DESIGN AND FABRICATION OF ELECTRIC SCOOTER

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Certification

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DESIGN AND FABRICATION OF ELECTRIC SCOOTER

Sustainable Development Goals

SDG No	**Description of SDG**	**SDG No**	**Description of SDG**
SDG 1	No Poverty	SDG 9	Industry, Innovation, and Infrastructure
SDG 2	Zero Hunger	SDG 10	Reduced Inequalities
SDG 3	Good Health and Well Being	SDG 11	Sustainable Cities and Communities
SDG 4	Quality Education	SDG 12	Responsible Consumption and Production
SDG 5	Gender Equality	SDG 13	Climate Change
SDG 6	Clean Water and Sanitation	SDG 14	Life Below Water
SDG 7	Affordable and Clean Energy	SDG 15	Life on Land
SDG 8	Decent Work and Economic Growth	SDG 16	Peace, Justice and Strong Institutions
		SDG 17	Partnerships for the Goals

Range of Complex Problem Solving			
	Attribute	**Complex Problem**	
1	Range of conflicting requirements	Involve wide-ranging or conflicting technical, engineering and other issues.	
2	Depth of analysis required	Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models.	
3	Depth of knowledge required	Requires research-based knowledge much of which is at, or informed by, the forefront of the professional discipline and which allows a fundamentals-based, first principles analytical approach.	
4	Familiarity of issues	Involve infrequently encountered issues	
5	Extent of applicable codes	Are outside problems encompassed by standards and codes of practice for professional engineering.	
6	Extent of stakeholder involvement and level of conflicting requirements	Involve diverse groups of stakeholders with widely varying needs.	
7	Consequences	Have significant consequences in a range of contexts.	
8	Interdependence	Are high level problems including many component parts or sub-problems	
Range of Complex Problem Activities			
	Attribute	**Complex Activities**	
1	Range of resources	Involve the use of diverse resources (and for this purpose, resources include people, money, equipment, materials, information and technologies).	
2	Level of interaction	Require resolution of significant problems arising from interactions between wide ranging and conflicting technical, engineering or other issues.	
3	Innovation	Involve creative use of engineering principles and research-based knowledge in novel ways.	
4	Consequences to society and the environment	Have significant consequences in a range of contexts, characterized by difficulty of prediction and mitigation.	
5	Familiarity	Can extend beyond previous experiences by applying principles-based approaches.	

Abstract

The number of cars on the road worldwide is rising at an alarming rate each year, but the reliance on gasoline derived from oil continues to increase largely uncontrolled. Hence electric vehicles have become a viable option. In Pakistan, there is a growing demand for electric bikes due to the country's need for an inexpensive and effective means of transportation.

This project is an opportunity to design and contribute to the production of the greatest electric bike in its class for daily commuting. Everyone must travel large distances to visit one area from another due to the expanding infrastructure of universities, colleges, and businesses. On campus, excessive movement can strain and hurt your body. Therefore, this project will help to initiate a shuttle service within the premises of our university.

Refining its design and making it compact in design to lower its cost was the priority in this project. Electric Scooter is a two-wheeled plug-in electric vehicle with electric hub motor that may be driven by an external power source, like a rechargeable lithium-ion battery. Unlike ordinary scooters, it does not have a step-through frame. Because they have a motor and produce no pollution, electric scooters are a useful form of transportation on the road. This Project report covers the basic model of an electric scooter as well as the product design, manufacturing process, cost analysis, and other related information and study on the conception and creation of a more intelligent, cost-effective, and secure electric bike. This was achieved by doing in-depth market research, evaluating the possibilities to find out what the world wanted and the challenges they faced.

Keywords: Electric vehicles design, Lithium-ion battery, Gear Hub motor, Cost- effective.

Undertaking

I certify that the project **Design and Fabrication of Electric Scooter** is our own work. The work has not, in whole or in part, been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged/ referred.

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List of Acronyms

A:	Ampere
BLDC:	Brushless Direct Current
FEA:	Finite Element Analy
HP:	Horsepower
PMDC:	Paramagnetic Direct Current
QFD:	Quality Function Development
RPM	Revolution per min
V	Volts
W	Watt

Chapter 1

1. Introduction

1.1 Introduction of E-Bike:

The electric scooter is designed as a battery-powered, single-passenger vehicle, catering to individuals with limited mobility. It serves as a practical solution for people who face challenges in walking for extended periods. Electric scooters come in three main types, suitable for indoor, outdoor, or versatile use in both environments. These scooters can have either three or four wheels. The eco-friendly nature of electric scooters stems from their battery-powered operation, which eliminates pollutant emissions. Typically, two rechargeable batteries are utilized in an electric scooter. The type, grade, and capacity of the battery significantly impact the scooter's operating duration between charges. Many batteries boast an eight-hour life expectancy, covering a range of 20 to 30 miles before necessitating a recharge. Some people are a little hesitant to buy an electric scooter because they think it would be challenging to use. Once one gets the hang of it, the control console makes everything quite straightforward. Advanced brake systems are also included with electric scooters, making stopping easy and comfortable. There is little opportunity for sudden or jarring stops because the brake starts to operate as soon as the operator releases the throttle. Most scooters also feature a parking brake to prevent rolling when parked. [1]

From 2015 to 2023, 6 million electric motorcycles and scooters will be sold worldwide, according to the Navigant Research prediction. This represents a 50 million sales increase in a very short period of time. More people are starting to use two-wheel vehicles, such as electric motorcycles (e-motorcycles) and electric scooters (scooters), because of rising gasoline prices and congested city streets. Scooters are categorized as a motorcycle subclass. We may now discover a variety of scooters on city streets and in parks. The primary frame, wheel, type, brake system, battery and charger, motor, on/off switch, speed control, and one-way bearing are the components of an electric scooter. This kind of scooter is portable and simple to use because it is compact and light. Although it can be used indoors or out, the majority of individuals chose to utilize it for outdoor activities.

There are various ways that scooters can operate. It all relies on the intended use by the user. It can be driven by an engine, an electric motor, or by foot power. Each variety of them has advantages and disadvantages of its own. However, because they are lightweight, affordable, and simple to produce, electric scooters are the preferred option. There are many eyes caught by it, and sales are rising daily. The production and development of electric vehicles, such as scooters, bicycles, motorcycles, and cars, have received greater attention in recent years, and sales are expected to rise steadily. The creation of electric scooters is the extent of this project's work. To make it easier for people to get around, especially in big cities, electric scooters are becoming a new means of transportation. Instead, it offers an alternate mode of transportation that enables someone with little energy to move rapidly, and most importantly, it is environmentally friendly. [2]

Electric cars are making a name for themselves in several areas, particularly the transportation sector. Electrical motors in bicycles and automobiles offer a wide range of benefits and new opportunities. Electric motor cars are an idea worth considering both today and, in the future since they may create new opportunities or perhaps take the place of current internal combustion engine options. It has a very tiny ecological impact, especially when compared to cars, which are either barely polluting or nonexistent. The substantial differences in occupation rates are another factor that makes this variation more pronounced. Bicycles use their full capacity rate, boosting efficiency and decreasing footprint, compared to cars, which typically have occupancy rates between 1 and 2 people, or 20 to 40% of their overall capacity. Through their study, Kumar, et al. 993 made clear information about electric vehicles available. They used nickel metal batteries to power the car, which had a 100-kilometer range between recharges. When they installed the power kits on the current bicycles, they exponentially expanded their range to 300 km, which resolved several problems like cost and pollution. As a result, the commutator of short distances, such as medical supply stores, schools, and locations in both rural and urban areas, will benefit. They designed the controller designs and employed a DC motor and motor controller for power regulation. The study by Henry M. and Gannon from 2016 deals to multi-wheeled vehicles but is not applicable to bicycles. A regular bicycle with a multi- speed transmission, an electrical generating system, and a solar charging setup makes up the device. The device was powered by a pedaling and motor combination that was connected such that power was always available. Lead acid batteries, a DC hub motor, and a hand lever that controls a throttle mechanism make up the electrical system. Regenerative braking systems were investigated to use them to produce energy that charged batteries. Battery charging is a common issue with the usage of electric scooters; it takes a long time for the battery to fully charge, which is why a model of the hybrid concept is introduced in the current study. Pedaling helps to some extent to charge the battery, and it can also benefit the rider along the route by allowing them to move or to help them reach top speed more quickly. This idea may also prove to be very helpful for those who have trouble moving around, since it has the potential to upgrade and modify an ordinary scooter or other similar vehicle to better serve users' needs, facilitating travel and enhancing mobility. [3]

As the name implies, an electric scooter is one that is required when a car or scooter needs to run on electricity. It doesn't need fuel to run, in contrast to ordinary scooters that run on gasoline or other fuel. These are frequently recharged using a battery charger. Electric scooters are a future-proof form of transportation that is environmentally benign. E- scooters are economical and environmentally friendly, which is now a key component of social and economic development in the world. [4]

