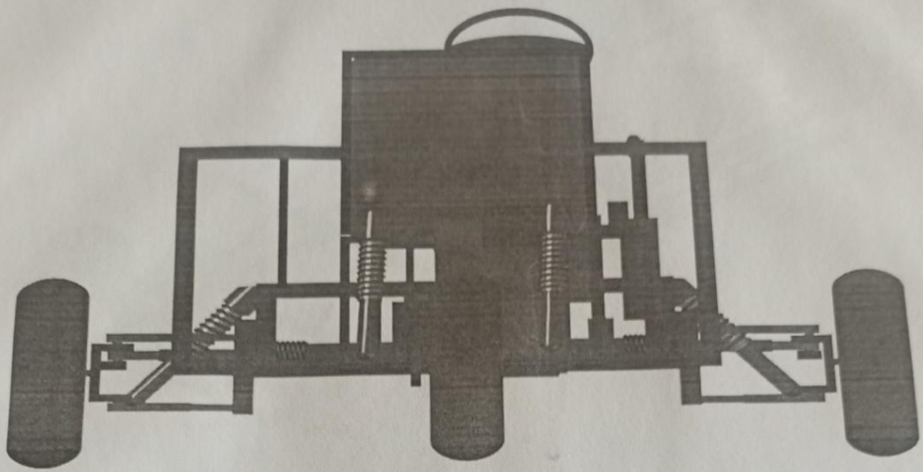

Fig 4.4 Right View

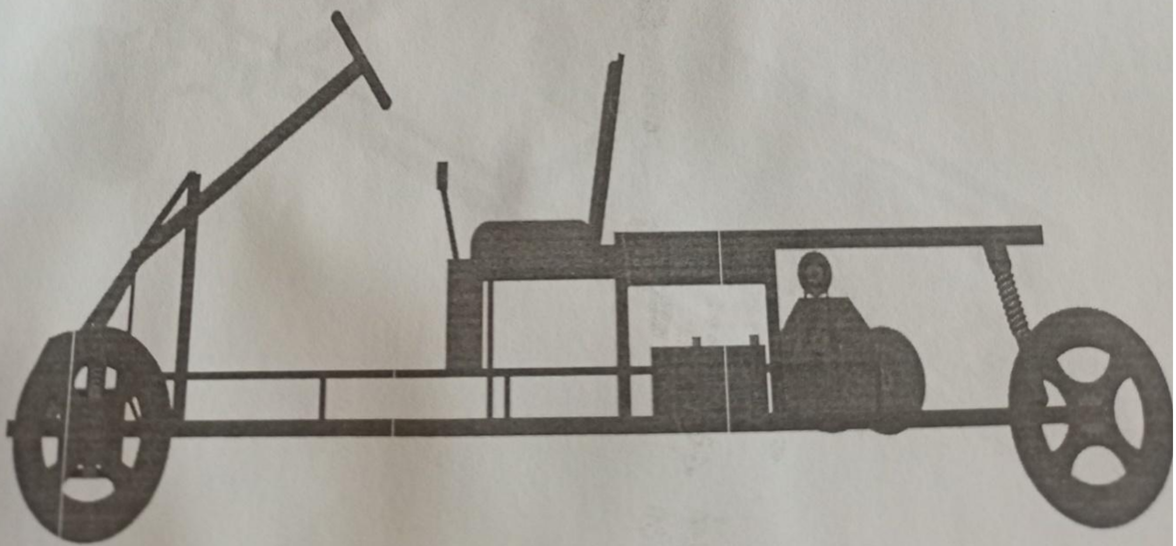

Fig 4.5 Front View

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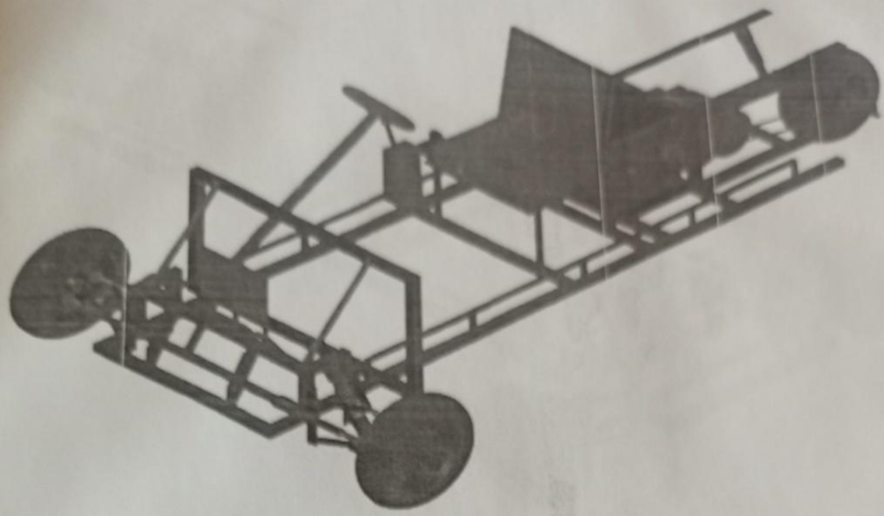


