"Design and Fabrication of Solar E-Trike"

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Design and Fabrication of Solar E-Trike

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Declaration

We declare that the work contained in this thesis is our own, except where explicitly stated otherwise. In addition, this work has not been submitted to obtain another degree or professional qualification

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First of all, we would like to express our sincere gratitude to Allah Almighty for giving us the intellect used in this project. We pay the best of our compliments to our Head of Department **Engr. Dr. Liaquat Ali Najmi** Project supervisor **Engr.Muhammad Aqib** Project Coordinator **Engr.Hassan Kazmi** and all faculty members provided precious technical guidance to us. We are grateful to them because they sacrificed their valuable time and provided all possible facilities. Last but not least from the depths of our hearts, we express our gratitude and respect to our loving parents whose blessings, affectionate love, continuous efforts, magnificent devotions, and sacrifices led us to success throughout our academic career.

Dedication

We dedicate this effort to our Parents and Teachers who always guided us. They are our spiritual support. Our parent's and teacher's encouragement were a great motivation in our graduate studies. We also dedicate this effort to our friends who always worked in a team with us.

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List of Abbreviations

ICE: Internal combustion Engine

AFPM: Axial-flux permanent magnet motors

IOT: Internet of Things

AI: Artificial intelligence

DC: Direct current

VSD: Variable speed drive

TOU: Time-of-use

PLC: Programable logic control

PV: Potential velocity

ECO: Estimation-Calculation Optimization

RPM: Revolution per minute

CAD: Computer aided design

I/O: Input/output

MS: Mild steel

FEA: Finite Element Analysis

FOS: Factor of Safety

REI: Recreational Equipment, Inc

RFID: Radio-frequency identification

ASTM: American Society for Testing and Materials

ACC: Association of Corporate Counsel

CHAPTER 1

INTRODUCTION

1.1 Introduction

Transportation plays a key role in overall development of the society both economically and socially. Never the less, it has many spillover effects such as traffic congestion, safety, global warming and depletion of non-renewable sources of energy. Transportation assists in economic growth by making accessibility to resources and markets. In Pakistan there are presently close to 26 million petrol-powered two wheelers and about 1 million petrol and diesel powered three wheelers and their population is growing at a rate of about 15% per annum. It is a common sight in Pakistan and in other developing countries that during traffic jams in congested areas of cities these vehicles produce tremendous air pollution. Therefore, the aim was to design a three wheeled human powered electrically assisted vehicle having simple, high performance, easy maintenance and safety at a very reasonable price, hence capable of replacing fuelled vehicles contributing towards environmental sustainability [8].

1.2 Historical Background

The history of the upright tricycle dates back to the mid 1600's, but the recumbent didn't make its appearance until much later. In fact, while the first geared recumbents appeared in the 1890's, it wasn't until the 1930's that interest truly gained momentum.

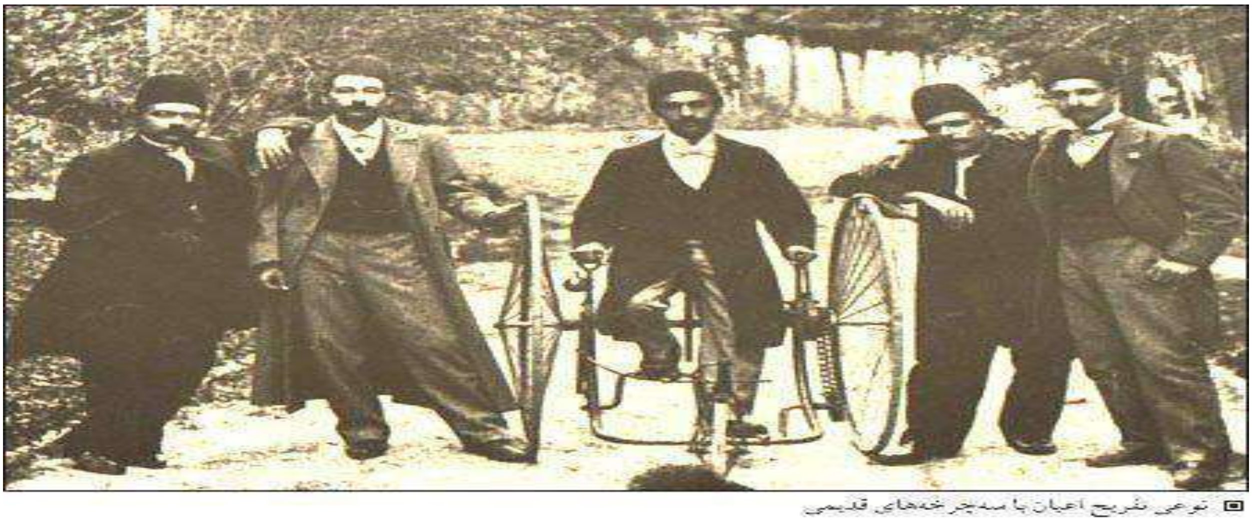

Figure 1-1: Historical background of trike

came about in the 1890s, shortly after two-wheeled safety bikes started to increase in popularity. It is believed that an Italian professor from Geneva, Charles Challand, designed the first geared recumbent, naming it the "Normal Bicycle," a direct reference to the rider's more "normal" riding position (as opposed to the hunched over riding stance in which non recumbent vehicles place the rider). The recumbent tricycle craze spawned from Charles Moche's Pre-World War I invention, the Veloce, originally designed for his young son, George, and it featured four wheels, a lower sitting position, and was human-powered.

1.3 Aims and Objectives

- The aim of the project is to provide an alternative to short-distance transport and in turn reduce the ever-increasing pollution and demand on fuel resources.
- Our objective is the development of a solar-powered electric recumbent trike which will cater to present-day transport needs without being a burden on the environment and also does not compromise on matters like stability and comfort.

1.4 Problem Statement

We will be developing a mode of transportation that will be more environmentally friendly, easier to maintain, and less expensive.

1.5 Research Gap

The Solar E-Trike as a new form of private transport has led to a new approach to mobility, especially in cities, both for countries with large populations and for countries that are concerned about the environment. The research on the electric trike is relatively new, but today, we want to develop a trike that is manually and pedal assist with battery charging mechanism. The objective of this manuscript is to detect how the worldwide research of the electric trike is being developed, and, especially around which scientific domains it is clustered. Finally, the main trends in this field can be identified.

1.6 Methodology

1.6.1 Theoretical Studies

One of the key renewable energy sources that can effectively replace fossil fuels is solar energy. There have been numerous efforts made to integrate tricycles and solar energy into daily transportation. However, the majority of tricycle developments are pricey and impractical for developing nations. In this study, a less expensive solar tricycle with more solar energy utilization potential is built for developing nations. The solar PV panel, brushless PMDC motor, controller, and battery make up the majority of the tricycle's components. The solar tricycle's power transmission is likewise straightforward. It has been discovered that a tricycle uses a solar panel to provide 24% of its running power. Additionally, the tricycle only cost 240 dollars to create on its whole. It has been discovered that a tricycle uses a solar panel to provide 24% of its running power. This essay focuses on the benefits of dual charging, such as the tricycle's viability from an economic and environmental standpoint.[9]

1.6.2 Experimental Setup

The solar-powered recumbent trike has two front wheels and one rear wheel to which the motor is attached which powers the vehicle. The 500W motor can be charged either from solar energy or by connecting to an external power supply and can carry a load of up to 130kg. This single seat vehicle can attain speed of 20kmph in both the forward and reverse modes and can cover a distance of approximately 15km on a single charge. During day time, it automatically recharges itself from the sun’s energy even while driving, thus avoiding the need of constant refuelling [36].

Figure 1-2: Solar power recumbent trike

1.6.3 Results Expected

The result of this study is to design and construct of a cheaper solar assisted tricycle. The body of a tricycle, charging system, battery and the power transmission system are designed. After performance study, it is obtained that storage system can run the tricycle about 25 km and it gets back up about 24% power from a solar system which is equivalent to 6 km, if the solar intensity is around 1150 w/m^2 at the time of running of the tricycle. The maximum speed of the tricycle has been found at 26 km/h. This ensures continuous energy input to the tricycle without any additional cost. So, the tricycle designed and constructed in this study can be used as a green vehicle in developing countries due to its less expensive and zero pollution effect nature.

1.7 Project working block diagram

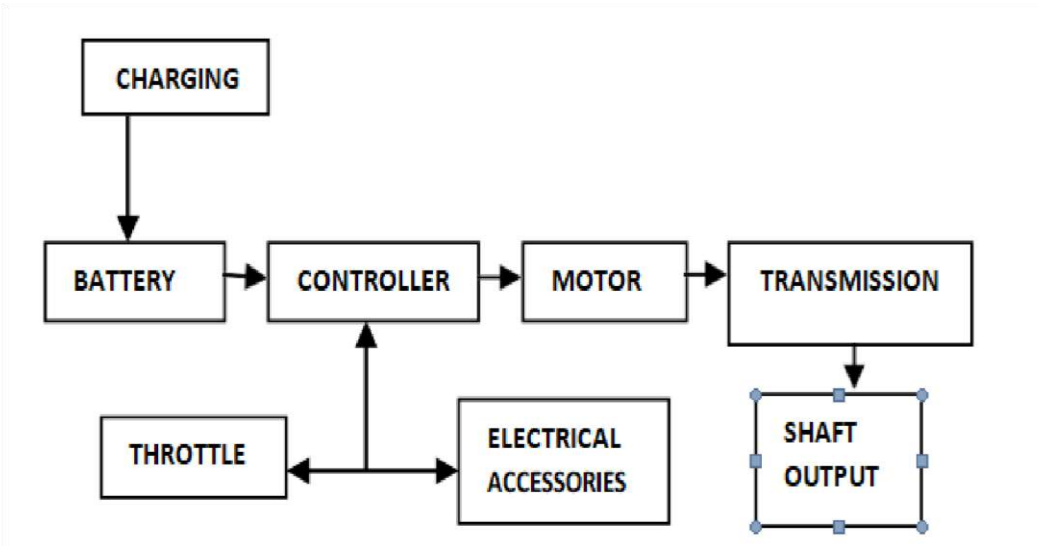

Figure 1-3: Block Diagram

1.8 How our project has positive effects SDGS:

The 2030 agenda for Sustainable Development, adopted by all United Nations Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. At its heart are the 17 Sustainable Development Goals (SDGs), which are an urgent call for action by all countries developed and developing in a global partnership. They recognize that ending poverty and other deprivations must go hand-in with strategies that improve health and education, reduce inequality, and spur economic growth all while tackling climate change and working to preserve our oceans and forests. Our project will attain some SDGS are following

Goal 7: Affordable and Clean energy

The environment provides a series of renewable and non-renewable energy sources i.e., solar we utilize solar power as a source of energy for batteries.

Goal 8: Decent Work and economic growth

In relation to SDG8, Engineers need to explore what kind of contributions are expected from them and what the engineering community has to offer to enable a faster economic growth, particularly in the global and regional context of post-COVID19 pandemic trends.

Goal 9: Industrial innovation and infrastructure

Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation.

Figure 1-4: SDGs

1.9 Utilization of Results

Recumbent trikes are a wonderful tool for getting exercise, getting outdoors, leaving the car parked or even getting off the beaten path. Trikes for adults and kids offer much greater stability than a two-wheeled bike, and with modern technology, are more fun, faster, and safer than ever before.

1.10 Work Schedule Plan

Project Management Design

The total duration of the project is 14 months (May 2022 to July 2023) which is further divided into following four phases.

- **Phase 1 (Collection of relevant literature and data)**

  The estimated time for this phase is 10 months (May 2022 to April 2023) in which different literatures will be studied.

- **Phase 2 (Study of literature and literature review)**

  Experiments will be performed on test rigs for analysis under fretting fatigue. The estimated time for this phase is 7 months (May 2022 to November 2022).

- **Phase 3 (Designing and fabrication)**

  The Estimated time for this will be 4 months (October 2022 to January 2023).

- **Phase 4 (Experimental and result analysis)**

  The estimated time for this will be 3 months (February 2023 to April 2023).

- **Phase 5 (Thesis write up and submission)**

  The estimated time for this will be 3 months (May 2023 to July 2023).

Table 1-1: Project Work Schedule

Phase	May	June	July	August	Septemb	October	Novemb	Decembe	January	Februar	March	April	May	June	July	August
Collection of data																
Study of literature and literature review																
Designing and fabrication																
Experimental and result analysis																SUBMISSION
Thesis write up and submission																

CHAPTER 2

Literature Review

2.1 Design and fabrication of solar e- trike

2.1.1 A load bearing tricycle chassis and springs design with performance analysis calculations

(Faraz Ahmad, Ekta Upadhyay, Ritika Mehra,19 August 2022)

The significance of delay in an automobile can't bring or come to a halt or end-emphasized, as it shapes the cross-slice for the link of the various parts as well as the material. Similarly, the delay foundations fill a double need - donating hugely to an instrument's equilibrium for improved safety and forceful pleasure, also having to do with secluding the inhabitants from unnecessary knocks and quivering. The point concerning this work search out plan and analyse vehicular delay and springs to construct an improved burden posture tricycle. In the plan thinking for the frame, choice of tolerable shapes and cross unspecified case things were espoused. Likewise, the support of the suspension side and cross part junctures, in addition to various acquiring game plans was gifted. In the plan, the spring rate K was driven to be 24273 N/m that is by means of what much strength wanted to pack the chosen spring by individual rhythm. The power used by a full spring upon the tricycle for balance restoration was driven expected 1699.11N, while 228.96mm was persistent and had as the spring free length. The guarded and cautious choice of the fabrics used to give the frame allowed ideal killing for minimal price, it was conceived accompanying a 2.5mm width mild gird empty square line, accompanying extreme return solidarity to present the tricycle the help it anticipates to have the alternative to send the particularized heap of 755 kg [1].