In order to recharge the electric bicycle, it is necessary to connect the charger to the battery by plugging it into a power socket. Lithium-ion batteries are the most used type of battery for electric bicycles, and their characteristics vary in terms of size, weight, capacity, price, and management system. To determine the amount of time required for a battery to recharge in hours, the battery capacity in ampere-hours [Ah] is divided by the charger's ampere [A]. A higher battery capacity will result in a longer recharging time with the same supplied amperes. Conversely, batteries with lower capacity will provide a lower range. The energy capacity of batteries from different manufacturers can be compared by their watt hours [Wh]. The higher the watt hour value, the greater the distance that can be traveled on a single charge, although typically, a higher energy capacity value leads to a heavier battery. The range of electric bicycles on various factors, including the energy capacity of the battery, the motor, the weight, wind direction and speed, terrain, steepness of the route, and the battery's age. [6]

1.2 Problem Statement:

As time goes on, the number of automobiles worldwide is rising by millions each year. 80 million vehicles were produced only in 2022. The world's highways are being overrun by vehicles, which puts strain on petroleum supplies and increases combustion in engines, which produces harmful hydrocarbons, carbon dioxide, and nitrogen oxides that are terrible for the environment. Nowadays, people frequently use mini scooters for transportation, relaxation, and exercise following a day at the office. There are numerous scooters of the standing or seated variety all around us even though it is already small, most of the scooter is rigid, which is a problem. Even while some manufacturers make them flappable, there are only a select few elements that can be flipped, including the seat, handle, and occasionally the arm bar. The rider swings their leg to move most flip-style miniature scooters. It seems uncomfortable to use some of the scooters for long amounts of time. Even with an electric scooter, most of that cannot be flipped. And the price range of this scooter is not comfortable for a group of people to manage. We will try to refine its design and make it compact in design to lower its cost that will be our priority in this project. That will help those people to manage to afford that are unable now to afford electric scooter for their price range. The entire world is switching to electric-powered modes of transportation, including electric automobiles, trains, trucks, and vehicles. We are developing a vehicle that is both financially sound and environmentally responsible to encourage and support the emerging power trend in electrical mobility. So, this will help to contribute to the start of the new trend of electric vehicles, especially e- scooter in our country that will prove beneficial in future.[7]

1.3 Aim and Objectives:

1.3.1 Our Aim:

In this modern era, conventional fuel vehicles are shifting towards electrical vehicles. That’s why there are a lot of renowned companies that are manufacturing electric vehicles with unique and versatile sets of features. Along with that new companies and new variants of electric bikes are getting introduced in the market every day.[8]

Our aim behind this entire project is to fabricate electric scooters for the university shuttle service. We have observed that the distance from the one gate to the other gate of the university is over 1 km. The students must cover a lot of walking distance to reach from the gate to any department. So, we’ll introduce a shuttle service to fulfill this need of students.

The design that we’re providing is simple, the speed of the electric scooter is expected to be about 30kmph, and the weight will be about 35-50 kg. Through the success of this project our university can also initiate the shuttle service as few other universities of our country. So that’s why we are aiming to fabricate Electric Scooter that support and empower this upcoming power trend on electrical Transportation, and we are making a vehicle which is economical reliable and eco -friendly.

1.3.2 Objectives:

- To reduce pressure on petroleum products and fossil fuels.
- To reduce the use of non-renewable energy assets.
- To reduce the pollution in the environment.
- To be used for transportation to airports, colleges and in universities premises.

Chapter 2

2. Literature Review

Electric scooters have gained popularity in recent years as a cost-effective and eco-friendly mode of transportation. However, the design and Development of electric scooters present significant challenges that need to be addressed. The development of efficient and lightweight batteries, as well as the design of a safe and ergonomic vehicle frame, are two key issues that need to be considered. Furthermore, the lack of adequate infrastructure for electric scooters in many cities poses challenges for users. This literature review aims to provide an overview of the current issues and solutions in the design and Development of electric scooters. The review will focus on recent research studies that have addressed these challenges, including the development of battery technologies, the design of vehicle frames, and the implementation of smart charging and safety systems. The review will also discuss the potential of electric scooters as a sustainable and convenient mode of transportation and the challenges that need to be addressed to promote their wider use.

2.1 Battery Technology

The battery is a critical component of an electric scooter, as it provides the energy to power the vehicle. The performance, safety, cost, and environmental impact of electric scooters are affected by the battery technology used.

The performance of an electric scooter is directly related to the battery technology used. The battery technology determines the range, speed, and power output of the electric scooter. A study conducted by Li et al. (2019) analyzed the performance of different battery

technologies, including lead-acid, nickel-cadmium, nickel-metal hydride, and lithium-ion batteries, and concluded that lithium-ion batteries are the most suitable for electric scooters, due to their high energy density, low self-discharge rate, and long cycle life.

The safety of an electric scooter is also affected by the battery technology used. The safety of the battery depends on its chemistry, design, and management. A study conducted by Cheng et al. (2020) analyzed the safety issues of lithium-ion batteries in electric scooters and proposed a set of safety measures, including temperature monitoring, voltage balancing, and current limiting.[9]

2.2 Electric scooters.

The cost of an electric scooter is also influenced by the battery technology used. The cost of the battery is a significant part of the total cost of the electric scooter, and it varies depending on the type of battery and its capacity. A study conducted by Baral et al. (2019) analyzed the cost of different battery technologies for electric scooters and concluded that lithium-ion batteries are the most cost-effective, due to their high energy density and long cycle life.

The environmental impact of an electric scooter is also linked to the battery technology used. The production, use, and disposal of batteries can have a significant impact on the environment, including the depletion of natural resources, the emission of greenhouse gases, and the generation of hazardous waste. A study conducted by Varsani et al. (2021) analyzed the environmental impact of different battery technologies for electric scooters and proposed a set of environmental criteria, including the use of sustainable materials, the reduction of greenhouse gas emissions, and the adoption of circular economy principles.

The results showed that the environmental criteria can promote the development of sustainable battery technologies for electric scooters.

Table 2. 1 Comparison of Battery Types

Results	**VRLA**	**Li-ion**
cost ($)	75	424
Mass (kg)	26	8

Lifetime (yrs)	10	9
Volume (L)	6.2	5
Max Theoretical Power (kW)	5.8	2.9
Recharging Safety	High	Low
Temperature effects	moderate	high
Assumptions	VRLAI	LIB
Specific Energy (Wh/kg)	35	110
Energy Density (Wh/L)	86	170
Power density (W/kg)	240	350
Cost (S/kWh)	83	505
Cycle Life	300	800

In conclusion, battery technology is a critical component of an electric scooter, and it affects its performance, safety, cost, and environmental impact. New battery technologies, designs, and management strategies can be developed to improve the performance, safety, cost, and environmental sustainability of electric scooters.

2.3 Safety

Safety is a critical issue for electric scooters, as they share the road with other vehicles and pedestrians. The safety of electric scooters is affected by various factors, including rider behavior, vehicle design, road conditions, and regulations.

Rider behavior is a key factor that affects the safety of electric scooters. Riders should be aware of the risks and dangers associated with electric scooters and should take necessary precautions to ensure their safety and the safety of others. A study conducted by Zhang et al. (2021) analyzed the riding behavior of electric scooter riders in China and proposed a set of safety recommendations, including wearing helmets, obeying traffic rules, and avoiding distractions while riding. The results showed that the safety recommendations can improve the safety of electric scooters and reduce the risk of accidents.[10]

Vehicle design is another critical factor that affects the safety of electric scooters. The design of electric scooters should be optimized for safety, stability, and maneuverability, while also providing comfort and convenience for riders. A study conducted by Huang et al. (2020) proposed a new design for electric scooters, which uses a three-wheeled structure and a tilting mechanism to improve stability and maneuverability. The results showed that the new design can improve the safety and usability of electric scooters, especially in urban areas. Road conditions are also important factors that affect the safety of electric scooters.

The road conditions, including surface conditions, traffic density, and weather conditions, can affect the stability and maneuverability of electric scooters and increase the risk of accidents. A study conducted by Sun et al. (2021) analyzed the effects of road conditions on the safety of electric scooters and proposed a set of guidelines for road maintenance and improvement. The results showed that the guidelines can improve the safety and usability of electric scooters by providing better road conditions.

Regulations are crucial for ensuring the safety of electric scooters and promoting their integration into urban mobility systems. The regulations should be designed to ensure the safety of riders and other road users, while also balancing the interests of different stakeholders. A study conducted by Wang et al. (2019) analyzed the regulations for electric scooters in China and proposed a set of policy recommendations to improve their safety and sustainability. The results showed that the proposed policy recommendations can improve the safety of electric scooters and promote their integration into urban mobility systems.[11]

In conclusion, safety is a critical issue for electric scooters, and it is affected by various factors, including rider behavior, vehicle design, road conditions, and regulations. New safety recommendations, designs, technologies, and policies can be developed to improve the safety of electric scooters and promote their integration into urban mobility systems.