Fig 4.6 SW Isometric

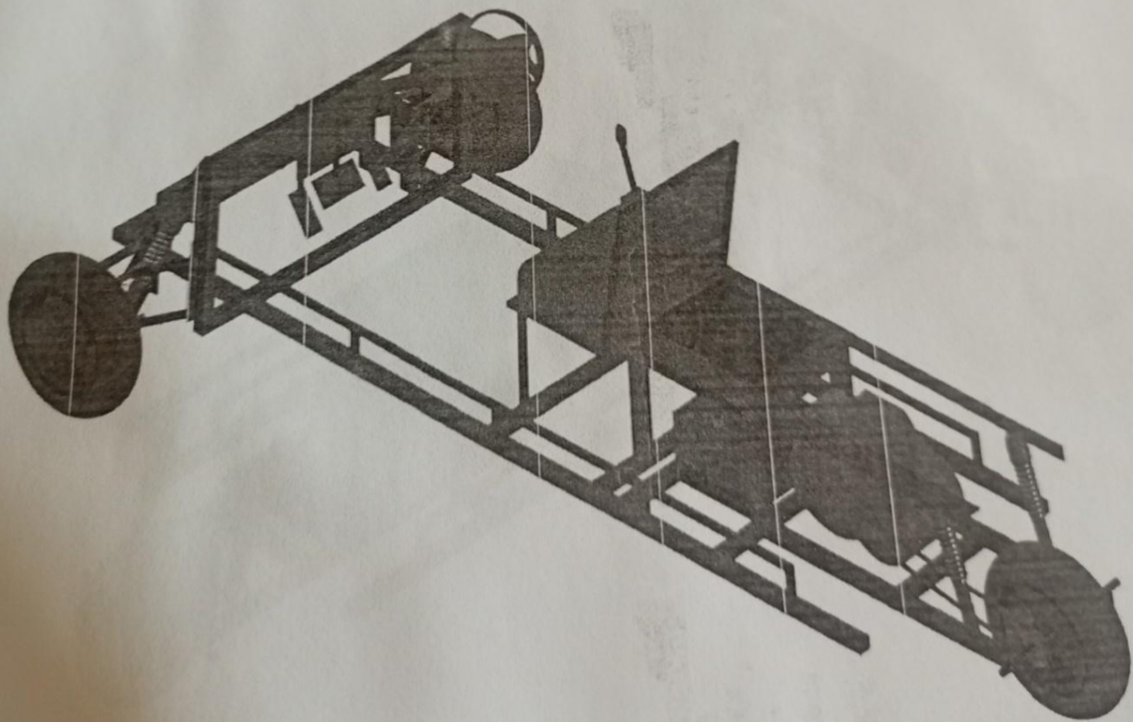


Fig 4.7 SE Isometric

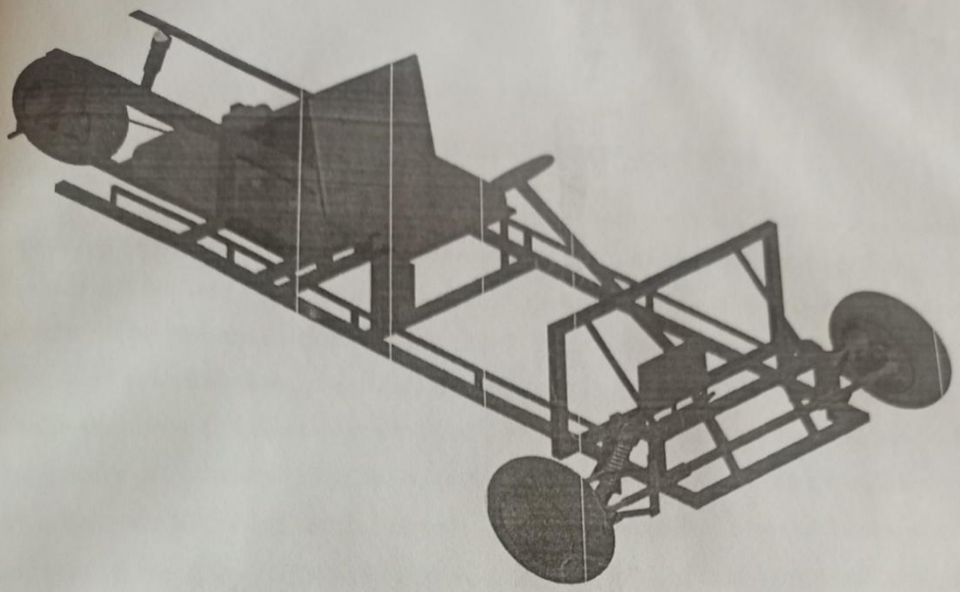
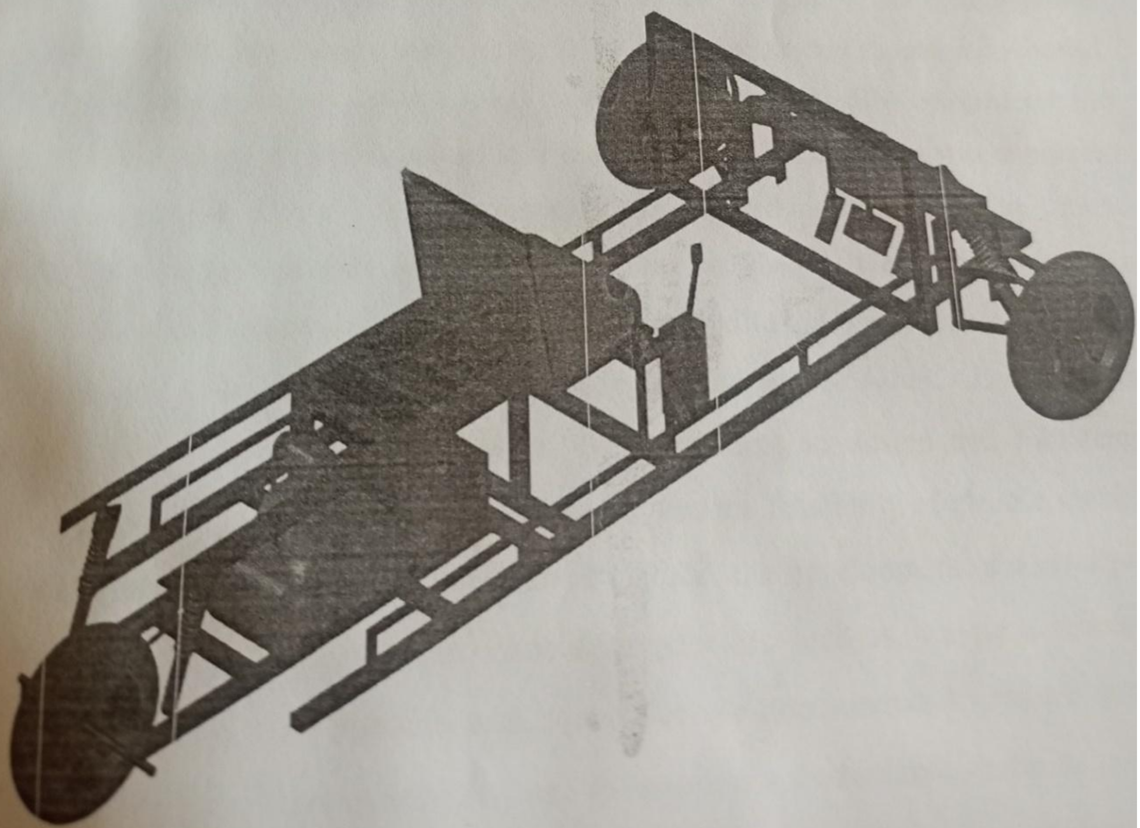


Fig 4.8 NW Isometric



Conclusions

This project aimed at the design and fabrication of a 3 wheeled electric vehicle was based on a conceptual design that was optimized to improve the vehicle's stability and performance. The electric vehicle design and fabrication focused on creating a simple, lightweight, and easy to operate vehicle. The material selection for the 3 wheel electric vehicle with the identification and prioritization of critical design criteria. This selection of materials for the electric vehicle was done to balance the trade-offs between cost, performance and environmental impact. The choice of materials for the electric vehicle components was carefully evaluated based on a variety of factors including strength, weight, durability, cost and compatibility. For the structural part of the EV, lightweight and strong materials such as iron, steel and aluminum were used to provide significant weight savings and improved performance for the electric vehicle. Lead acid batteries were used for this electric vehicle because of their high power density, fast charging time, easy accessibility, and it is of lower cost. In this chapter a 3 wheeled electric vehicle has been modeled and designed. This vehicle is propelled by brushed electric motors, using electrical energy stored in a lead acid battery. The electric motors was connected to a multi speed transmission which gives the electric car the required instant torque. The vehicle was made with lightweight materials in order to increase its range. It also produces zero emissions hence, reduce the health hazards and environmental pollution also reduces global warming. The modeling of the electric vehicle was done with the use of AutoCAD thereby the aims and objectives of this project was achieved. The aim being to design and fabricate a prototype of a 3 wheeled electric vehicle that demonstrates the feasibility of electric mobility as a sustainable transportation solution. The objectives include: the development of a conceptual design for the three-wheeled electric vehicle, considering factors such as weight distribution, and energy efficiency, selection of suitable and cost effective components to ensure optimal performance and range for the electric vehicle, and to develop a sustainable mobility solution that reduces greenhouse gas emissions and contributes to a greener and more environmentally friendly transportation system.

Recommendation for Further Work;

The following ideas can be used to facilitate this project further

- Use of lithium ion batteries for longer ranges and better performance
- Use of regenerative braking system for energy conservation

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