2.1.2 Human powered vehicle team

(Spencer Brodie, Maria Griffin, Ryan Serraglio,22 April 2022)

As concerns about global warming and product availability increase, a movement is being made towards more environmentally friendly alternatives. One large facet of this ideology is replacing individual motorized transportation with public transit and Human Powered Vehicles (HPVs). Both electrically assisted and fully manual HPVs have many benefits over traditional automotive transportation, such as lower manufacturing costs, less road wear, cheaper maintenance, long-term sustainability, and providing consistent access to physical activity. These aspects coupled with the wide range of potential designs could contribute to an increase in popularity and performance of HPVs in the future. This report will focus on the design, testing, and fabrication aspects of a Human Powered Vehicle, with an emphasis on safety, ergonomics, and innovation. The continued improvement and research of HPVs will aid future designs and allow this highly versatile field of transportation to continue to expand moving forward [2].

2.1.3 User-centred design and spatially-distributed sequential electrical stimulation in cycling for individuals with paraplegia

(Roberto S. Baptista, Marina C. C. Moreira, Lucas D. M. Pinheiro,8 May 2022)

In this work, we share the enhancements made in our system to take part in the CYBATHLON 2020 Global Edition Functional Electrical Stimulation (FES) Bike Race. Among the main improvements, firstly an overhaul, an overhaul of the system and user interface developed with User-centred design principles with remote access to enable rehabilitation. Secondly, the implementation and experimental comparison between the traditional single electrode stimulation (SES) and spatially distributed sequential stimulation (SDSS) applied for FES Cycling. We report on the main aspects of the developed system. To evaluate the user perception of the system, we applied a System Usability Scale (SUS) questionnaire. In comparing SDSS and SES, we collected data from one subject in four sessions, each simulating one race in the CYBATHLON format. User perception measured with SUS indicates a positive outcome in the developed system. The SDSS trials were superior in absolute and average values to SES regarding total distance covered and velocity. We successfully competed in the CYBATHLON 2020 Global Edition, in 6th position in the FES Bike Race category [3].

2.1.4 A three-wheeled vehicle for the disabled people

(K Stańko, Pająk, B Bursa, J Seńko,7 Oct 2022)

This article presents the construction of a prototype three-wheeled vehicle for people with disabilities, approved in the L2e category. The vehicle is equipped with a special tilt mechanism that allows people with disabilities, who cannot balance their body, to return to an upright position after completing a driving man ever on a curve of the road. The tilt angle of the vehicle depends on its speed and steering angle. When designing the vehicle, the availability and price of spare parts for scooters and motorcycles were taken into account to make the vehicle as cheap as possible. The structure of the vehicle in the Delta 1-2 system is a support structure in a form of a frame that is tilted together with the driver when driving along a curve of the road [4].

2.1.5 Pedalling Comfort of a Custom Pedal Series Hybrid Drivetrain in a Cargo E-Tricycle

(Jordi D’hondt, Peter Slaets, Eric Demeester,27 June 2022)

A Pedal Series Hybrid Drivetrain (PSHD) uses an electrical power transmission rather than a chain, belt, or shaft. It creates exciting opportunities for the vehicle’s design, but pedalling does not always feel comfortable. This study evaluates the pedalling comfort of a custom PSHD in an electric cargo tricycle. In this PSHD, pedal-driven generator converts human mechanical power to electrical power that is used by two hub motors to propel the vehicle. The pedal-driven generator is mechanically decoupled from the propulsion of the vehicle. Therefore, natural pedalling is replicated using a custom programmable controller for the mechanical resistance of the generator. Test subjects reported a very comfortable pedalling feeling, however slightly different from the feeling of a traditional e-bike. They failed to explain the differences in more detail. Further measurements show that the pedal generator of the PSHD has the same power cycle as the pedals in a traditional e-bike, but the pedal generator has a greater variation in the instantaneous angular velocity. All test subjects were impressed by the performance and natural feeling of the test tricycle. They stated that pedalling the tricycle feels natural once departed. They used the level of assistance just like with a conventional e-bike [5].

2.1.6 Effects of a Torsion Spring Used in a Flexible Delta Tricycle

(Jordi D'hondt, Peter Slaets, Eric Demeester and Marc Juwet,9 August 2022)

A new tilting delta tricycle is developed as a last-mile vehicle. This vehicle has a hinge between the front driver module and the rear cargo module to allow the driver to tilt while man euvering. The driver module resembles a conventional bicycle without a rear wheel and the cargo module consists of a cargo area between two propelled rear wheels. The concept vehicle ensures proper handling qualities independent of the cargo. However, the driver module can still tip over when parked. Multiple solutions are being considered to improve the ergonomics of this vehicle. A metal-elastomer torsion spring with an integrated angle limit has the most advantages as this prevents the driver module from tipping over without requiring it to enable a mechanism while stepping off. Furthermore, the torsion system dampens vibrations while cycling and influences tilting while turning. These improvements are tested using the concept vehicle. The influence of this torsion system is calculated and validated with measurements. The influences of different torsion curves aimed to improve the low-speed stability are calculated [6].

2.1.7 Development of an electric tricycle for service companies and last-mile parcel delivery

(Jordi d'hondt1, marc juwet, eric demeester,17 Feb 2022)

In many city centres and some large urban areas, access restrictions are imposed on trucks and vans. On the other hand, the number of e-commerce packages to be delivered daily is increasing rapidly, and service companies of all kinds also have to serve their customers in these areas. The use of cargo bikes is seen as a possible solution. The direct reason for this research is the observation that there is still room for a new type of cargo bike that meets the needs of the outlined target groups. This article summarizes how the quality function deployment (QFD) method has been used for the systematic development of an electric cargo tricycle that meets these needs. The developed tricycle distinguishes itself from existing cargo bikes mainly by its loading capacity, stability and manoeuvrability. The prototype tests performed by professional couriers were so positive that a pilot series was built [7].

2.1.8 Solar electric recumbent trike

(T. Tom, T. Chacko, S. Lokanathan, J. Joy, and V. Kulkarni,19 August 2015)

The solar powered recumbent trike has two front wheels and one rear wheel to which the motor is attached which powers the vehicle. The 500W motor can be charged either from solar energy or by connecting to an external power supply and can carry a load of up to 300kg.This single seat vehicle can attain speeds of 35kmph in both the forward and reverse modes and can cover a distance of approximately 50km on a single charge. During daytime, it automatically recharges itself from the sun's energy even while driving, thus avoiding the need of constant refuelling [8].

2.1.9 Survey-based accident analysis for human-powered three-wheeled vehicles

(Toni Wilhelm, Volker Dorsch and Frank Gauterin,30 Sep 2022)

The causes of accidents involving non-conventional bicycle types have hardly been investigated in the literature to date. However, these vehicles could play an important role in reducing the CO^2 emissions generated by traffic. As a basis for improving the driving safety of these environmentally friendly vehicles, this article presents the results of a survey on accidents and near-accidents of multitrack bicycle vehicles. More than 120 critical or accident situations of 86 drivers were analysed. The situations are investigated with respect to the circumstances, the causes, and the consequences of the accidents using manual analysis and multiple correspondence analysis. A distinction is made between single accidents and accidents with another party. The aim of the survey is not to make statistically accurate statements on the frequency and probability of accidents, but rather to analysed the accident or near-accident circumstances. It is shown that the causes of single accidents are usually too high cornering velocities in combination with other factors such as road conditions. In the case of accidents with external involvement, the person who caused the accident is usually the other party involved [9].

2.1.10 Spring 2021 HPVC exhibition capstone

(Abel Aldape Preston Berchtold Martin Dorantes Trent Todd, 15 March 2021)

In this Thesis customer requirements like safety, stability, ease of operation, adjustability, and transportability were referenced heavily in decision making. The client also established multiple constraints including a three-wheel design, and the inclusion of a roll cage for safety purposes. Through benchmarking, decomposition models, and concept generation and evaluation, our team finalized our six major subsystems decisions. Which lead our team to build the HPV seen about which is a recumbent tadpole tricycle (two wheels in front one in back) with indirect steering, a rear-wheel-drive chain system, three calliper breaking devices, a four-point roll cage, and ergonomic values that determine the angles at which the body is oriented within the device to make it ideal for children [10].

2.1.11 Development of a high-power capacity open-source electrical stimulation system to enhance research into FES-assisted devices validation of FES cycling

(T. Coelho-Magalhães, E. Fachin Martins, A. Silva, Coste, H. Resende-Martins,1 Nov 2021)

Since the first Cybathlon 2016, when twelve teams competed in the FES bike race, we have witnessed a global effort towards the development of stimulation and control strategies to improve FES-assisted devices, particularly for cycling, as a means to practice a recreational physical activity. As a result, a set of technical notes and research paved the way for many other studies and the potential behind FES-assisted cycling has been consolidated. However, engineering research needs instrumented devices to support novel developments and enable precise assessment. Therefore, some researchers struggle to develop their own FES-assisted devices or find it challenging to implement their instrumentation using commercial devices, which often limits the implementation of advanced control strategies and the possibility to connect different types of sensors. In this regard, we hypothesize that it would be advantageous for some researchers in our community to enjoy access to an entire open-source FES platform that allows different control strategies to be implemented, offers greater adaptability and power capacity than commercial devices, and can be used to assist different functional activities in addition to cycling. Hence, it appears to be of interest to make our proprietary electrical stimulation system an opensource device and to prove its capabilities by addressing all the aspects necessary to implement a FES cycling system. The high-power capacity stimulation device is based on a constant current topology that allows the creation of biphasic electrical pulses with amplitude, width, and frequency up to 150 mA, 1000 μs, and 100 [11].

2.1.12 Design and fabrication of customized tricycle for corporeally challenged people

(R Karthikeyan, V B Tamizhan, S Subhash and K Sathish Kumar, 22 Nov 2021)

This paper describes the design and fabrication of a Custom hand-driven Delta frame tricycle. In a developing country like India disability is a major issue. People using tricycles are facing various kinds of difficulties. The commonly faced problems are the requirement of more effort while riding in rough terrains, the chance to roll back while climbing through sloped paths, Carrying the tricycle while travelling and the space occupied by the tricycle. There are many models of tricycles are available in the market to address these issues. Some of the common solutions available in the market are motorized tricycles powered by both solar and electric, Hybrid tricycle and Hand powered. Each of them has its advantages and drawbacks. Though the motorized tricycles are easy to operate and efficient it is not affordable by all and also the maintenance cost is also high. The hand-driven tricycles are simple and affordable by most people and don't require more maintenance. This paper describes the various problems faced by the people using tricycles and their available solutions and the things that can be done to improve the functionality of a hand driven tricycle [12].

2.1.13 Mass data measurement, approximation and influence on vehicle stability for ultra-light human-powered vehicles

(Wilhelm, Toni, Dorsch, Volker, Gauterin, Frank,13 June 2021)

The mass properties of a vehicle play a decisive role in its dynamics and characteristics and are fundamental for vehicle dynamics models and controllers. These values are not yet known for the vehicle class of the ultra-light mobiles and similar multi-track bicycle vehicles. In the future, however, such vehicles could play a role in reducing the CO2 emissions generated by individual transportation. As a basis for vehicle dynamics modelling, accident reconstruction, and controller development for this vehicle class, this paper investigated ranges of mass properties and their influence on vehicle stability considering driver influence. In total, 13 vehicles (10 mobiles and 3 trikes) were examined using different experimental setups. It was shown that most vehicles exhibited understeering behaviour based on the centre of gravity position and calculations of the static stability factor showed significantly lower rollover stability compared with conventional vehicles. The measured moments of inertia were used to develop and examine different approximation approaches for the yaw moment of inertia using conventional approaches from the passenger car sector and stepwise regression. This created the basis for parameter estimation from easily measurable vehicle parameters and provided the possibility to generate realistic parameter sets for vehicle dynamic models. Existing tests do not consider the influence of driver movements, such as pedalling movements or possible inclination of the upper body. This offers the potential for further investigations of the dynamic influences on the investigated variables [13].

2.1.14 Innovative design and CFD analysis of human powered ecofriendly trike

(Kopelli, J R Ravi Kiran, April2021)

Large amounts of chemicals are released into the atmosphere by vehicles powered by gasoline and diesel. As a result, a healthy atmosphere is become unhealthy for people. There is growing worry about traffic and pollution using automobiles that run on conventional fuels for private transportation in contrast, battery-powered drives are not pollutant-free emissions. This project seeks to create a potential vehicle replacement that is environmentally friendly is the tricycle for trips that aren't too far. Tadpole: The tadpole type of trike has two wheels in the front and one wheel in the rear. Both the trikes have their pros and cons. But tadpole configuration always has certain advantages over the delta configuration in almost every field. Being a rear wheel driven configuration, the tadpole configuration will have all the tractive effort available from its share of the weight. Also because of the major weight on the front side of the vehicle there is much grip available for both steering and braking [14].