2.4 Infrastructure

The infrastructure for electric scooters plays a significant role in their usability, accessibility, and sustainability. The infrastructure includes charging stations, parking facilities, road infrastructure, and regulations that govern the use of electric scooters.

Charging stations are critical infrastructure for electric scooters, as they provide the necessary energy to recharge the batteries. The availability and accessibility of charging stations can affect the usability and convenience of electric scooters for riders. A study conducted by Chen et al. (2020) proposed a new charging station design for electric scooters, which integrates solar panels and energy storage systems to provide renewable energy and reduce the reliance on the power grid. The results showed that the new charging station design can improve the sustainability and accessibility of electric scooters.

Parking facilities are also important infrastructure for electric scooters, as they provide safe and convenient places for riders to park their vehicles. The availability of parking facilities can affect the accessibility and safety of electric scooters for riders. A study conducted by Wang et al. (2018) proposed a new parking facility design for electric scooters, which uses a modular and compact structure to optimize the use of space and increase the capacity of the parking facility. The results showed that the new parking facility design can improve the usability and safety of electric scooters.[12]

Road infrastructure is another critical infrastructure for electric scooters, as it provides the necessary conditions for safe and efficient mobility. The road infrastructure includes roads, sidewalks, and bike lanes, which should be designed to accommodate electric scooters and other micro-mobility vehicles. A study conducted by Milakis et al. (2019) analyzed the road infrastructure for electric scooters in European cities and proposed a set of design guidelines for infrastructure improvements. The results showed that the proposed guidelines can improve the safety and usability of electric scooters on the road.

Safety, accessibility, and sustainability of electric scooters, while also balancing the interests of different stakeholders. A study conducted by Bassok et al. (2020) analyzed the regulations for electric scooters in the United States and proposed a set of policy recommendations to improve their sustainability and safety. The results showed that the proposed policy recommendations can improve the governance of electric scooters and promote their integration into urban mobility systems.[13]

In conclusion, the infrastructure for electric scooters is crucial for their usability, accessibility, and sustainability. The infrastructure includes charging stations, parking facilities, road infrastructure, and regulations that govern their use. New designs, technologies, and policies can be developed to improve the infrastructure for electric scooters and promote their integration into urban mobility systems.

2.5 Design

The design of an electric scooter is an important aspect that affects its performance, safety, and usability. The design of an electric scooter involves various components such as the frame, suspension, braking system, motor, and battery, which must work together to provide an efficient and safe vehicle.

The frame of the electric scooter should be designed to provide adequate support and stability for the vehicle. A strong and durable frame can ensure the safety of the rider, while a lightweight frame can enhance the vehicle's performance and maneuverability. A study conducted by Guan et al. (2021) proposed a new lightweight frame design for an electric scooter using high-strength aluminum alloys. The results showed that the new frame design was more lightweight and had better performance compared to traditional steel frames.

The suspension system is another important component of an electric scooter, as it can affect the comfort of the rider and the stability of the vehicle. The suspension system should be designed to absorb shock and vibrations from the road to ensure a smooth and comfortable ride. A study conducted by Xia et al. (2019) proposed a new suspension system design for electric scooters using a variable stiffness and damping system. The results showed that the new suspension system design improved the stability and ride comfort of the vehicle.

The braking system is also a crucial component of an electric scooter, as it can affect the safety of the rider and the vehicle. The braking system should be designed to provide effective and reliable braking performance, especially in emergency situations. A study conducted by Zou et al. (2020) proposed a new regenerative braking system design for electric scooters, which can improve the energy efficiency of the vehicle and reduce the wear and tear on the braking system.[14]

The motor and battery are the core components of an electric scooter, as they provide the power and energy needed for the vehicle to move. The motor should be designed to provide sufficient power and torque for the vehicle, while the battery should be designed to provide adequate energy storage and long life. A study conducted by Yang et al. (2020) proposed a new motor and battery design for electric scooters, which can improve the vehicle's performance and energy efficiency.[15]

In conclusion, the design of an electric scooter involves various components that must work together to provide an efficient and safe vehicle. The frame, suspension, braking system, motor, and battery should be designed to provide adequate support, comfort, safety, power, and energy efficiency. New designs and technologies can be developed to improve the performance and sustainability of electric scooters.

2.6 Sustainability

The production and disposal of batteries in electric scooters have significant environmental impacts. Traditional batteries contain heavy metals and toxic chemicals, which can lead to soil and water contamination. Moreover, the production process for traditional batteries requires significant energy consumption and emits greenhouse gases. To address these issues, sustainable battery technology has been proposed, such as recycling and reuse. .[16]

Dunn, Kamath, and Tarascon (2020) evaluated different electrical energy storage options, including batteries, for their potential to be sustainable. The authors propose that lithium- ion batteries can be made more sustainable by recycling materials like cobalt, nickel, and lithium. Recycling can help reduce the environmental impact of battery production and disposal, as well as the cost of manufacturing new batteries. Additionally, the authors suggest that used batteries can be repurposed for stationary energy storage, such as in buildings, to extend their lifecycle. .[17]

Furthermore, the use of renewable energy sources can contribute to the sustainability of electric scooters. One way to accomplish this is by using solar panels to charge the batteries of electric scooters. In a study conducted by Mekhilef, Saidur, and Safari (2021), the authors proposed a solar-powered electric scooter that can be charged by solar panels. The results showed that the solar-powered electric scooter can reduce the environmental impact of transportation and promote sustainable mobility.[18]

In conclusion, sustainable battery technology and the use of renewable energy sources have the potential to improve the sustainability of electric scooters. Recycling and reusing materials, as well as utilizing solar panels for charging, can reduce the environmental impact of battery production and disposal, as well as contribute to sustainable mobility.[19]

2.7 Simple Frame Design:

The frame of an electric scooter provides support and protection for the rider and the components of the vehicle. The design of the frame affects the weight, cost, and performance of the electric scooter.[20]

One of the common problems with the frame design of electric scooters is that it can be complex and require advanced Development techniques, which can increase the cost and difficulty of manufacturing. To address this problem, a study conducted by Bhattacharjee et al. (2020) proposed a simple frame design for electric scooters, made of metallic pipes, that can be easily fabricated and assembled, and provides adequate support and protection for the rider and the components of the vehicle. The results showed that the simple frame design can reduce the cost and difficulty of manufacturing, without compromising the safety and performance of the electric scooter. [21]

Another problem with the frame design of electric scooters is that it can be heavy, which can affect the range and acceleration of the vehicle and increase the energy consumption. To address this problem, a study conducted by Wang et al. (2021) proposed a lightweight frame design for electric scooters, made of carbon fiber reinforced polymer (CFRP), that can reduce the weight of the vehicle by up to 50%, without compromising the strength and stiffness of the frame.[22]

The results showed that the lightweight frame design can improve the range, acceleration, and energy efficiency of the electric scooter, while maintaining the safety and comfort of the rider.[23]

In short, the frame design of electric scooters is a critical factor that affects the weight, cost, and performance of the vehicle. Simple frame designs, made of metallic pipes, can reduce the cost and difficulty of manufacturing, while lightweight frame designs, made of advanced materials, such as CFRP, can improve the range, acceleration, and energy efficiency of the electric scooter. New frame designs and materials can be developed to optimize the performance, safety, and sustainability of electric scooters.[24]

Chapter 3

3. Methodology

3.1 Design Configurations

After the literature review, we started to analyze the various aspects of the and configurations of the design of our electric scooter. Thus, on the basis of several categories and components, we analyzed that how many design configurations are possible and after searching for that we concluded that following are the factors on which the design is primarily dependent upon (Mai, 2021):

- Frame/Chassis Design
- Motor Type
- Type of Battery
- Sort of Microcontroller

The frame design plays a vital role in the entire design and specifications selection of our electric scooter hence we considered all the possible ways of frame design that could be manufactured easily and that could be proved reliable in terms of mechanical strength (Different e-bike frame types, styles, and sizes for you to choose from, n.d.). For that purpose, we narrowed down our range and concluded that the options that we had were fabricating the chassis by sheet metal or by metallic pipes.

Sketching various design types based on the selected concept.

3.1.1. Final Dimensions:

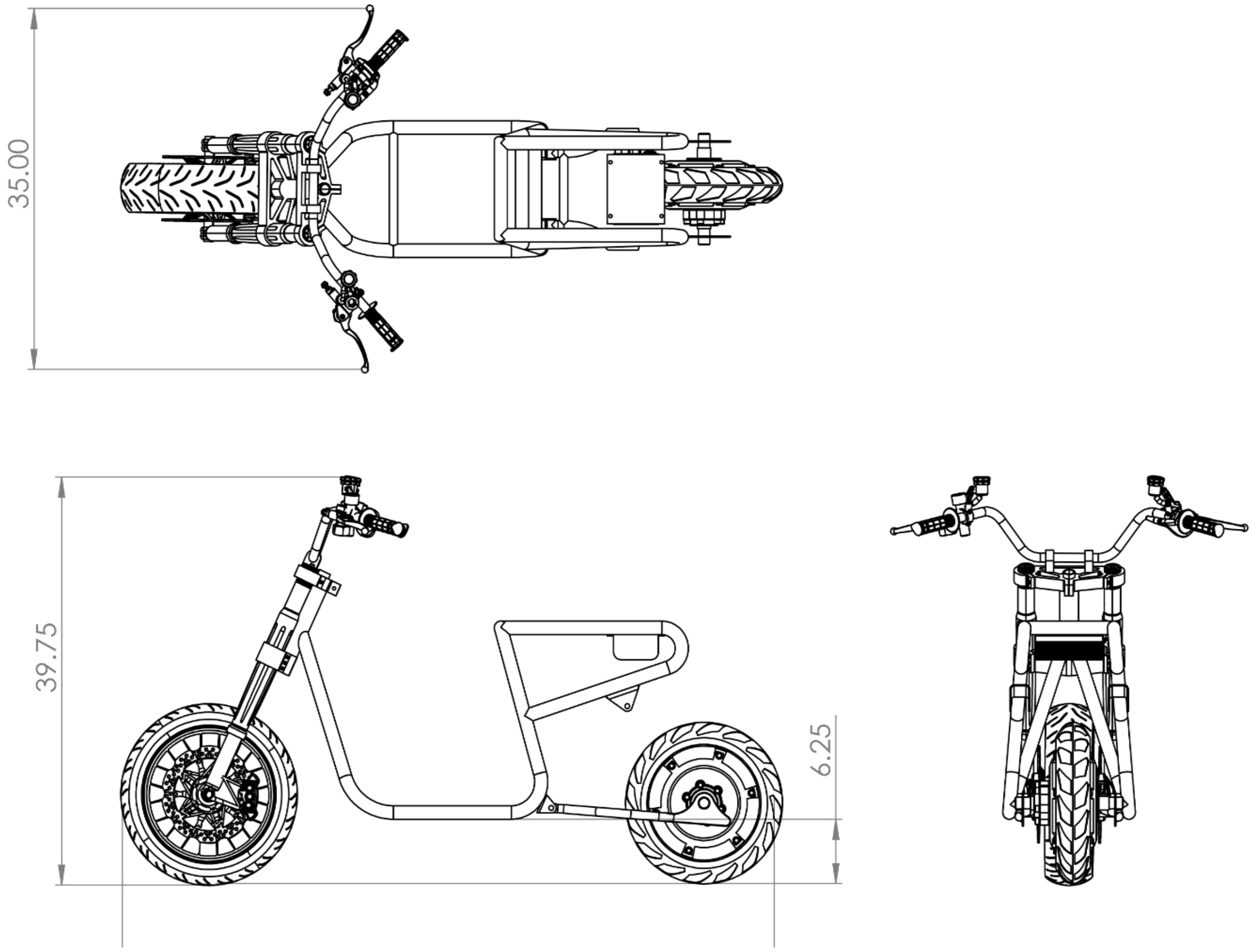

Fig 3. 1 Bike Dimensions

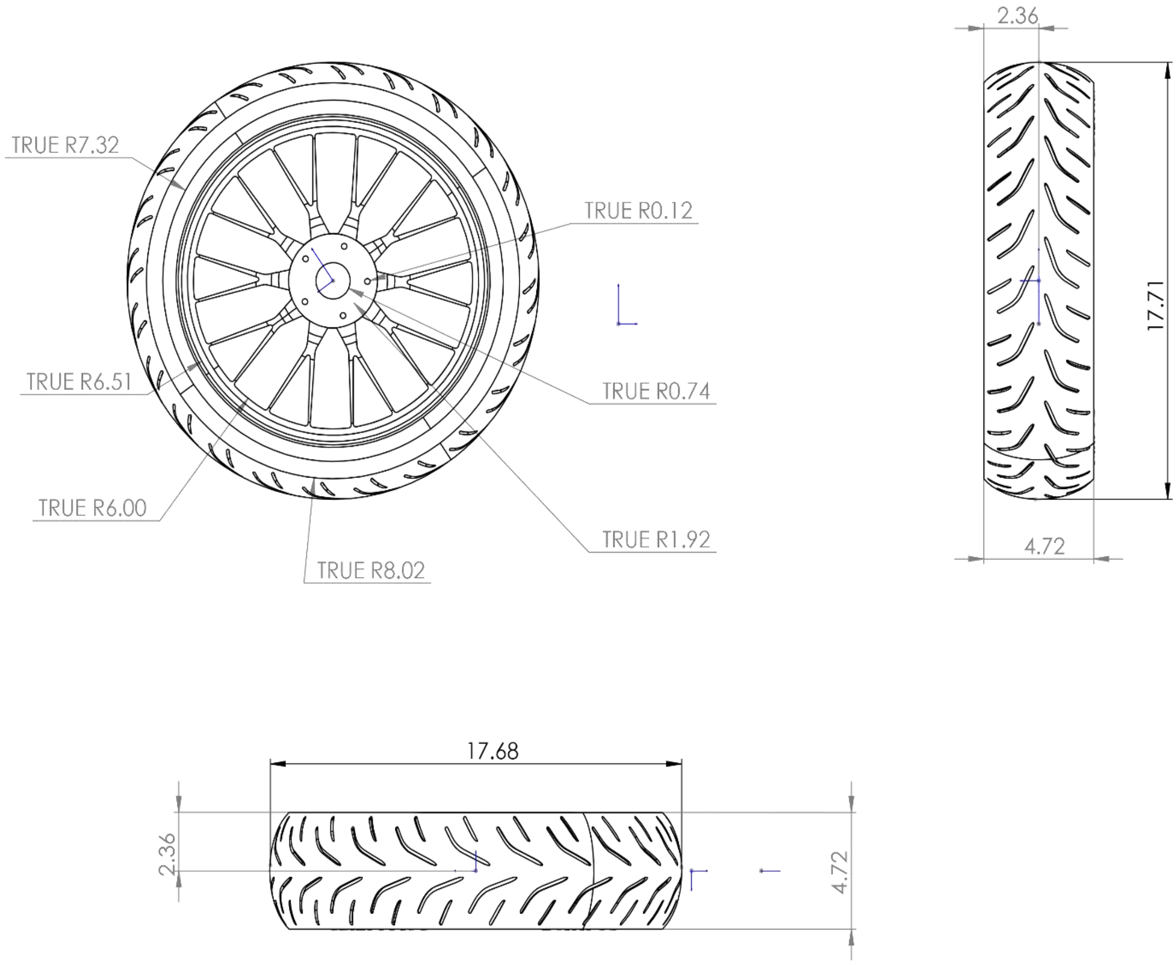

Fig 3. 2 Rim's Dimensions

Dimensions of Front and Rear Rim

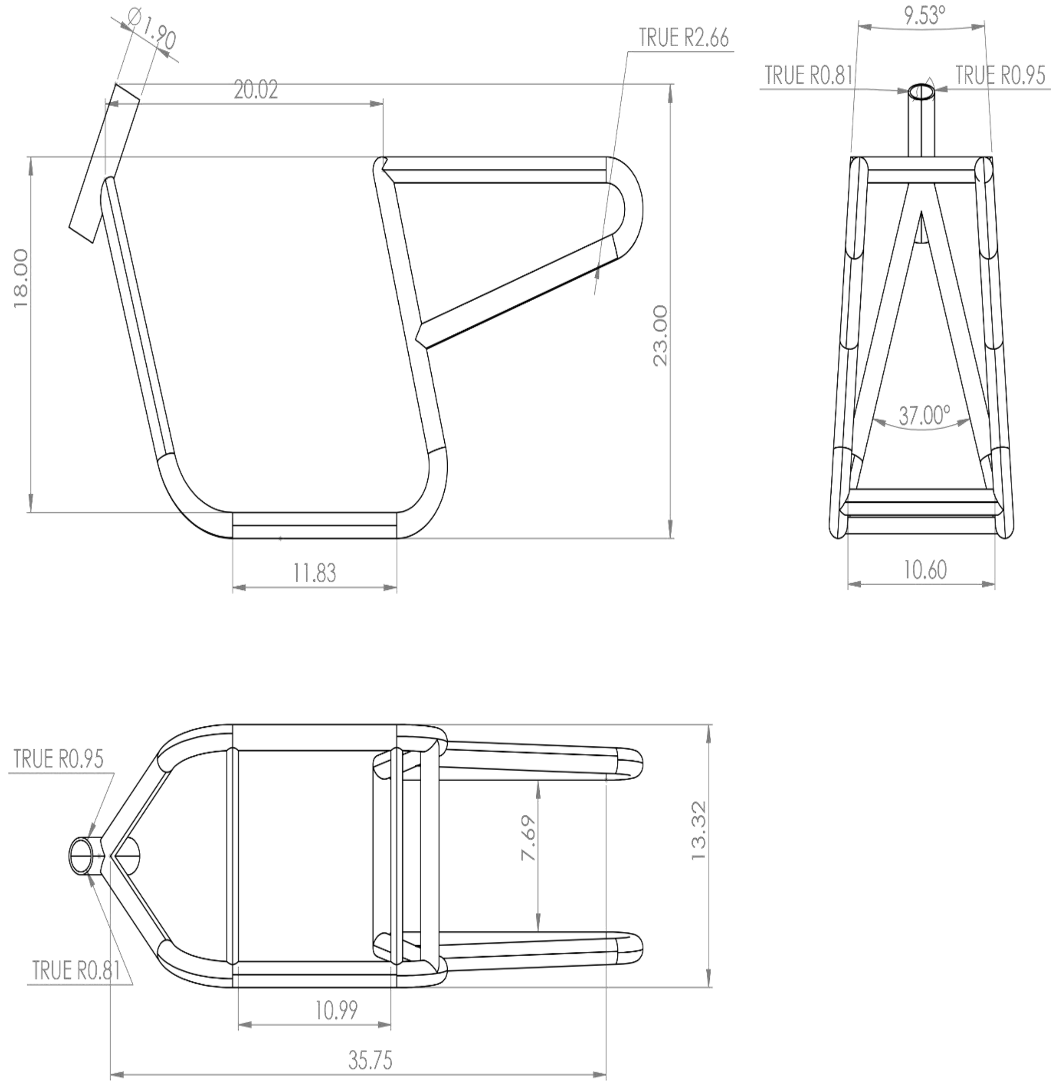

Fig 3. 3 Frame Dimensions

Dimensions of frame’s every component

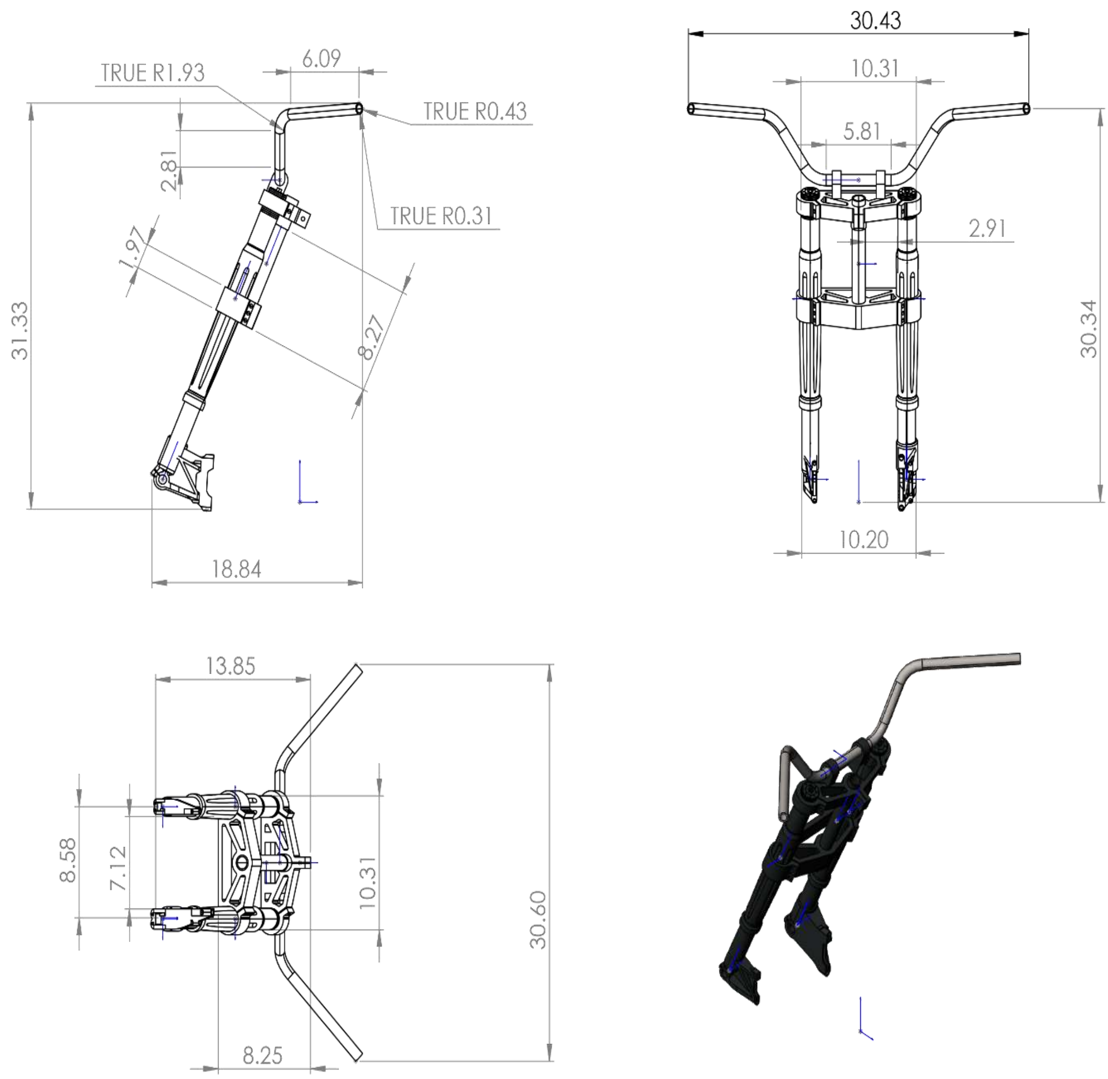

Fig 3. 4 Handle and Front shocks Dimensions

Dimensions of Handle and front shock’s every component

3.2 Designing

3.2.1. Frame Designing:

After reviewing different research papers and different model design by different industries and finding the problem which are still present in