2.1.15 Solar electric tricycle development and research

(Berjoza, Jurgena, Bergspics, July 2021)

The solar electric tricycle was operated in two modes - with and without using a solar battery. The data obtained in the mileage tests are summarized. In both modes, the tests were done according to the driving conditions, thereby trying to move at the maximum speed. If using the solar photovoltaic panel, the average distance covered was 50.20 km. In this experimental regime, the tricycle ride was not stopped when the speed dropped below 15 km h-1 as originally planned; however, in the acceleration regime, the solar controller started to limit fast acceleration after turning in the opposite direction. In this way, it was concluded that the batteries were empty. By starting the acceleration of the tricycle very smoothly, even after the batteries were completely discharged, it was possible to continue riding the tricycle at a speed of 20–22 km h^{-1}. The distance covered if using the solar battery was 2.93 times longer than that without using it. It could be hypothetically assumed that at the next stages of the research, the maximum speed to be identified might be in the range of 20–25 km h^{-1}, as at high solar intensity, the battery energy is not consumed to ensure smooth propulsion. If using the solar battery, the maximum speed was 11.5% higher, while the average speed was 22.4% higher [15].

2.1.16 Solar Powered Tricycle for Handicapped Person

(Aniket Sanjay Babar, Abhijeet Pawar, Sanket Chavan, January-2021)

The standard tricycle has three wheels and is pedalled by a disabled person seated in the Center of the provided seating. The ride of these tricycles is mostly impacted by India's rough, uneven, and potholed roads. In order to minimize human effort, we have covered how to use solar energy to power the brushless DC motor, controller, battery, throttle, and other components. The panels' ability to recharge is decent. We are confident that we can accomplish our goals and that we have a system that will be useful in supplying accessible transportation for people with impairments. Appropriate takes into account longevity, dependability, and efficiency in addition to availability for reproduction [16].

2.1.17 Dreirad

(Ayushi Singh, Anamika Singh, Kajal Kumari, October 2020)

The aim of this paper is to explore DREIRAD modelling. The German word DREIRAD means trike. It is a three-wheel motor-based vehicle with a tadpole configuration that is two front wheels and one rear wheel. This design has more robustness than delta design. On the rear the vehicles are powered with electric motor and brakes. The vehicle will run on both electricity and solar power. Sun powered solar-panels are connected to the vehicle so that the vehicle can be charged at the time of driving or elsewhere where there is no electricity supply Theft detection and LDR sensors are used. LDR is used as a register of light dependents. Theft detection sensor is used for the purposes of security. This is eco-friendly due to use of electricity and solar panel. It reduces energy wastage and reduces pollution. The Department's Agency-Energy Advanced Development Projects (ARPA-E) is developing game-changing technology that could transform the way we think about electric vehicles. From investing in new battery types that could go further on a single charge, to cost-effective alternatives to essential materials electric motors, electric vehicles could be converted by ARPA-E ventures. In the end, only time will tell what direction electric vehicles can take in future [17].

2.1.18 Velocity tracking control of recumbent trike with functional electrical stimulation

(Toshiyuki Murao Yasunori Kawai Miyako Kishitani, December 2020)

This study examines the effects of a recumbent trike's movement velocity tracking control system using functional electrical stimulation (FES) cycling. The created system is meant to be used for rehabilitation outside on a trike with FES pedalling. The recommended control strategy. The movement velocity must be controlled to follow the intended velocity. Rider and FES trike by taking into account movement resistances and features is described as a Euler Lagrange system of the free wheel, and force direction of the four muscular groups in each lower limb. The stability of utilizing Lyapunov v-based techniques, the created controller is examined [18].

2.1.19 Review paper on solar electric tricycle

(Ajith Kumar, Chandru, Devarajan, June-2020)

Our daily lives depend heavily on the solar. We specifically created the solar tricycle for those with disabilities. We have given priority to the tricycle rider's comfort because it is crucial. The solar PV panel, brushless wiper motor, charge controller, and battery make up the majority of the tricycle's components. This will address the project's fundamental idea and provide a more comprehensive understanding of the issue with the state of the art technologies. The cost of fuel is rising every day these days; thus, a solar tricycle offers an option by using solar energy to charge the battery that powers the motor. Since India is blessed with nine months of sunny climate thus concept of solar tricycle is very friendly in India. Solar hybrid tricycle can become a very vital alternative to the fuelled automobile Thus its manufacturing is essential [19].

2.1.20 Senior / Honors Design Project Internal Systems of a Human Powered Vehicle HPVT Internal Systems Senior Design Project

(Broadbent, Zachary, Broadbent, Zack, April-2020)

In accordance with ASME 2020 Human Powered Vehicle Challenge Guidelines, the University of Akron's Human Powered Vehicle team created a fully functioning vehicle. This project's objectives are safety and efficiency in completing the course. Beyond the project's objectives, it is the goal of every individual to apply engineering principles and classroom knowledge to a real-world challenge. The undergraduate engineering students performed the necessary operations to complete the vehicle at the University of Akron. This work was executed during the 2019-2020 academic year. Due to the amount of work required, this project was broken down into tasks completed by smaller sub-teams. A few examples of the sub-assemblies include wheels, steering, seating, and fairing. This process was beneficial as it allows students to explore their interests and become familiar with the intricacies of the challenge [20].

2.1.21 Effect of number of passengers [loading] on centre of gravity of a three wheeled vehicle.

(B. Sunday, U. Thomas, I. S. Ityokumbul A. Nasir,10-March-2019)

In order to combat insecurity and to reduce the rate of accidents caused by commercial motorcyclist; many States Government in Northern Nigeria have substituted the use of motor cycles commonly known as Okada, with the use of three wheeled vehicle commonly known as keke-napep.

The Static and dynamic characteristics of these vehicles are not as those of the usual vehicles. Therefore, the need to know more about the effects loading on these vehicles is highly needed by Nigerians in order to ensure good road and passengers' safety. This paper uses simple approach to highlight the effects of number of passengers (loading) on the position of Centre of Gravity (CG) of the three wheeled vehicles. It will serve as a measure for ensuring safe riding and reducing road clashes. As the load on the three wheeled vehicle increases from 3505N to 5410N, the Static Stability Factor decreases. This reduces the safety margin against rollover of the three wheeled vehicles compared to those of the four wheeled vehicles. The keke-napep is a rear wheel drive vehicle with rear engine and rear passenger arrangement. It subjects the vehicle to high weight transfer during braking. This causes the change in position of Centre of Gravity and the instability of the three wheeled vehicles. Therefore, it is hereby recommended that the wheelbase, track length, loading space and the Centre of Gravity position should be given a critical consideration during chassis design in order to improve the static and dynamic stability of these vehicles. Also, Components such as the engine and transmission system should be rearranged to obtain a more reliable position of the Centre of Gravity [21].

2.1.22 Kinematic analysis of triple ball tie-rod in Ackermann steering and tilting mechanism for tricycle application

(Wimba Pramudita Widi, Aufar Syehan, and Danardono Agus Sumarsono, December 2019)

Tilting three-wheel vehicle is introduced, one of which is the electric tilting tricycle to provide an alternative mode of transportation. Some of the tilting tricycle design using a tadpole trike configuration and it needs an adequate steering system that can be synergized with tilting mechanism. The steering mechanism follows the Ackermann steering geometry. Usage of Ackermann geometry means applying a mechanism of trapezoidal four-bar linkage to the tricycle. To create and maintain the simple trapezoid shape, Triple Ball Tie-rod model, a single rod which supports three ball joints, is proposed. Since the capabilities of the model are yet to be proven, this research evaluates the usage of a tie-rod model to find out its capabilities to support the works of the steering mechanism of the tricycle. The measurements are conducted after the simulation of the 3D model to extract some data such as maximum lean angle and inner and outer steering angles. Another simulation using regular tie-rod model also conducted with the same method for comparison purposes. The results of the study are maximum allowed tilting angle and generated Ackermann steering angles. Each designed models have their respective advantages [22].

2.1.23 Economic Street trike: steering and braking

(Alexander Faulkner, May-2019)

The main advantage of the recirculating ball assembly is that the ball bearings reduce friction considerably. There is a steering wheel play and it is adjustable, usually by a slotted bolt with a securing nut mounted on top of the housing. The rack and pinion, while giving the driver a sense of directly steering the vehicle, it is not adjustable. Once the rack and pinion assembly wear out, they have to be replaced. Newer cars use the more economical rack-and-pinion system while the recirculating balls are found in older vehicles. Both types of steering can be powered. For this application it will not be necessary to add power steering. The above methods are for using a conventional steering wheel. The OSS and USS methods are for using some type of handle bars. They are applicable in much smaller personal vehicles such a bike or trike. The advantages are that they are cheaper and simpler to design, however the disadvantage is that they do not incorporate power steering and are therefore for smaller vehicles. Between these two handle bar methods it is clear that most cyclist prefer USS because of comfort. The advantages and disadvantages of drum braking is that it provides solid and reliable braking, yet it performs poorly in weather conditions if moisture gets into the drum and it's susceptible to heat fading. As for disc brake it provides smooth braking even during the harshest weather conditions which is more applicable for our design. Although it is heavier when compared to drum brakes. The rim brakes would be the lightest option but may not be applicable if our application is the preform efficiently under inclement weather [23].

2.1.24 Designing efficient commuter vehicle using finite element analysis and computational fluid dynamics

(Syed Saadat Shakeel, Khurram Abbas, Imran Shafi,12-Jan-2019)

This paper attempts to give an efficient designing approach for an affordable, environment friendly human powered vehicle that serves the purpose of exercising along with being a commuter vehicle using finite element analysis. The proposed design is an aerodynamically enclosed trike which makes it more efficient and less drag prone than a regular bicycle. Along with pedalling power it is assisted by an electric motor, powered by a rechargeable battery. The frame is designed using commercially available software and its structural rigidity is ensured using finite element analysis. The individual components are designed sequentially and combined to create the complete assembly. Later, electric motor calculations are also carried out to estimate power required for driving the vehicle. Coefficient of drag is calculated, using 2-D computational fluid dynamics techniques (CFD), for both faired and un-faired configurations of trike and then values are compared. Furthermore, total drag force is determined for the faired trike in a high wind simulation. Calculations are then carried out to ensure that the recommended motor is sufficiently powered to propel the vehicle even in adverse high wind conditions. The experimental results demonstrate the effectiveness of the design [24].

2.1.25 A recumbent trike design with maximum performance and vehicle dynamics analysis

(Dwaipayan Roy Chowdhury, Aditya Mitra, January 2019)

The car's design was inspired by the ASME HPVC International Trike Competition. As these characteristics will be put to the test in the competition, the vehicle was created to excel in speed, handling, efficiency, practicability, and safety. As we work to establish a distinctive design that sets us apart from rivals, the team has also put a lot of effort into the inventive aspect of the design. To ensure the greatest design possible, the vehicle's design includes background study, concept generation, analysis, and testing. The team was split into five sections, each headed by a different team member, to streamline the design process. These divisions comprise the drive train, fairing, steering, and braking systems. Concepts for each part of the design [25].

2.1.26 Design and manufacturing of reverse electric trike

(Ostrava, prof. Dr. Ing. Ivan Mrkvica, June-2019)

In this paper the model is created to a hybrid system during which the facility will be obtained from the alternative energy and additionally from a generator with regulator connected to the shaft. The energy generated by this regulator is employed as a backup once the alternative energy isn't obtainable. The expected outcome of this project could be a velocipede with a much better style and ergonomically compatible for a physically challenged person. Pollywog style can offer higher dynamic stability which is able to avoid slippery of the vehicle and can offer higher weight distribution to the vehicle. It'll additionally offer higher braking mechanism as pollywog style has 2 tires within the front wherever the load transfers once decelerating. The pollywog style lends itself higher to the aeromechanics tear drop with the proper length to dimension magnitude relation [26].

2.1.27 Design To Control the Center of Gravity and Friction of a Tricycle

(E. Uday Kiran, Dr.P. Malikarjun Sharma, Dr.P. Sridhar, June 2018)

A Tricycle (recumbent trike) is cheap means of short distance transportation both in urban and rural areas. It is generally propelled by human energy. Traditional tricycles are also used by handicapped persons for transport, but they use out dated technology. An effort has been made to design a light weight strong electric powered vehicle with speed control, regenerative braking, frictional brake, hand brake head light, horn, tail light. It can be charged throughout night and used during day time. Manual pedalling can also be resorted when battery is fully discharged. To improve battery [27].

2.1.28 Tilting human powered trikes: principles, designs and new developments.

(Stephen Nurse, Mark Richardson, Robbie Napper, April-2018)

This study examines tilting recumbent trikes without motors (tilters). They belong to the family of recumbent bikes, which may travel farther for the same amount of exertion and with less wind resistance than more traditional cycles. The study discovers that tilting trikes have the potential for static stability as well as leaning and dynamic stability features from bicycles. A tricycle may turn without having to be broad and low in order to maintain stability. Compared to a typical, low recumbent trike, this can make the trikes more visible and acceptable from the standpoint of a car driver. To address the need for comfortable, covered vehicles that can carry luggage on lengthy travels, high-end tilting trikes can incorporate hybrid (human / electric) propulsion. These expensive high-end tilters are not widely available in Australia. Less complex tilters can be better-than-bicycle practical vehicles with features such as stability when stopped, integrated luggage capacity, ease of starting and improved aerodynamics [28].