the previous designs now, we are moving toward designing of complete assembly in **SolidWorks**.

Fig 3. 5 Frame of E-Scooter

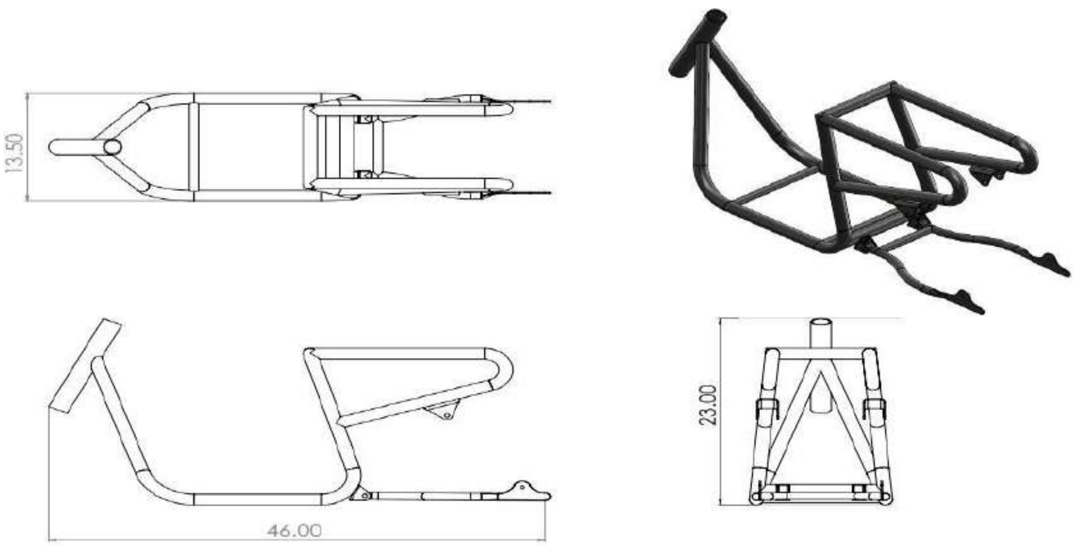

Fig 3. 6 Overall Dimensions and Basic Views

3.2.2. Final Model:

Fig 3. 7 Complete Model of E-Scooter

Fig 3. 8 Structural Component Model

Component Structural Final Model

3.3 Design Calculation of E-Scooter:

In this setup, we have implemented a 250-watt permanent magnet self-generating motor with a speed of 2100rpm. The motor operates using 48-volt power supply drawing 7.5 amps. During the starting phase, the motor can reach a peak current of 15 amps.