2.1.29 Design, construction and performance study of a solar assisted tricycle

(Mahadi Hasan Masud, Md. Shamim Akhter, Sadequl Islam, March-2017)

One of the key renewable energy sources that can effectively replace fossil fuels is solar energy. There have been numerous efforts made to integrate tricycles and solar energy into daily transportation. However, the majority of tricycle developments are pricey and impractical for developing nations. In this study, a less expensive solar tricycle with more solar energy utilization potential is built for developing nations. The solar PV panel, brushless PMDC motor, controller, and battery make up the majority of the tricycle's components. The solar tricycle's power transmission is likewise straightforward. It has been discovered that a tricycle uses a solar panel to provide 24% of its running power. Additionally, the tricycle only cost 240 dollars to create in its whole. It has been discovered that a tricycle uses a solar panel to provide 24% of its running power. The tricycle's overall building cost is also under 240 dollars, with almost little environmental impact. This essay focuses on the benefits of dual charging, such as the tricycle's viability from an economic and environmental standpoint [29].

2.1.30 Design, modification & implementation of tilting steering system

(Shubham Namadeo Raut, Ketan Rajkumar Chougule, Nilesh Vijay Sabnis,03 May 2017)

In general, all vehicles have a steering system in which wheels are steered to take turn. But there is a vehicle called tilting trike in which wheels are tilted instead of turning. Currently some foreign automobile companies like Toyota, Harley Davidson are working on tilt steering system. It gives some advantages like anti-skidding effect, reduced turning radius at.al. But this system has its own disadvantages also e.g., it doesn't work properly at low speed. So, in our project we have designed & implemented a new steering system in which both turning & tilting are possible. So, we will have combined advantages of both turning & tilting. We have successfully implemented the combination of steering systems which are capable of giving combined advantages of both the steering systems like anti-skidding effect, reduced turning radius. While working on this project we have focused on implementation the steering system, finding the problems opposing to implement these system & finding solutions for those problems. During this project we have designed total 5 steering systems, each time improving & making it better & better [30].

2.1.31 Cadence tracking and disturbance rejection in FES cycling for paraplegic subjects: a case study

(Lucas O. da Fonseca, Antônio P. L. Bo, Juliana A. Guimarães, May 2016)

Functional Electrical Stimulation cycling has numerous benefits for subjects with Spinal Cord Injury. It can improve cardiovascular function, increase muscular mass, and reduce bone mass loss. However, some limitations, e.g., lack of optimal control strategies that would delay fatigue, may still prevent this technology from achieving its full potential. This work tests a control strategy on a complete spinal cord injury subject with a stationary tadpole trike. Two experiments were performed: reference tracking and disturbance rejection. The results show that reference tracking is possible above the cadence of 25 rpm with a mean absolute error lower than 2.5 rpm. The disturbance test showed that it may cause the cadence to drop but still maintain movement if it doesn't get below 25 rpm. When the disturbance is removed, the system is capable of returning the cadence to the initial value [31].

2.1.32 Design of Solar Tricycle for Handicapped Person assistant in MGIRI Wardha

(Kandasamy, Ravikumar, Raut, Sachin, Varma, Deep, There, Ganesh, April 2013)

This paper will discuss about the main idea of this project and to get a larger picture on what is the problem in the current technologies, what that I want to achieve in this project and the area that will cover on this project. This paper is divided into some categories that are project background to describe the reasons to do this project, problem statement to inform about the problem or weakness of the existing technology, objective to make sure what actually this project must achieve and scope of this project to specify what will be used in this project [32].

2.1.33 Design and FEA of a recumbent trike

(Er. Vikas Gulati, Er. Sameer Mehta, Ankur Kashyap, Kartik Pawar, January-2012)

The design of an eco-friendly human-powered vehicle with a compounded electric drive system is presented in this study. The emphasis has been placed on the design's simplicity, great efficiency, low maintenance, and extreme affordable costs. The majority of the elements have been selected. Keeping in mind the reliability and ease of access. The components utilized are described in full in the study, and performance metrics taken into account while constructing the vehicle this hybrid trike is propelled by humans. Incredibly effective, developed with ergonomics, and may be demonstrated as a more effective fuel-efficient car replacement contributing to the sustainability of the environment [33].

2.1.34 The golden rule of trike design

(Patrick Fenner, 04 Oct 2010)

Note that this is article is a review of, and discussion about, published findings. Investigation, debate, disagreement and reasoning are all normal parts of the scientific method, and should not be construed to be a personal attack on anyone. In a similar vein, please contact the author (above) with any questions, clarifications, improvements or counter-arguments. The Huston, Graves and Johnson's (HGJ's) paper on three-wheeled vehicle dynamics looked at two components of vehicle stability, namely lateral stability and rollover stability. It includes analysis of four-wheeled vehicles and three-wheeled vehicles with two wheels on the front axle (tadpole configuration) and two wheels on the rear axle (delta configuration) [34].

2.1.35 Design of the Tadpole Type Three-Wheel Vehicle with Dynamic Conditions

(Ramaiya, Amit, Thattil, Ansh, Vachhani, Sumit, Raval, Darshan, June 2008)

Study of the effect of lateral stability and ride comfort of a three-wheeled vehicle, which has two wheels in the front and one in the back, known as a tadpole design. Also presents a methodology for chassis design of the three-wheel tadpole design vehicle. Since the three-wheeled vehicle in this study is a light and narrow vehicle, controlling the stability of this vehicle, particularly during turning and cornering is a very challenging task [35].

2.2 Reference Model

Solar power recumbent trike helps the rider travel by relaxing and eco-friendly way and go fast, further. Meanwhile, a large volume solar panel gives shelter for the rider in the sun and rain. It makes starting first-time long-distance traveling or world-traveling easy. The inclined seat provides an easy seating option to getting on and off the trike. Suitable for big figures and less flexible riders. With 250watts solar panel, you could pedal all day in the sunlight without charging. It carries a load up to 150kg. This trike is constructed up with BLDC motor, controller, reversible batteries, solar panel, and a throttle.

Figure 2-1: Reference Model

2.3 Literature Gap

Table 2-1: Literature gap table

Title	Year	Hub motor	Solar	Throttle	Result
Human Powered Vehicle Design Team [2]	2022	Yes	No	Yes	Runs mechanically or by electric energy.
Innovative Design and CFD Analysis of Human Powered Eco-Friendly Trike [14]	2021	Yes	No	No	Reducing air resistance, and helping to build stress distribution base frame.
Velocity tracking control of recumbent trike with functional electrical stimulation [18]	2020	No	No	No	Concept Development and Selection Methods (Rider Configuration, Vehicle Style, Frame Material)
Review paper on solar electric tricycle [19]	2020	Yes	Yes	Yes	Calculating (Speed, Torque, and power) of an e-trike.

A recumbent trike design with maximum performance and vehicle dynamics analysis **[25]**	2019	No	No	No	Use push and pull type steering in a tadpole trike.
Design, modification & implementation of tilting steering system **[30]**	2017	No	No	No	Effect of lateral stability and Turning effect while trike moving.
Design and FEA of a recumbent trike **[33]**	2012	Yes	No	Yes	helping to build stress distribution base frame
Design and fabrication of tadpole tricycle model solar-powered **[35]**	2008	Yes	No	Yes	Calculating air and rolling resistance, angular velocity, and peak torque.

CHAPTER 3

DESIGN AND FABRICATION

Design And Calculation

3.1 Design and Consideration

Human-powered hybrid vehicles present a new milestone in the realm of "Green Technology". The vehicle that is cheap to buy, cheap to run, and can be used from a track racer to a grocery seller everybody contributing towards a green environment. In the literature, there are two available designs of vehicle [1].

3.2 Delta

The delta type of trike has one wheel in the front and two wheels in the rear. These types of trikes can give their best in steering as they can have a zero turning radius. The power to the rear wheels of the delta trike ensures no slipping during cornering.

3.3 Tadpole

The tadpole type of trike has two wheels in the front and one wheel in the rear. Both the trikes have their pros and cons. But tadpole configuration always has certain advantages over the delta configuration in almost every field. Being a rear wheel-driven configuration, the tadpole configuration will have all the tractive effort available from its share of the weight. Also because of the major weight on the front side of the vehicle, there is much grip available for both steering and braking. Electrically assisted tadpole trikes are much more stable when compared during cornering. Delta trikes on the other hand have less front weightage due to which it can’t give its best in both braking and steering. Electrically assisted delta trikes are more unstable. After it is preferred to choose tadpole over delta.

3.4 Calculation

3.4.1 Calculations For Electric Solar Vehicles

Let us consider the following assumption in Electric Solar Vehicle

Mass of the Vehicle = 150 kg

Speed = 25 kmh^{-1}

Slope % = 0.1

Rear and Front Wheel Diameter= 0.6m & 0.5m

Battery Weight = 12 kg

Average Speed = 25 kmh^{-1}

Range = 15 km

3.4.2 Calculation For Angular Velocity of The Wheel

Considering Linear Velocity =25 kmh^{-1}

Speed = 25 x (5 / 18) ms^{-1} ⇒ 6.92 ms^{-1}

Diameter of wheel = 0.6 m

Radius =Diameter / 2 ⇒ 0.6 / 2 m ⇒ 0.30 m

Using the Relation,

Linear Velocity = Angular Velocity x Radius

Angular Velocity = Linear Velocity / Radius

From the Relation = 23 rad. s^{-1}

Angular Speed = 2 x π x frequency

Frequency Angular = Speed / (2 x π) RPS

= Angular Speed x 60 / (2 x π) RPM

= 23 x 60 / (2 x 22 / 7) RPM

= 219.54 RPM

3.4.3 Calculation For Peak Torque Required Moving the Vehicle

Peak torque power required = (Mass of Vehicle + Battery) x Acceleration due to gravity x Wheel Radius x Slope%

= (150+12) x 9.8 x 0.30 x 0.1 N-m

= 47.62 N-m

= Torque x Angular Velocity

= 47.62 x 23 Watt

= 1080 Watt

3.4.4 Calculation For Air Resistance

Air Resistance = (5 / 100000) x mass of vehicle x (Average Speed)3

= (5 / 100000) x 150 x 253

= 117.18 Watt

3.4.5 Calculation For Rolling Resistance

Rolling Resistance = 0.092 x mass of vehicle x average speed

= 0.092 x 150 x 25

= 345 Watt

3.4.6 Calculation For Continuous Power Required

Power Required (Continuous) = Air Resistance + Rolling Resistance

= 117.18 + 345

= 462.18 Watt

3.4.7 Calculation For Continuous Speed

Continuous Speed = Average Speed x 60 / (2 x π x Radius of Wheel)

= 25 x (5 / 18) x 60 / (2 x π x 0.30)

= 214.85 rpm

3.4.8 Calculation For Continuous Torque Required

Torque Required = (Air Resistance + Rolling Resistance) x 60 /

(Continuous) (2 x π x Continuous Speed)

= (462) x 60 / (2 x π x 214)

= 20.60 N-m

3.4.9 Final Results

Table 3-1: Final Results

Angular Velocity	23 rad. s^{-1}
Frequency	219.54 RPM
Peak Torque	47.62 N-m
Power Required	1080 WATT
Air Resistance	117.18 WATT
Rolling Resistance	345 WATT
Power Required (Continuous)	462.18 WATT
Continuous Speed	214.85 RPM
Torque Required	20.60 N-m

3.5 Motor specification

Power = 1000watt

Operating voltage = 48v

3.6 Battery Specification

Voltage = 12V

Capacity =7 AH

Quantity = 4

Power = 1000w

Operating Voltage =48V

3.7 Solar Panel Specification

Power =500W

Open Circuit Voltage= 48 V

Short Circuit Current= 6.11 A

The voltage at maximum power=39.99 V

Current at maximum power =5.57 A

Quantity = 1

Dimensions =220 x 115 X 3.0 mm

3.8 Energy Calculation

Power consumed by motor in 3 hrs. = Power x Time

= 1000 x 3

= 3000WH

Energy produced by solar panels for 3 hrs. = Power x Time

= 225 WH

Energy Stored in battery = Capacity x Voltage

= 7 x 48

= 336 WH

3.9 Energy Discharging and Charging of Battery

Discharging time (without power loss) = (Capacity x Voltage)/Power of load

= (7 x 48)/1000

= 30 min

Discharging time (with power loss of about 25%) = 0.5 x (75/100)

= .375 hr

= 22 minutes

Charging time (from 0 to 100% without considering power loss) =Energy Stored in Battery/Power of panel

= 336/150

= 2.24 hours

3.10 Calculation Of Optimal Centre of Gravity (COG)

After construction, the recumbent tricycle was tested according to maximum velocity, turning radius, braking distance, mass, manoeuvrability etc.

3.10.1 Optimal Centre

Looking down from above, if we draw a triangle between the three contact patches, and at the midpoint of each line we draw another line to the opposite corner, then the intersection of these three lines is the optimal point where the rider COG should be.