P = 2 x 3.14 x
N x T /60 250 =
2 x 3.14 x 2100
x T /60 T = 1.13
N m = 1136 N-
mm

Reduction
in chain
drive R
chain =
66/11 = 6:1

Torque at wheel shaft = T x R chain = 1136 x 6 =
6820 N mm Speed of wheel shaft = 2100 /6 = 350
rpm

Vehicle mass = 55kg
(Approximated) Vehicle
weight = (55 * 9.81) N =
539.55 N

Vehicle speed = 35 km/h = 35*(1000/3600)
= 9.72 m/s (To calculate resistance due to
movement)

3.3.1. Force through gradient (F gradient)

Fh = W sin Φ (slope angle Φ is 2.5)

= Mg sin Φ

= 539.55 x sin 2.5

= 23.72N

3.3.2. Rolling resistance:

Fr = Cr W cosΦ (Cr=0.004 for asphalt road)

= 0.004 × 539.55 × cos2.5

= 2.15 N

3.3.3. Air resistance:

Fd= 0.5 ρ Cd A V2 (Cd value of surface A=0.6 m2 is 0.5)

= 0.5 × (1.2) × 0.5 × 0.6 × 9.72^2 (ρ is air density 1.2 kg/m3)

= 17.1 N

The total force on the vehicle is F = Fh+ Fr + Fd = 42.97 N

Power required for propulsion, P = F*V = 42.97*9.72 = 417.66 watts

3.4 Designing of Bike shaft

3.4.1. BENDING:

Bending stresses are produced at a particular cross section of the shaft due to the force that arises across that specific area, leading to the development of internal or resisting moments, which are subject to maximum loading.

3.4.2. Torsion:

When a shaft is subjected to a couple, or a system of forces with equal magnitude and opposite directions that act along the same line but at different points, it undergoes a phenomenon known as torsion. Torsion is a type of mechanical loading that causes the shaft to twist about its longitudinal axis.

3.4.3. Combined Bending and Torsion:

In actual practice the shaft is subjected to a combination of the above two types of stresses i.e. bending and torsion. The bending stresses may occur due any one of the following reasons:

- Weight of belt
- Pull of belts
- Eccentric Mounting of shafts/gears
- Misalignment of shafts/gears

Contrarily, the occurrence of torsional movement in a shaft arises from either a direct or indirect twisting force applied to it. Consequently, at any specific point along the cross- section of the shaft, it becomes subjected to a combination of both bending and torsional stresses simultaneously. This simultaneous action of bending and torsion gives rise to a complex stress distribution within the shaft, necessitating careful consideration in engineering designs and structural analysis to ensure its mechanical integrity and safe operation.

3.5 (FEA) Analysis

- Using ALGOR to analyses the strain-stress structure design.
- Identify the crucial point.

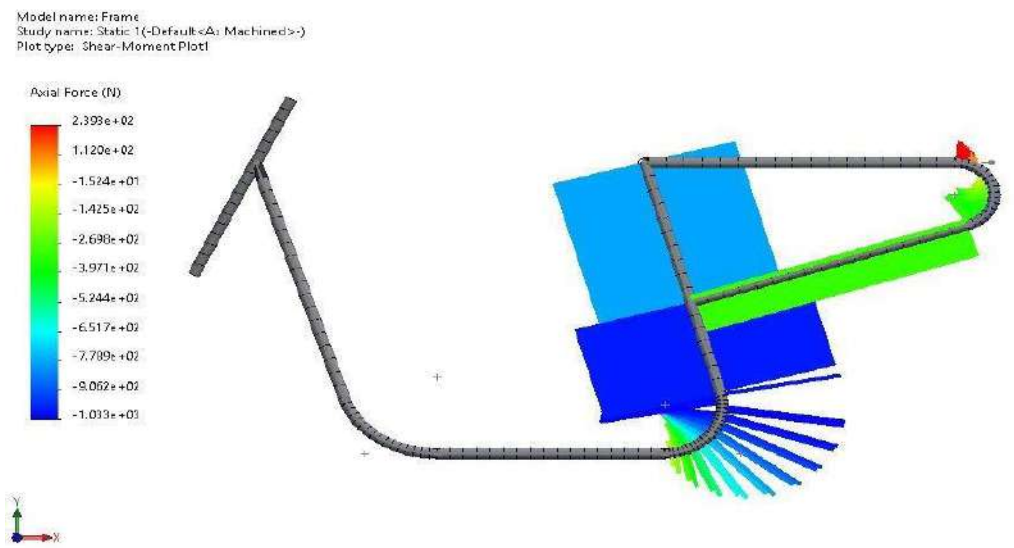

Fig 3. 9 Beam Stress Plot

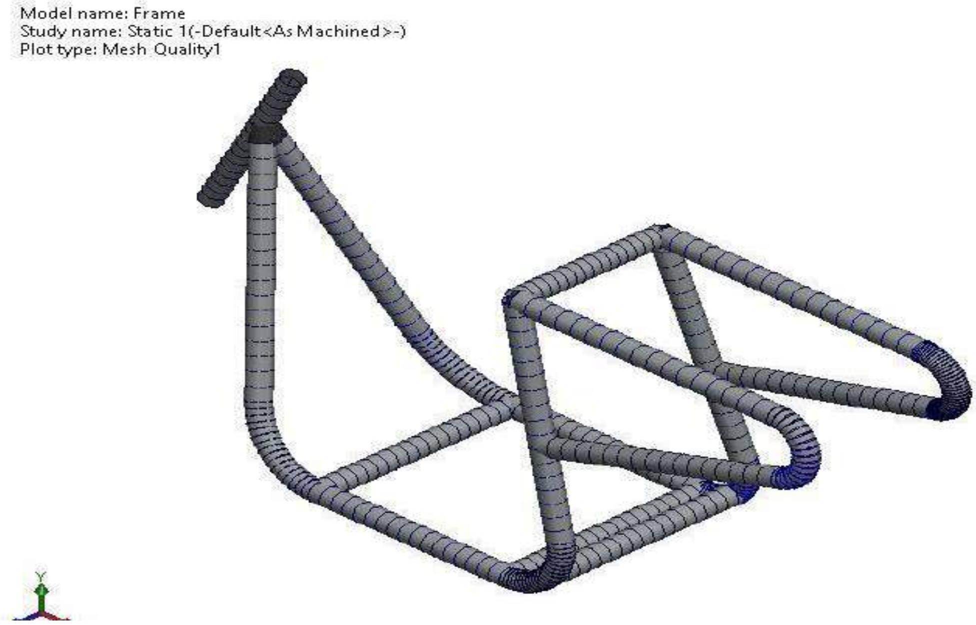

Fig 3. 10 Mesh

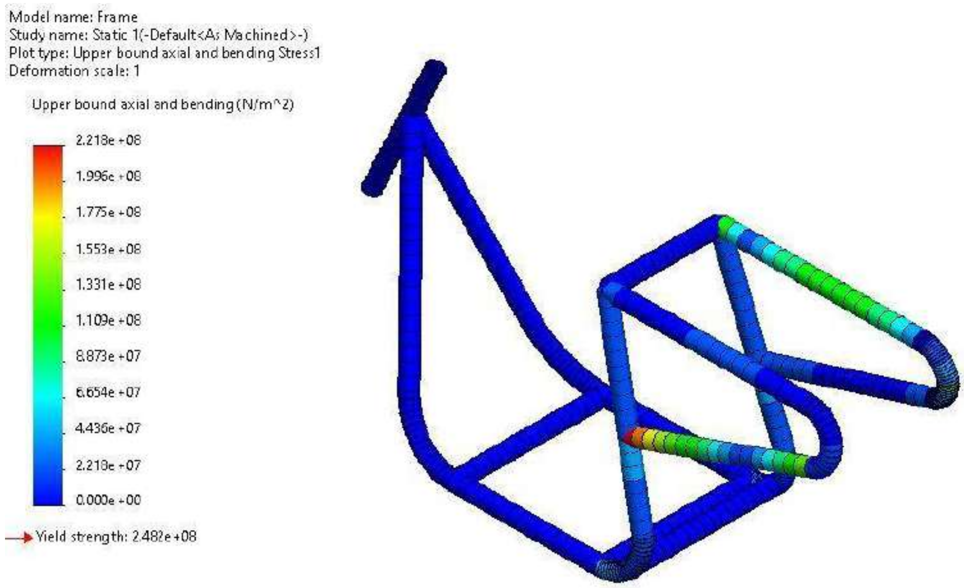

Fig 3. 11 Stress Simulation

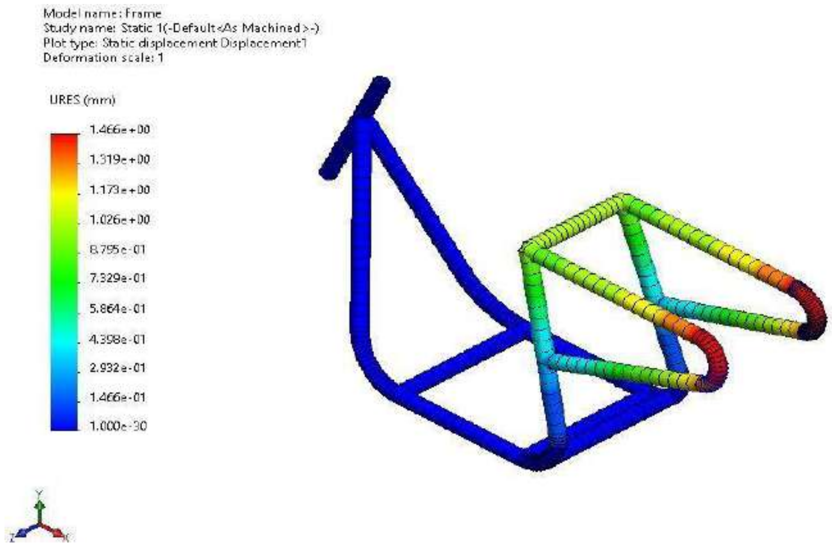

Fig 3. 12 Deformation Plot

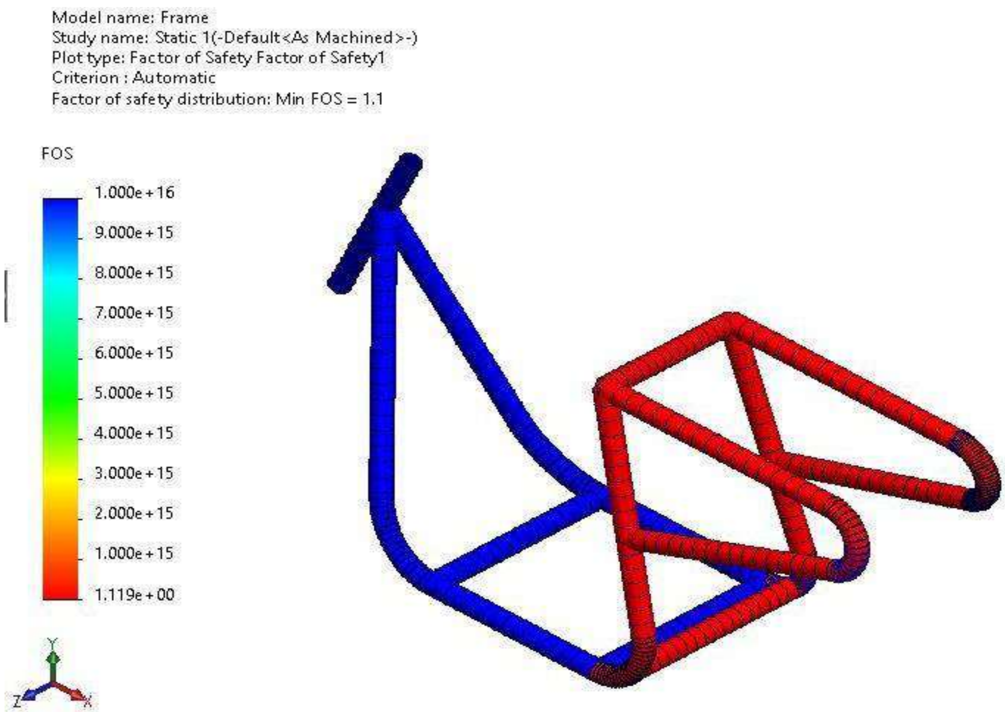

Fig 3. 13 Factor of Safety

3.6 Developing

- After Finalize all the components used in Development
- And Finalize the design and calculations on design
- Performs All the deformation and FEA Analysis
- Assemble every component according to the design.

Fig 3. 14 Methodology

3.7 Design and Development

After complete model and self-reviewing and correcting the design several times we will consult some industrialists and experts to review our design and made corrections accordingly. As cannot afford Research and development after manufacturing due to less available time and budget imitation so we will be performing all the research and development at the designing stage before the Development to save time and cost.

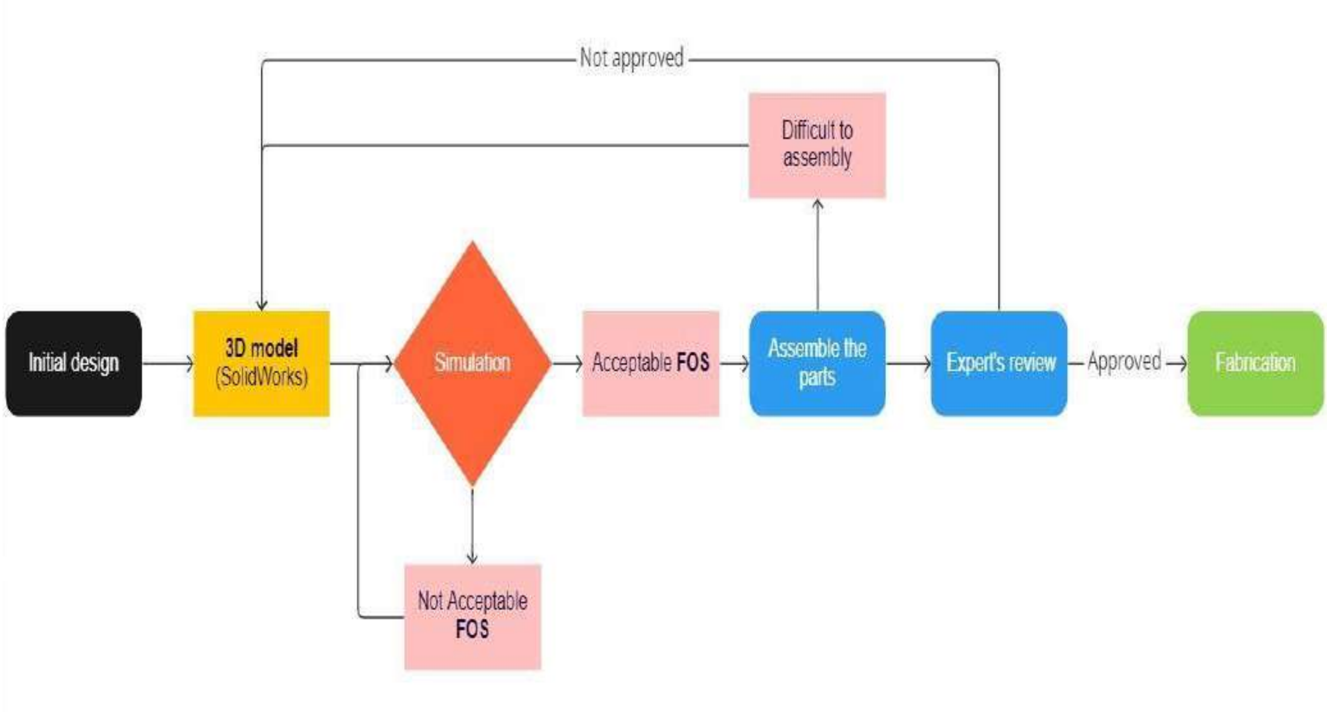

Fig 3. 15 Design and Development

3.8 Development

After considering several design configurations discussed above, we decided to design the bike frame with circular pipe because of its several advantages over square or rectangular pipe.

Here are some benefits of round shape.

- Less welding required
- Easy to deform by bending •
- Aesthetic look

The overall process of Development is explained in below chart completely.

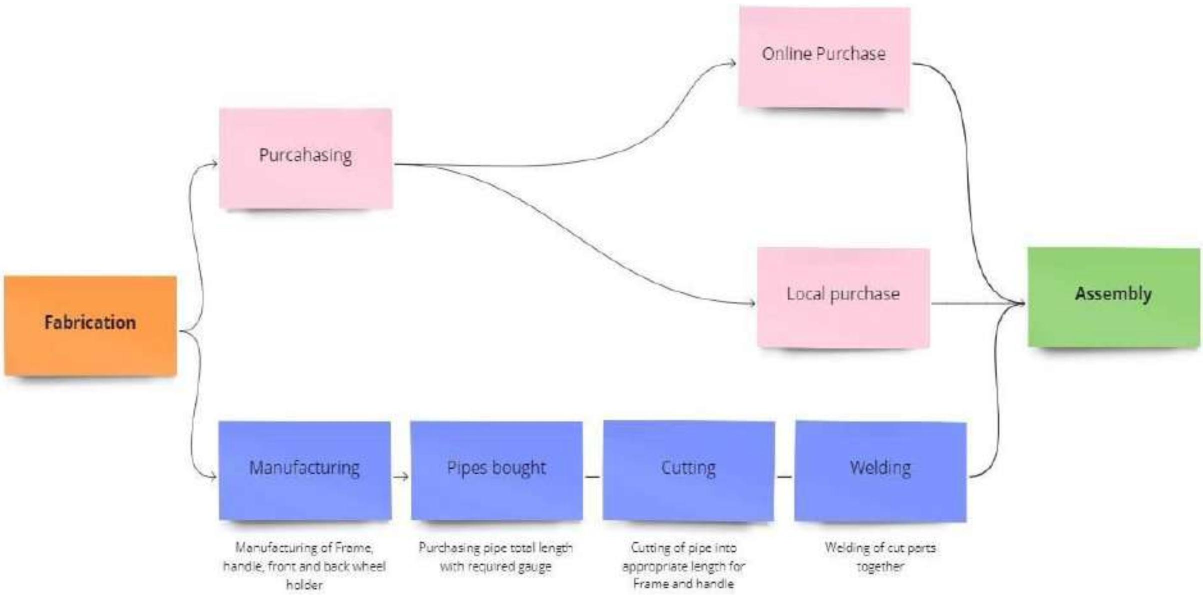

Fig 3. 16 Development Flow Chart

Development of vehicle starts with purchasing of metallic circular pipe, cutting it in appropriate length, bending it and then welding it together. And at the end assemble all the components.

circular pipe -→Cutting ⇨ Bending ⇨ Welding.