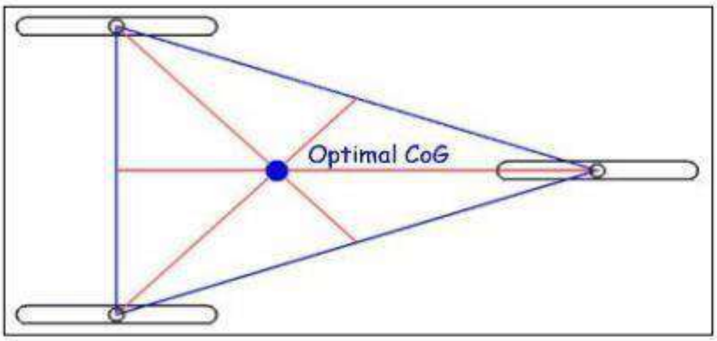

Figure 3-1: Optimal Center

3.10.2 Calculating Lateral Tipping Point (Front View)

Now looking from the front, if we take the track measurement B and divide it in half, we get A. We use A to construct an isosceles triangle between the contact patches. This triangle represents the tipping point for the trike. If the COG is inside the triangle, then the trike will skid when it loses traction while cornering, if the COG is above it, the trike will tip.

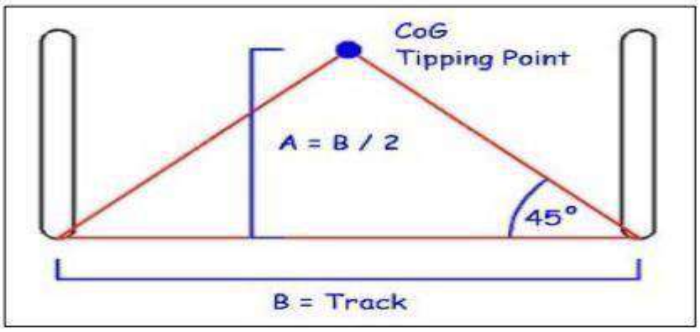

Figure 3-2: Lateral tipping point

B=41"

A=B/2

A=41/2

A=20.5"

3.10.3 Calculating Lateral Tipping Point (Side View)

Draw a similar triangle on a side view of the trike using the wheelbase measurement for B to derive A. You can then use this side-on triangle to calculate where to place the COG to prevent the trike from tipping forward when braking -- more of a problem for tadpole configurations. The previous two calculations would be fine if the COG on either axis was directly between the two wheels, but it's not. The optimum place is 1/3 of the wheelbase length back from the isosceles triangle's base. At this location, the triangle is only 2/3 of the track width. Now we use this 2/3 track measurement as B to derive A which is 1/3 of the track width. We then use A to draw a vertical line up from the optimal COG point. We then use the point at the top of this line to create a 3-sided pyramid This pyramid represents a 3D view of the tipping space, inside which the rider COG must remain for the trike to be stable.

B=52",

A=B/2

A=52/2

A=26"

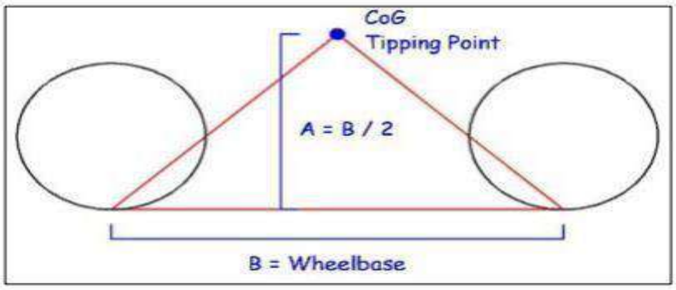

Figure 3-3: Tipping Top View

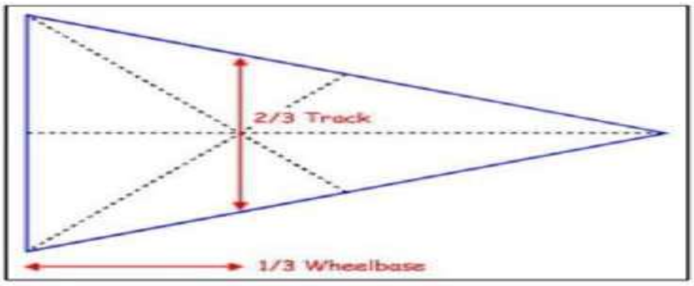

Figure 3-4: Tipping Point Side

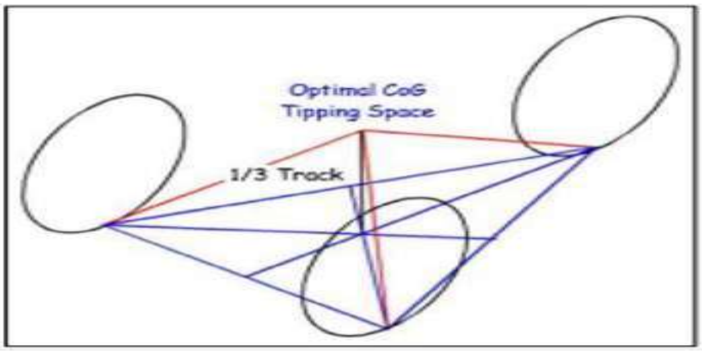

Figure 3-5: Orthogonal View

3.11 Selection of material

Mild steel

Mild steel is a type of carbon steel with a low amount of carbon – it is also known as "low carbon steel." Although ranges vary depending on the source, the amount of carbon typically found in mild steel is 0.05% to 0.25% by weight. Less carbon means that mild steel is typically more ductile, machinable, and weldable than high carbon and other steels, however, it also means it is nearly impossible to harden and strengthen through heating and quenching. We use mild steel to design the frame of the machine. Following are the properties of mild steel according to base on ASTM A53-Standard Specification for MS.

Table 3-2: Mild steel properties

Material	Mild Steel
Ultimate tensile strength yield	440-500 Mpa
Thermal expansion	10.1-16.6*10-6 (mm/ °C)
Young's Modulus	68.9-207 Gpa
Poisson Ratio	0.23-0.3
Melting point	1230-1530(°C)

3.12 CAD modelling of frame

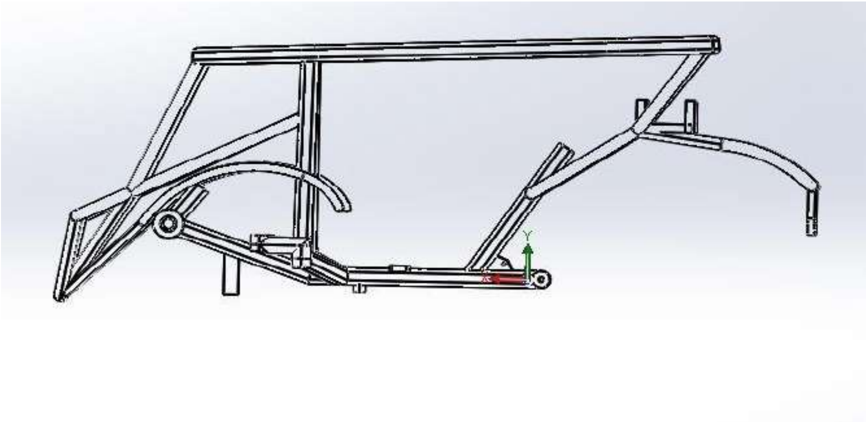

Figure 3-6: 2D CAD model of frame

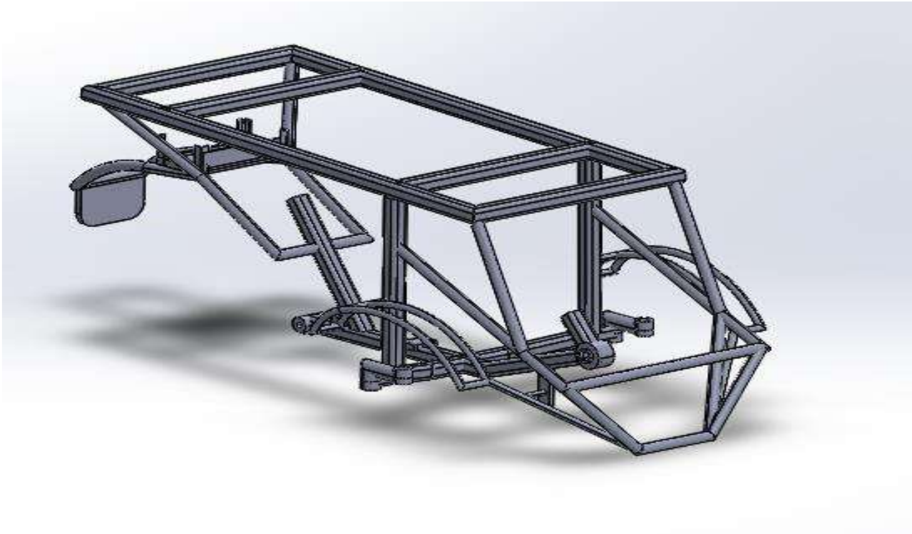

Figure 3-7: 3D CAD model of frame

3.13 3D CAD Model of Project

Figure 3-8: 3D CAD model of the project

3.14 FEA Analysis

3.14.1 Applying Forces

- Add a force. From the Force Property Manager
- Then graphics area, select the desired faces. (Roof, Seat fixed point which is 2/3 or frame Battery foundation.
- Normal to apply the force in the direction normal to each selected face.
- Selected direction to apply the specified force value to each face in the direction of its normal

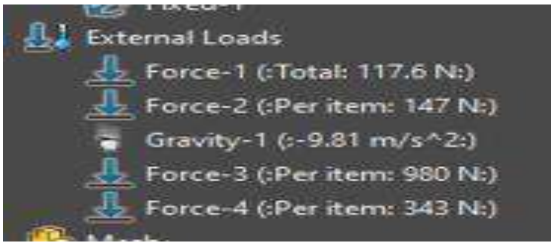

Figure 3-9: External loads

- Select the force units first, then enter the force value. As shown in Fig 3.9
- The force appears in the External Loads folder in the Simulation Xpress study tree, and a checkmark appears next to Loads in the Simulation Xpress wizard.
- Click Next

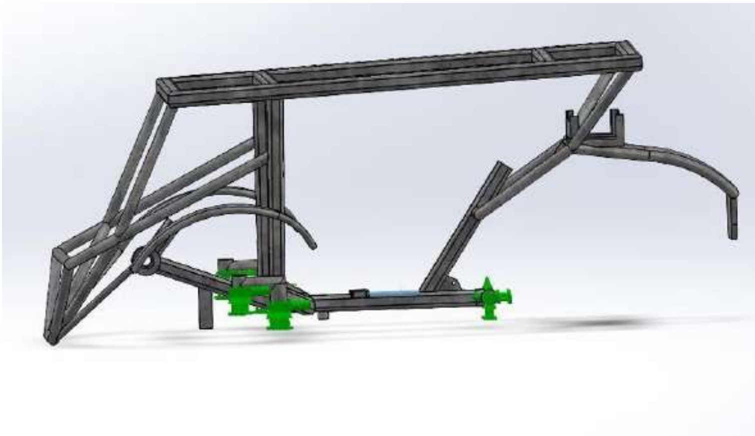

Figure 3-10: Fixed point reversed direction Forces

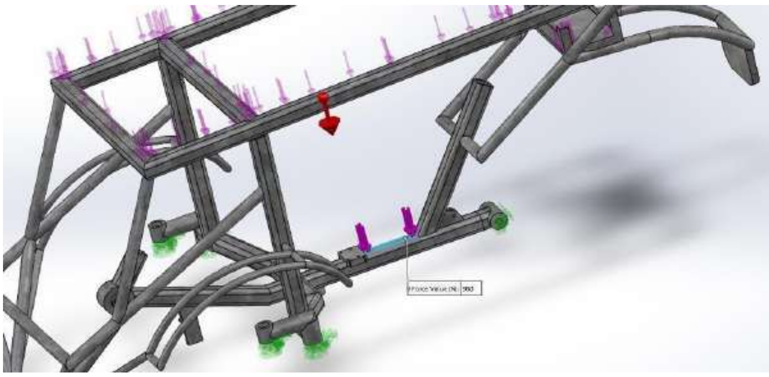

Figure 3-11: All External loads act on Frame

3.14.2 Meshing

The Blended Curvature-based Mesher has improved performance based on optimized code architecture, multithreading, and parallel multicore processing. The improved meshes can mesh parts and large assemblies significantly faster. It can also mesh models that previously failed to mesh.

Mesh Details

Study name	Static 1 (-Defau
Mesh type	Solid Mesh
Mesher Used	Blended curvat
Jacobian points for High quality mesh	16 points
Max Element Size	25 mm
Min Element Size	5 mm
Mesh quality	High
Total nodes	521328
Total elements	262980
Maximum Aspect Ratio	8,367.3
Percentage of elements with Aspect Ratio < 3	80.6

Figure 3-12: Blended Curvature mesh detail

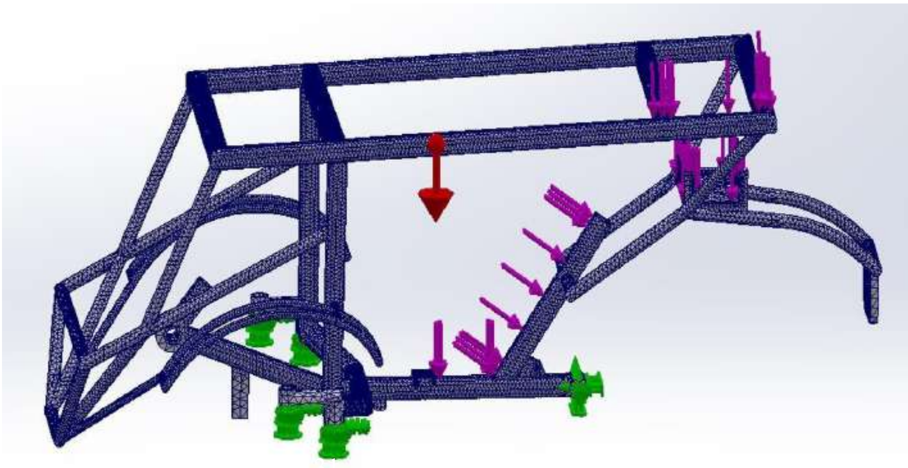

Figure 3-13: Complete Meshing of Frame

3.14.3 Factors Factor of Safety

The Factor of Safety Wizard allows you to assess the safety of your design based on a failure criterion. Large factors of safety in a region indicate that you can save material from that region. Many codes require a minimum factor of safety between 1.5 and 3.0.

- A factor of safety less than 1.0 at a location indicates that the material at that location has failed.
- A factor of safety of 1.0 at a location indicates that the material at that location has just started to fail.
- A factor of safety larger than 1.0 at a location indicates that the material at that location is safe.

The results of the FOS analysis of the frame are shown in the below table.

Table 3-3: FOS analysis of frame

Minimum	Maximum	Average
1.16e+00	5.175e+06	2.587e+06

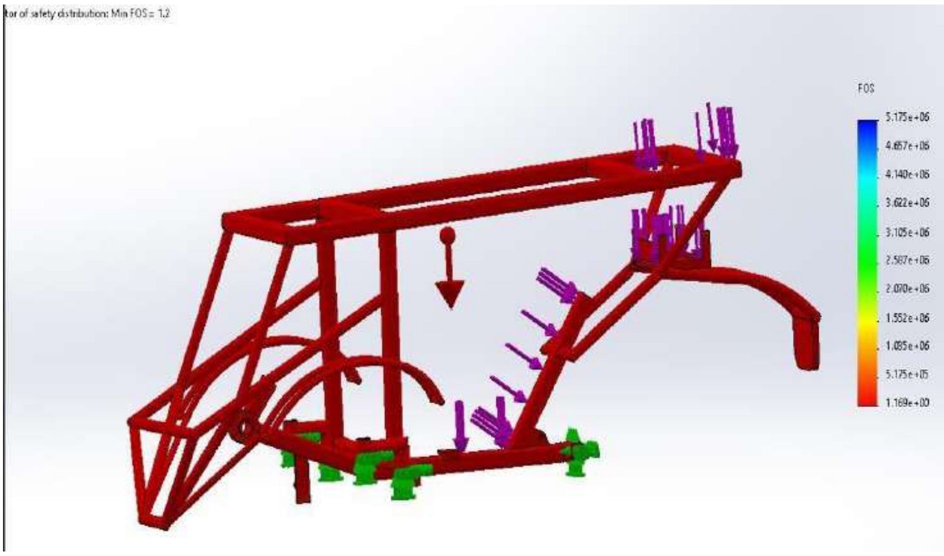

Figure 3-14: FOS analysis of frame

3.14.4 Resultant Displacement Analysis

The Resultant Displacement Plot Property Manager allows you to plot displacement and reaction force results for static, nonlinear, dynamic, drop test studies, or mode shapes for bucking and frequency studies. To display this Property Manager, run a static, nonlinear, dynamic study, or drop test study. Right-click Results and select Define Displacement Plot. The result of URES is shown in Table 3.4.

Table 3-4: URES analysis of frame

Minimum	Maximum	Average
1.00e-30	1.240e+00	6.202e-01

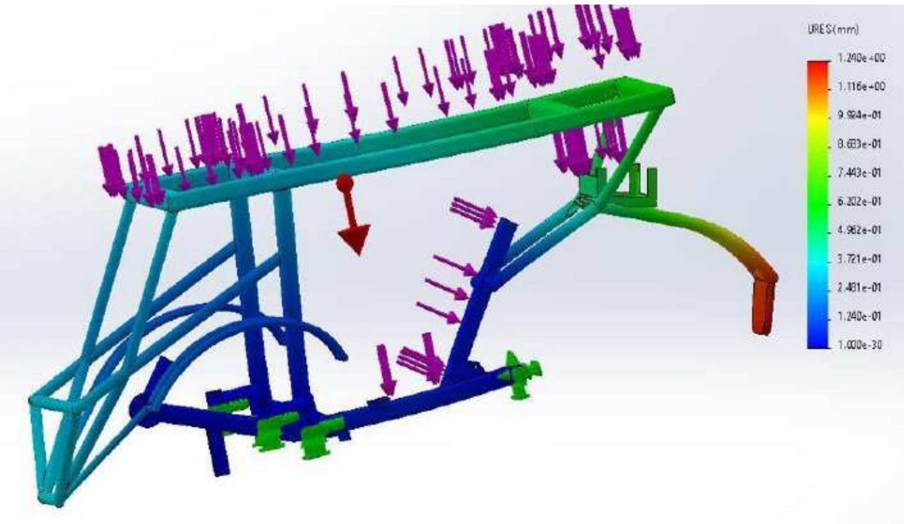

Figure 3-15: URES analysis of frame

3.15 Fabrication

List of Components

- DC Brushed motor
- DC motor controller
- Frame
- Battery
- Chain Drive
- Break mechanism
- Sprockets
- Tyres
- Steering Mechanism
- Solar panel
- Solar charge controller
- Seat

3.15.1 DC Brushed motor

A Direct Current (DC) motor is a rotating electrical device that converts the direct current, of electrical energy, into mechanical energy. A gear motor is an all-in-one combination of a motor and gearbox. The addition of a gearhead to a motor reduces the speed while increasing the torque output. The most important parameters regarding gear motors are speed (rpm), torque (lb-in), and efficiency.

Figure 3-16: DC brushed motor

3.15.2 Controller

A DC motor controller manipulates the position, speed, or torque of a DC-powered motor and easily reverses, so the DC motor drive current runs in the opposite direction. Enjoy higher starting torque, quick starting and stopping, reversing, variable speeds with voltage input, and more. Select technology type, input voltage, output voltage, continuous current, enclosure, braking type, reversing type, and isolation.

Figure 3-17: 48v Motor Controller

3.15.3 Frame

The Frame is made up of iron along with some additional lightweight components. The frame is designed to sustain the weight of the person driving the unit, the weight of the load to be conveyed, and also to hold the accessories like a motor. Also, it should be designed to bear and overcome the stresses that may arise able to due to different driving and braking torques and impact loading across the obstacles. It is drilled and tapped enough to hold the support plates.

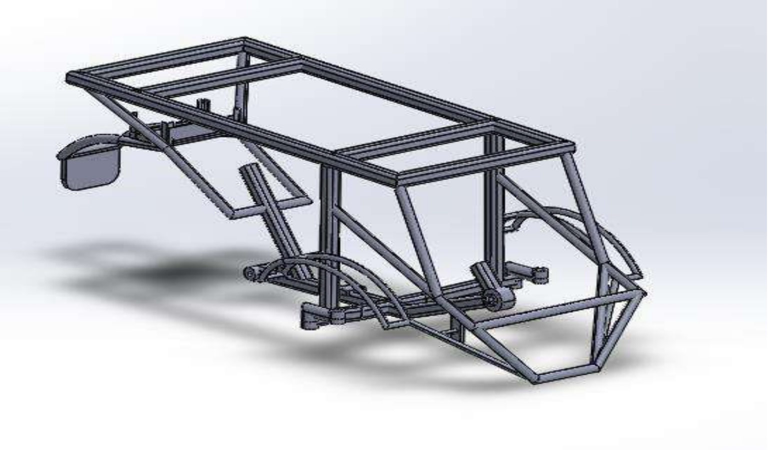

Figure 3-18: Frame of Trike

3.15.4 Battery

The battery also acts as a condenser in a way that it stores the electric energy produced by the generator due to electrochemical transformation and supplies it on demand. A battery is also known as an accumulator of electric charge. This happens usually while starting the system.

Figure 3-19: Battery

3.15.5 Chain Drive

The biggest advantage of a chain is its ability to deliver almost all your pedal power to your rear wheel. On a trike, the chain drive has the lowest drop-off of power. It only drops around 1% to 3% from the engine to the rear wheel. Whereas a Drive Belt drops between 11% to 14% and a Drive Shaft a massive 25% to 31%.

Figure 3-20: Chain drive with idlers

3.15.6 Break mechanism

For the braking system, it is convenient to use the braking system used in the band brake system which consists of a spring-loaded friction-shoe mechanism, which is driven with the help of a hand lever.

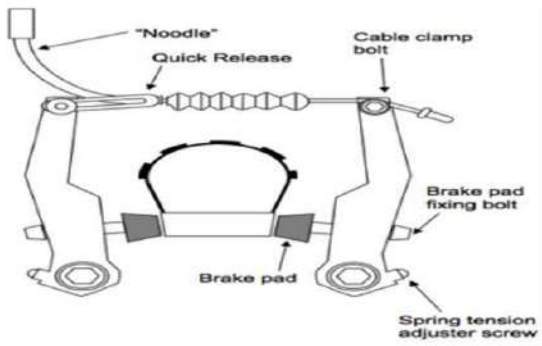

Figure 3-21: Shoe Breaks

3.15.7 Sprockets

The chain with engaging with the sprocket converts rotational power into rotary power and vice versa. The sprocket which looks like a gear may differ in three aspects

- Sprockets have many engaging teeth but gears have only one or two.
- The teeth of a gear touch and slip against each other but there is no slippage in the case of a sprocket

Figure 3-22: Sprockets and Rear derailleur

3.15.8 Tyres

Wheel size does impact how a trike works, but manufacturers compensate for any possible challenges using gearing. It has more to do with the trike design rather than just the wheel size. The wheel size makes some difference, but it is not everything. And that's why you're probably not going to feel much difference just by changing out the wheel.

Figure 3-23: Front and rear wheels

3.15.9 Steering

As our primary goal was to reduce weight, we decided to use a simple push-pull type handle where we could take advantage of leverage. Considering that situation, it is vital to design steering control such that it would not restrict the movement of legs while pedaling. Moreover, the driver should have a clear line of sight. Hence, we decided to move away from the conventional steering wheel which comes in front of the driver. We tried to locate the steering control so that it would come in the driver's hands from both sides of the seat.

Figure 3-24: Simple push and pull type steering

3.15.10 Solar panel

Solar power recumbent trike helps the rider travel in a relaxing and eco-friendly way and go fast, and further. Meanwhile, a large volume solar panel gives shelter for the rider in the sun and rain. It makes starting first-time long-distance traveling or world-traveling easy.

Figure 3-25: Solar Panel

3.15.11 Solar charge controller

It provides a stable ratio of the current from the solar panel to the battery. Because of changes in solar radiation, change output varies vary time to time of the solar panel. We provided two solar charge controllers in a series connection and because of that continues flow of the current passed to the battery.

Figure 3-26: Solar charge controller

3.15.12 Seat

Recumbent tricycle seats are usually about the height of a dining room chair. That makes them easy to get in and out of but also can cause issues if you tend to go faster and take a lot of corners.

Figure 3-27: Recumbent trike seat

3.16 Machines and machining process used

Machining refers to the process of shaping metal by removing unwanted material from it. This process can be performed in a variety of ways. There are many different machining processes, including drilling, turning, and milling. Drilling uses a rotary cutting tool, the drill bit, to cut a hole in the material. The drill bit presses against the metal while being rotated very quickly to create a circular hole. Turning uses a lathe to rotate the metal while a cutting tool moves in a linear motion to remove metal along the diameter, creating a cylindrical shape.

3.16.1 Disc-cutting cutting process

A disc cutter is a specialized, often hand-held, power tool used for cutting hard materials, ceramic tile, metal, concrete, and stone. Discs are often used for cutting metal; they are composed of an abrasive mix of grit and adhesive that is formed into a rigid and thin disc with Fiber webbing running through it for strength. The cutting of pipes for the structure of the project is done with a disc cutter as shown below in figure 3.27,3.28 and 3.29.

Figure 3-28: Disk Cutting of cast iron for trike

Figure 3-29: Disc cutting iron bar

3.16.2 Arc Welding

Welding is a process of permanently joining two or more metal parts by melting both materials. The molten materials quickly cool, and the two metals are permanently bonded. In our fabrication process, we have used Electric Arc Welding. It is a type of welding that uses a high current supply to create an electric arc between an electrode and the base material to melt the metals at the welding point.

Figure 3-30: Welding of chassis.

3.16.3 Grinder cutting machine

A grinding machine, often shortened to a grinder, is one of the power tools or machine tools used for grinding, it is a type of machining using an abrasive wheel as the cutting tool. Each grain of abrasive on the wheel's surface cuts a small chip from the workpiece via shear deformation.

Figure 3-31: Grinder cutting machine

Figure 3-32: Grinding of welding parts

3.16.4 Seat Design

Figure 3-33: Template Making

Figure 3-34: Building the Cradle

3.17 Electronics Process Involve

This Controller is best for E-Bike MY1020 Motor High-quality product Made of Aluminium alloy material, it can protect the inner circuit and is good for heat dissipation to avoid thermal overloading. This brushed controller is sturdy and durable, widely suitable for most E-bike and scooters. This brushed motor controller can provide steady speed and sensitive control of braking and direction changes. E-bikes generally combine both pedal-assist sensors as well as a throttle. Some electric bikes have an electric motor that operates on a power-on-demand basis only. In this case, the electric motor is engaged and operated manually using a throttle, which is usually on the hand grip just like the ones on a motorbike or scooter

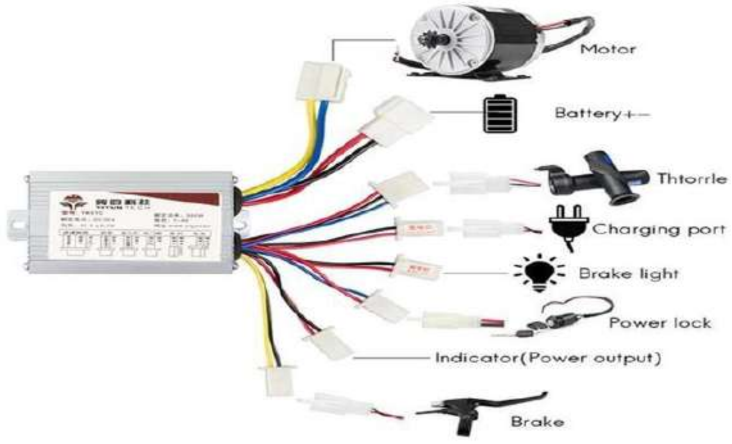

Figure 3-35: MY1020 Brushed Controller

3.18 Connection of Batteries

To connect a group of batteries in series you connect the negative terminal of one battery to the positive terminal of another and so on until all batteries are connected, you would then connect a link/cable to the negative terminal of the first battery in your string of batteries to your application, then another link/cable to the positive terminal of the last battery in your string to your application. When charging batteries in series, you need to use a charger that matches the battery system voltage. We recommend you charge each battery individually to avoid battery imbalance.

Figure 3-36: Connection of Batteries in series

3.19 Group members working on a project

Figure 3-37: Group Members working on a project

3.20 Cost analysis of project

Table 3-5: Cost analysis

Sr. No.	Parts of Project	Cost (PKR)
1	Bicycle (Scrape)	5000
2	Motor	10000
3	Battery	8000
4	Raw Material	10000
5	Charge Controller	1200
6	Speed Controller	9000
7	Fabrication cost	10000
8	Solar panel	15000
9	wheels	9000
	Total cost	77,200/-

3.21 ISO standards for project design

ISO 5845-2:1995

Technical drawings, simplified representation of the assembly of parts with fasteners Part 2: Rivets for aerospace equipment

ISO 10721-2:1999

This part of ISO 10721 specifies the requirements for the fabrication, erection, and inspection of structural steelwork in buildings designed by ISO 10721-1, including steelwork

ISO 15614-5:2004

Specifies how a welding procedure specification is qualified by welding procedure tests. It defines the conditions for the execution of welding procedure tests and the range of qualification for welding procedures for all practical welding operations within the range of variables

ISO 13203:2005

Chains, sprockets, and accessories, List of equivalent terms

ISO/TS 128-71:2010

Technical product documentation (TPD), general principles of presentation

Part 71: Simplified representation for mechanical engineering drawings.

ISO 6312:2010

ISO 6312:2010 specifies a method for measuring the strength of the bond connection between the lining material and the carrier in the disc brake pad and drum brake shoe assemblies (shear strength). ISO 6312:2010 applies to assemblies that are integrally moulded, bonded or that use mechanical retention systems (MRS) of both types used for brakes on road vehicles.

3.22 Fabricated model of project

Figure 3-38: Fabricated Model of Project

3.23 Proposed improvements in design

- Trike design is not simple. You need to do is specify what you want to achieve.
- Once the frame is completed the front forks need to be designed for impact, rider safety, etc.
- Then the wheels and tyres need to be chosen. This is affected by terrain and objectives.

CHAPTER 4

Experimentation and Results discussion

4.1 Methodology of experimentation

- Check all the components and wires connections of the project.
- Charge the battery of electricity by the power supply.
- Test the project by operating manually and then on zero loads.
- Then test on different load conditions to check the speed of the trike.
- Note the value of current at different conditions such as (zero, loadings)
- Note the speed and battery discharging time when the generator switch is turned off.
- Turn ON the generator switch and note the value of current by using a mustimeters.
- Note the charging and discharging of the battery in a E-trike.

4.2 Operating manual

- Please read this manual before using trike.
- Ensure that the power switch on the handlebar is switched off when the trike is not use.
- The seat post should not be raised beyond the safety line indicated.
- The handlebar post should not be raised beyond the safety line indicated.
- Always check that the front and rear brakes are working correctly and that the tyre pressures are correct before riding trike.
- The tightening torques of the front and the rear hub nuts are 18N.m and 30N.m respectively.
- Do not wash your trike with the battery charger connected to the battery whilst charging to prevent the possibility of electric shocks.
- Do not submerge the battery in water. Do not ride your trike through water deeper than 8” or 20 cm.
- Do not tamper with the electrical control unit on your trike. This could endanger the rider and will invalidate the warranty.
- Approximately every 6 months it is important to clean and lubricate the front, back and middle axles, flywheel, and front forks plus other moving parts with a good quality grease.
- Battery and charger safety advice.
- Please save this manual as it contains important operating and safety information about the battery and charger.
- Please read this manual before using the battery and charger, including the warning label on the charger and battery pack.
- Do not expose the battery charger to rainy or wet conditions or operate in temperatures below.
- 0°C or above 35°C as this may damage the charger.

4.3 List of experimental parameters

- Battery charging
- Battery Discharging
- Speed at different loading condition
- Brake Test

4.4 Battery Charging

The circuitry to recharge the batteries in a portable product such a mobile phone plays an important part in determining the battery longevity and the practicalities of using the product on a daily basis. The charging protocol (how much voltage or current for how long, and what to do when charging is complete) depends on the size and type of the battery being charged. The formula for battery charging is following.

$$\text{Batteries charging time} = \frac{\text{Battey capacity in (mAh)}}{\text{charging Current (mAh)}}$$

Batteries capacity = 7A*4 = 28000mAh

Charging current = 20000mAh

Now for Batteries charging time (Hours) = 28000/20000= 1.4hr

4.5 Battery Discharging

To calculate the battery discharging time of an electric trike with a 150 kg loading condition, a 1000 W motor, and a 28 A 48 V battery, running at an average speed of 25 km/h, we need to consider the following factors.

- The power output and efficiency of the trike's motor and battery
- The rolling resistance and air drag of the trike and its tires
- The gravitational force acting on the trike and its rider
- The distance travelled and the average speed
- One possible way to solve this problem is to use the following steps:
- Calculate the power consumption of the trike using the formula:

$$P = 2v^3\rho CdA+vmgCr$$

where:

P is the power consumption in W

v is the speed in m/s

ρ is the air density in kg/m^3

Cd is the drag coefficient (dimensionless)

A is the frontal area in m^2

m is the mass of the trike and rider in kg

g is the gravitational acceleration in m/s^2

Cr is the rolling resistance coefficient (dimensionless)

This formula takes into account the air drags and the rolling resistance acting on the trike.

Using some typical values for an electric trike, such as:

ρ=1.2 kg/ms^3

Cd=0.8

A=1.5 m^2

m=150 kg

g=9.81 m/s^2

Cr=0.01

v=25 km/h·36001000 m/s≈6.94 m/s

We can plug these numbers into the formula and get:

P=2(6.94)3·1.2·0.8·1.5+6.94·150·9.81·0.01

P≈433.5+102.4

P≈535.9 W

This means that the trike consumes about 535.9 W of power at a speed of 25 km/h.

Calculate the battery capacity using the formula:

C=IV

where:

C is the battery capacity in Wh

I is the battery current in A

V is the battery voltage in V

The battery current and voltage are given as 28 A and 48 V, respectively, so we can plug in these values and get:

C=28 A·48 V

C=1344 Wh

This means that the battery can store 1344 Wh of energy.

Calculate the battery discharging time using the formula:

t=PC

where:

t is the battery discharging time in h

C is the battery capacity in Wh

P is the power consumption in W

Plugging in the values, we get:

t=535.91344

t≈2.51 h

This means that the battery can last for about 2.51 hours or 151 minutes at a speed of 25 km/h.

4.6 Results and Discussion

Table 4-1: Speed at different loading conditions

Load	Speed at straight path(km/h)	Speed at downhill (km/h) at 5°	Speed at uphill(km/h) at 5°
130	30	27	14
140	28	29	12
150	26	31	10
160	25	33	7
170	24	35	4

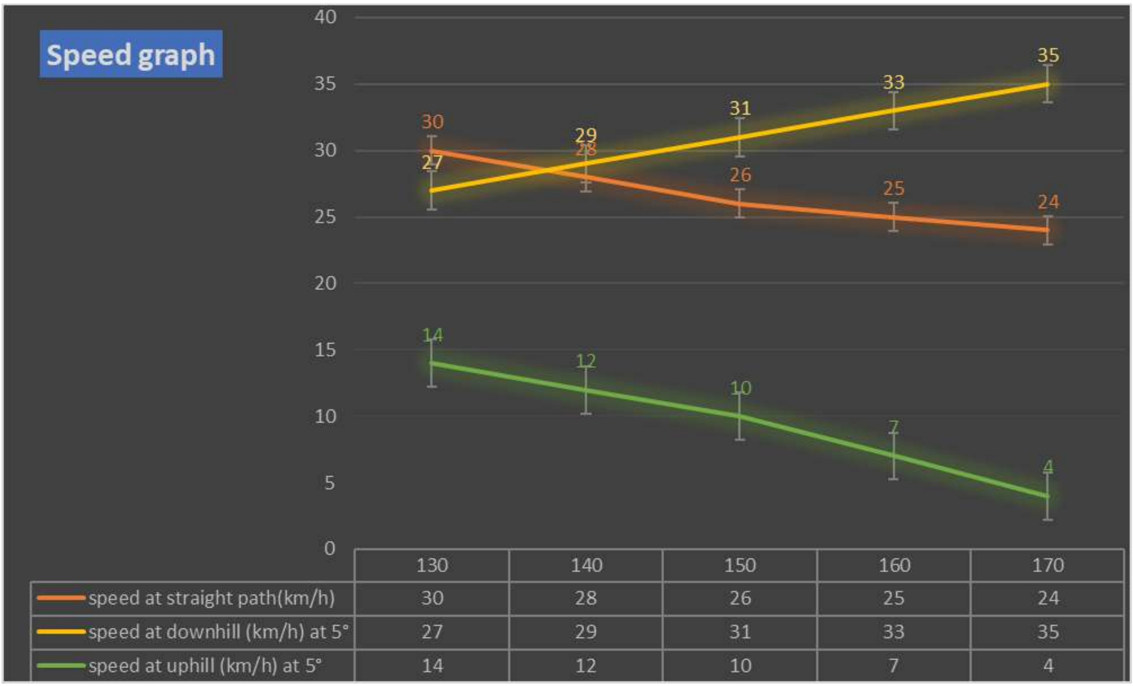

Figure 4-1: Speed graph at different loading conditions

To calculate the speed of an e-trike of 150 kg at a 5° uphill, we need to consider the following factors.

The resistance can be calculated as:

Resistance = Force applied - Total resistance = 1470 N - 789.8 N = 680.2 N

The speed of the vehicle on the slope can now be calculated as:

Speed = (1470 N+254.8 N) / 680.2 N = 2.5 m/s

Converting this speed to km/h

Speed = 2.5m/s * (3600 s/1 hr) * (1 km/1000 m) = 9.6 km/h

Therefore, the effect of the slope on the speed of the electric vehicle is a decrease from 25 km/h to 9.6 km/h.

To calculate the speed of an e-trike of 150 kg at a 5° downhill, we need to consider the following factors:

One possible formula to estimate the speed of an e-trike is:

$$v=\rho CdA2P\cdot \ln(1+mg\cdot(Cr+\sin\theta)\rho CdAd)$$

where:

v is the speed in m/s

P is the power output in W

ρ is the air density in kg/m^3

Cd is the drag coefficient (dimensionless)

A is the frontal area in m^2

d is the distance travelled in m

m is the mass of the e-trike and rider in kg

Cr is the rolling resistance coefficient (dimensionless)

θ is the slope angle in radians

$$v=1.2\cdot 0.8\cdot 1.52\cdot 500\cdot \ln(1+150\cdot 9.81\cdot(0.01+\sin 0.0873)1.2\cdot 0.8\cdot 1.5\cdot 1000)$$

$$V= 8.6 \text{ m/s}$$

4.7 Discussions

This table 4.1 shows the relationship between the load and the speed of a vehicle on different slopes. The load is the weight of the vehicle and its cargo, measured in kilograms. The speed is the average velocity of the vehicle, measured in kilometres per hour. The slope is the angle of inclination or declination of the road, measured in degrees.

The table suggests that:

- The speed of the vehicle decreases as the load increases, regardless of the slope. This is because a heavier load requires more force to overcome inertia and friction.
- The speed of the vehicle is highest on a downhill slope, followed by a straight path, and lowest on an uphill slope. This is because gravity helps to accelerate the vehicle on a downhill slope, while it opposes the vehicle on an uphill slope.
- The difference in speed between different slopes is larger for heavier loads than for lighter loads. This is because gravity has a greater effect on heavier objects than on lighter objects.

4.8 Break Test

Table 4-2: Break test at different loading conditions

Break test at different loading conditions			
Load (kg)	**Speed(km/h)**	**Breaking distance (m)**	**Deceleration rate (m/s²)**
130	30	4.39	-7.95

140	28	4.11	-7.25		
150	26	3.82	-6.64		
160	25	3.67	-6.23		

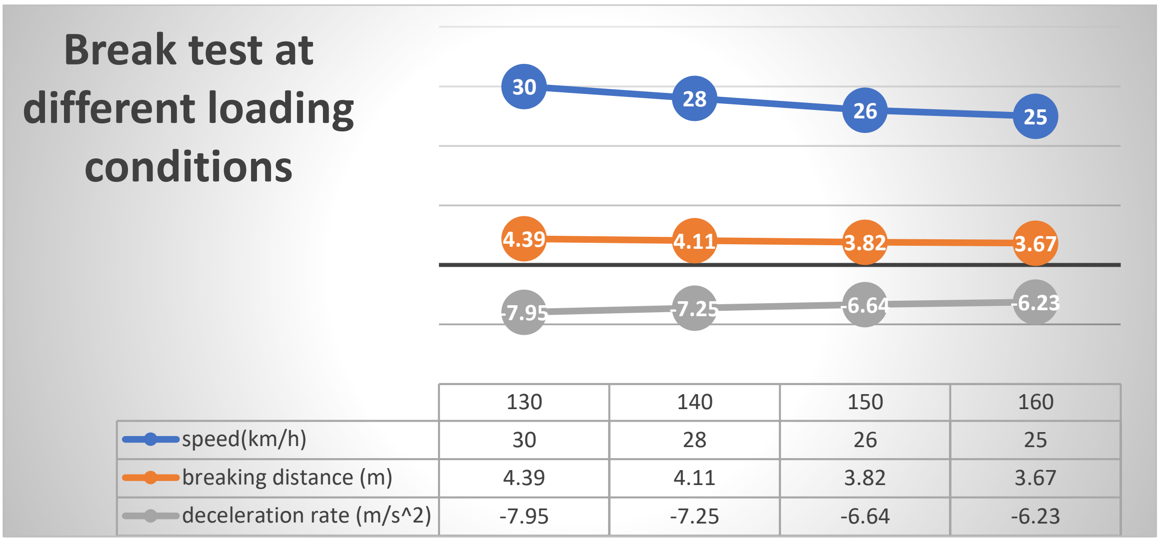

Figure 4-2: Break test graph at different loading conditions

4.9 Discussion

The table 4.2 shows the results of a break test at different loading conditions. The breaking distance is the distance travelled by the vehicle after applying the brakes and until the vehicle stops. The deceleration rate is the rate of change of speed during braking. The breaking distance can be calculated using the formula: BD = (Vb^2)/ (2*[g]*f) 1, where BD is the breaking distance, Vb is the speed of the vehicle before braking, g is the acceleration due to gravity, and f is the design coefficient of friction between the tires and the road surface.

The deceleration rate can be calculated using the formula: a = -Vb^2 / (2*BD) 2, where a is the deceleration rate, Vb is the speed of the vehicle before braking, and BD is the breaking distance.

The table shows that as the load increases, the speed decreases, and so does the breaking distance and the deceleration rate. This means that a heavier vehicle needs less distance and time to stop, but also experiences less force during braking. This is because a heavier vehicle has more inertia, which resists changes in motion. Therefore, it takes more force to accelerate a heavier vehicle, but also less force to decelerate it.

4.10 Reference model

Figure 4-3: Reference model

4.11 Present model

Figure 4-4: Present Model

4.12 Physical parameters compression

Table 4-3: Physical parameters compression

Sr. No.	Comparison	Farukh khan	Present
1	Designed for load (kg)	130	150
2	Motor Voltage (v)	24	48
3	Paddle Assist	No	Yes

4	Achieved load speed (Km/s)	20	30
5	Length (m)	2.5	2.134
6	Width (m)	0.8	1
7	Seat	Yes	Yes
8	Front tyres (″)	18	24
9	Rear tyre (″)	20	26
10	Front safety	No	Yes
11	Breaks	Rare Wheel	Front Wheel
12	Gear Mechanism	Single Gear	Six Speed
13	Frame Design	Straight	Aerodynamics (2″)

4.13 Safety precautions

- Wear a helmet. not all states require bicyclists to wear a helmet.
- Check your equipment before you ride.
- Wear reflective materials.
- Keep your hands on the Trike.
- Know your signals and use them.
- Limit your distractions.
- Ride as if you're in a car.
- Ride with the flow of traffic

CHAPTER 5

Environmental Sustainability

5.1 Sustainability Development

Electric vehicles emerge as the possible strategy for decarbonization and green transportation due to social demand. Researchers have made multiple efforts and initiatives as the demand surge for sustainable development in the electric vehicle industry. This study analyses the relevant research of the industry, thereby explores electric vehicle industry development trends with a scient metrics-based data evaluation system, where three key topics are detected: “Vehicle Exhaust Emissions”, “Climate Change”, and “Integration”.

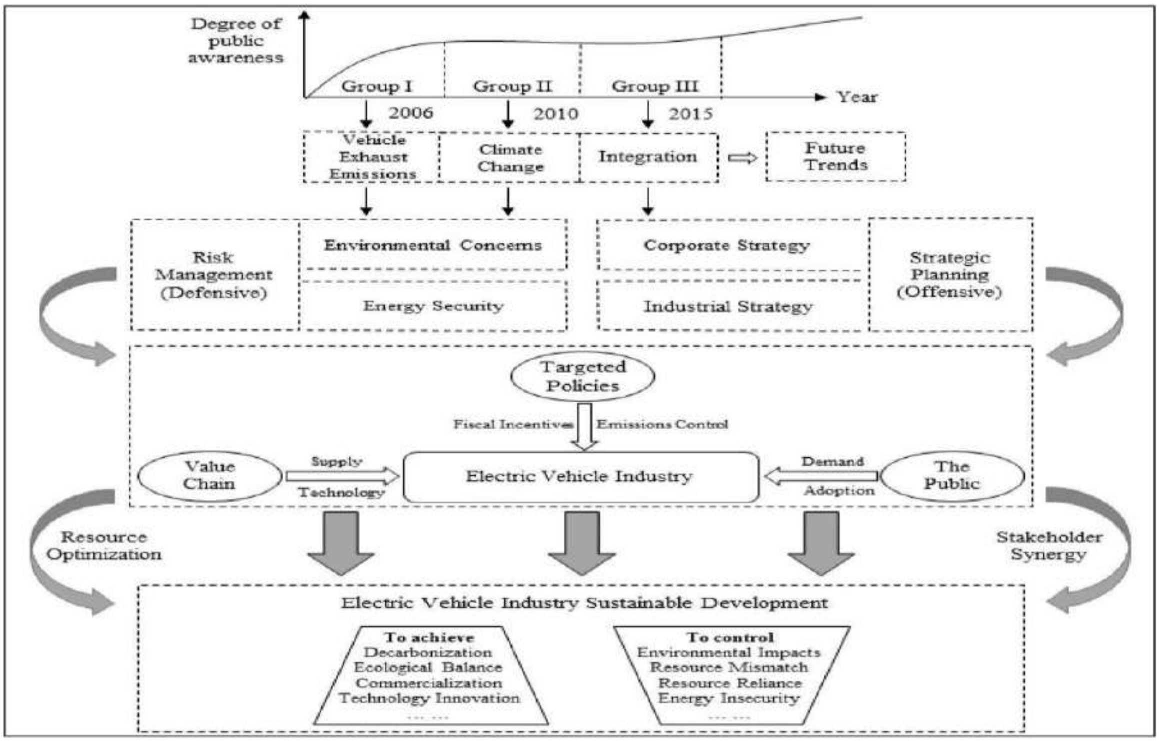

Figure 5-1: Sustainability Development

5.2 Positive impacts on Environment

With increasing in an air pollution and scarcity of fuels (petrol and diesel), electric trike was playing an important role in this new era. E-bikes were eco-friendly and cost effective for transportation. The demand and constantly increasingly of petrol and diesel cost has made engineers to think for new source of energy for transportation. Electric vehicles gave a breakthrough solution to satisfy the needs required but the cost of electric trikes was too high that normal people cannot afford it easily. The amount of air pollutants by different vehicles. We can see the electric vehicle with renewable energy has minimum CO_2 emission.

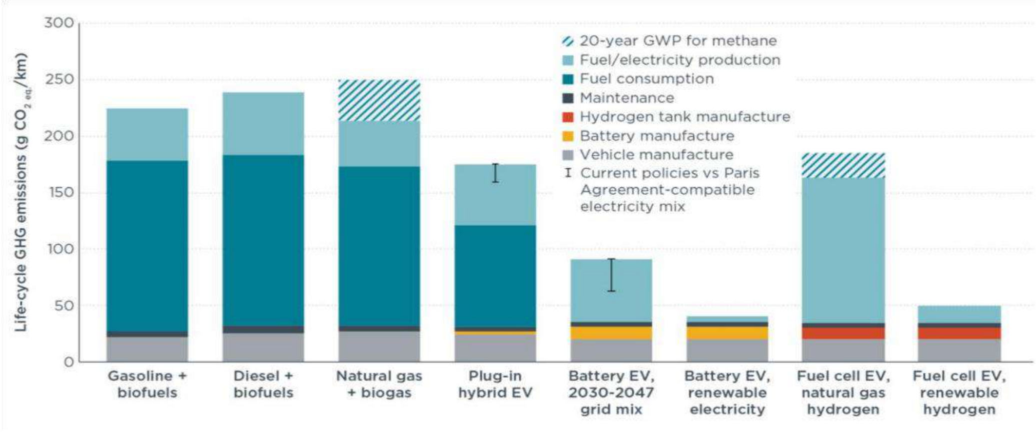

Figure 5-2: Environmental impact Analysis

5.3 Sustainability Analysis

Global warming is a severe problem affecting the environment worldwide, primarily due to the excessive consumption of fossil fuels for transportation, which accounts for a fifth of global carbon emissions. As a result, many environmentally conscious people are looking for sustainable alternatives to replace fossil fuels. Enter electric trike. They have shown great promise as an effective and environment-friendly transport solution. Not only are they affordable but they are easily portable as well. They also cost a lot less than cars. The purchase cost of a fossil fuel-based vehicle is just one of many expenses. As soon as you buy a car, insurance fees, daily fuel expenses, and routine maintenance costs soon start to pile up. By comparison, e-trikes are far cheaper and you don't have to worry about any other running costs. By the time you reach 18 months of use, the trike would most probably have paid for itself. On top of the financial benefits, folding electric trikes are much more portable, easier to store, and require barely any space. Yet the biggest advantage of electric trike is that they allow you to significantly reduce your fossil fuel consumption. By owning an e-trike, you can minimize greenhouse gas emissions and your overall carbon footprint.

5.4 Lowering CO_2 emissions and easing traffic congestion

Major cities attract many people in search of new opportunities from different places. As the population increases, so do the number of cars and motorcycles on the road. This eventually leads to traffic congestion, stretching the time it takes for you to reach your destination. Heavy traffic also increases the consumption of fossil fuels as cars have to keep moving at much slower speeds and for a longer time. This results in more emission of carbon monoxide (CO), which pollutes the air and harms our health. Instead, you can take advantage of battery-powered trike to cruise through city traffic with ease and safely. E-trike can significantly lower the traffic on the roads, cutting down the time required to get to places. Consequently, you can also do your part in lowering air pollution and helping the environment. As people are getting more conscious about the consumption of fossil fuel, electric trikes and tricycles for adults are gaining popularity. Not only are they a more sustainable option for our environment, but they also help you adopt a healthy lifestyle despite a sedentary routine. All in all, e-trikes are one of the best and most viable transportation solutions that empower you to decrease your environmental footprint and combat climate change on an individual level. If you want to avoid the tedious and time-consuming process of vehicle registration, getting a license plate, or getting it insured, electric trikes are a splendid choice worth considering.

5.5 Step toward reducing pollution

Our findings suggest that electric Three-wheelers can make urban transportation more sustainable. However, immediate market potential exists only for e-trikes; persisting price differentials and the absence of an obvious additional use value appear to present a barrier for the market penetration of mid-size and large electric three-wheelers. If we want to decrease transport related carbon dioxide emissions, urban noise and air pollution, and inner-city traffic, policy makers should consider supporting electric three-wheelers.

CHAPTER 6

Conclusions and Future Recommendations

6.1 Conclusions

Electric vehicles are the future of our world with the increasing consumption of non-renewable resources such as petroleum, and diesel which leads us to step our way toward renewable sources such as solar hydroelectric power and battery. There are alternative ways by which we can save energy. One of such way is Solar electric Trikes; it is also the new way of transport which provides us easy way of transport to provide of any age. It is cheap source of transport and affordable to anyone. The motor used in this trike has high efficiency and the battery bank has less weight with high speed. These bikes are environment friendly, needs less maintenance and can be also assembled to small component and the main feature of this proposed project is too rechargeable when it is in running condition.

6.2 Future recommendations

- The concept of electric and manually operated trikes can be implemented at large scale.
- Electric trikes are also available in market in online stores are much expensive and middleclass people are unable to afford hybrid bicycle is the better alternate of E-trike.
- Present electric and manually operated Trike has mechanism of self-charging but E-trike are unable to charge during running condition the following proposed model can be used in E-Trike commercially

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