Fig 3. 17 Development Flow Chart

3.9 Components Selected for E-Bike:

Three components make up an electric scooter:

1. Battery
2. Controller
3. Motor (Especially a Gear Hub Motor)

- The battery is used to store energy in the form of electricity that the hub motor can utilize.
- The controller draws electricity from the battery and supplies the electrical motor with an appropriate amount and works as a race of the vehicle.
- The battery provides the power for the motor, which then transforms the electrical energy into mechanical energy.
- The motor-connected wheel spins, which causes the vehicle to move. The motor- connected wheel spins, which causes the vehicle to move.

- Battery

3.9.1. Battery:

Battery is the main fuel source for our vehicle that supplies energy for its functioning, the scooter been electric powered and requires the supply of DC current source and for this purpose one of the two types of battery is available for use.

3.9.2. Lithium-ion batteries:

(LIBs), a family of rechargeable batteries with a high energy density that are frequently used in consumer electronics, are what are known as lithium-ion batteries. A LIB uses an intercalated lithium compound as its electrode rather than metallic lithium like a disposable lithium primary battery does. It typically weighs substantially less than other sizes of rechargeable batteries. Electronics for portable use frequently employ LIBs. Lithium ions migrate from the negative electrode to the positive electrode when a LIB discharges. Negative electrode becomes the cathode, and the positive electrode becomes the anode when a LIB is charging because lithium ions travel in the opposite direction.

Fig 3. 18 Li-Ion Battery

3.9.3. Battery Selection:

The table below demonstrates that lithium-ion batteries have a high energy density, efficiency, and energy density in addition to being lightweight and small, all of which contribute to determining the type of battery that is needed, namely a lithium-ion battery. That’s why we would prefer a lithium-ion battery in the Development of our project.

Table 3. 1 Specification of different Battery

SPECIFICATION	**Ni-Cd**	**Ni-MH**	**Li-ion**
Specific Energy (Wh/kg)	45-60	6-120	100-260
Energy Density (Wh/L)	50-150	150-300	250-700
Specific Power (W/kg)	150	260-1000	250-250
Charge/Discharge Efficiency (%)	70-80	65	80-90
Cycle Durability (cycles)	200	200-2000	1200

3.9.4. Specifications for a Selected Battery

The battery with the folowing specifications has been chosen to provide the greatest possible runtime and speed.

Voltage
Rating:
36V
Amp-h
Rating:
14.4A/h

Battery Runtime Voltage, V = 36V, as
Provided 350W is the motor's power.

Battery capacity is 14.4Ah.

Battery current is measured as I = P/V
=350/36 = 9.7A. The typical Li-Ion battery
drain rate is 60%.

(Reference - H.J. Bergveld, Battery management systems design by modeling)

The battery's actual capacity is 0.6 * 14.4 Ah, or 8.64 Ah.

Now, runtime, t = battery current drawn/effective capacity of
battery Duration, t=0.89 hours

With these characteristics, the battery can therefore operate for 0.89 hours under the provided circumstances.

3.9.5. Micro Controller:

An electric vehicle's controller is its brain, and it is essential to the successful implementation of the high-performance car with a perfect balance between top speed, acceleration, and range on a single charge. The controller couples the battery-powered power source to the real motor. It regulates direction and speed while maximizing energy conversion. In general, a controller oversees controlling the torque to speed ratio. Speed is regulated by adjusting armature voltage, whereas torque is managed by adjusting armature current. By chopping source current, it is possible to adjust the voltage. The voltage is turned on and off, and the ratio of on-to-off influences the average voltage. Either the width (duration) of the pulses or the number of constant width "on" pulses per unit time can be adjusted. Power electronics circuits diodes, thyristors, and silicon control rectifiers are used for chopping (SCRs). Typically, controller efficiencies are higher than 90%.

Fig 3. 19 Micro Controller

3.9.6. Motors:

The machinery that transforms electrical energy into mechanical energy and propels the vehicle is known as a motor. The fundamental tenet of a DC motor is that if a current- carrying conductor is positioned inside a magnetic field, that conductor will experience mechanical force. The possibilities that were open to us were two of its kind out of the different options that were offered. Those are.

3.9.7. Motor PMDC:

Permanent magnet DC motors, often known as PMDC motors, are DC motors that use permanent magnets to generate magnetic fields. A permanent magnet DC motor, often known as a PMDC motor, is what powers this battery-operated motor. These motors are made in a straightforward manner. These motors are frequently used in toys as well as starter motors for cars, washers, windscreen wipers, blowers for heaters and air conditioners, and windows that raise and descend. Field control of this sort of DC motor is

not possible since a permanent magnet's magnetic field intensity is fixed and cannot be changed externally. Therefore, permanent magnet Where a motor's field cannot be controlled to regulate speed, a DC motor is employed. Small permanent magnet fractional and sub fractional KW motors are now made.

Fig 3. 20 PMDC Motor

3.9.8. BLDC motor:

Brushless DC electric motors, also referred to as electronically commutated motors or synchronous DC motors, are synchronous motors that are powered by DC electricity through an inverter or switching power supply that creates an AC electric current to drive each phase of the motor through a closed loop controller. The controller controls the motor's speed and torque by sending short bursts of current to the motor winding. A brushless motor system is often built similarly to a permanent magnet synchronous motor (PMSM), although it can also be an induction (asynchronous) motor or a switching reluctance motor. A brushless motor has a high power to weight ratio, high speed, and electronic control over brushed motors.

Fig 3. 21 BLDC Motor

3.9.10. Charger:

An Electric charger is a recharging device i.e. used to charge the battery by providing electrical energy to it which gets stored in the form of chemical energy in the battery cells.

Fig 3. 22 Charger

3.10 Chassis:

The chassis can be chosen from among the numerous varieties based on the needs of the design and the planned usage of the vehicle. basically, four different types of frames obtainable for selection. The following out of the four can be chosen depending on the needed design specification and the necessity. As follows:

3.10.1. Ladder

By joining the solid parts in a manner that resembles a ladder, a ladder frame—a typical form of frame—is mostly used to build the base for vehicles.

3.10.2. Backdown

The body-on-frame design is comparable to this chassis design. In this, a substantial tubular-like structure connects the vehicle's front and rear ends.

3.10.3. Monocoque

A monocoque chassis is one made of metal that is molded from sheets of the substance, using the same technique as other frame components. The unibody form of chassis is comparable to this type.

3.10.4. Space

Even while a space chassis is not a real tubular in the traditional sense, it can nevertheless be referred to as one. The parts are joined by welding to form a sturdy frame with some flexibility. Compared to the ladder type, it is a construction that resembles a truss and offers more strength.

3.11 Bearings:

A bearing is a moving machine part that supports another moving machine part. the shifting. A journal is a type of machine component. While transferring the load, bearings permit relative movement between the contact surfaces of the parts. Power is lost in the process of eliminating frictional resistance. A lubricant may be used to reduce frictional resistance, wear, and to dissipate the heat produced. Mineral oil that has been refined from petroleum is frequently used as lubricant. Bearings were not used in the model because we wanted to keep costs down, although they were an essential part of the prototype.

Fig 3. 23 Bearing Used in E-Scooter

3.12 Steering:

A vehicle that is being driven straight forward can be turned and pointed in a different direction using the steering system. To achieve angular motion is the steering system's main goal. This is accomplished through linkage and steering gear, which change the steering wheel's rotatory motion into the front wheel’s angular motion. There are several alternatives for steering, including tilt steering, straight steering, and using motors. Using the proper steering geometry conditions, or "Ackerman Geometry," one can obtain the conditions for flawless steering.

Fig 3. 24 Steering of E-Bike

3.13 Wheels:

A wheel is a circular, rotatable component that spins around an axle bearing. Among the fundamental machines, the wheel and axle is a crucial element, enabling the smooth movement and transportation of large objects while bearing heavy loads or performing work in various machines. The applications of wheels are diverse, with examples such as ship's wheels, steering wheels, potter's wheels, and flywheels. The ingenious design of a wheel, in conjunction with an axle, significantly reduces friction and facilitates motion by rolling. To set a wheel in motion, it requires the application of external forces or torque to generate a moment around its axis. The outer edge of a wheel typically serves as the supporting structure for the tire. In the context of vehicles like automobiles, the outer circular design of the wheel houses the inner edge of the tire. For instance, in a bicycle wheel, the periphery consists of a robust hoop connected to the outer ends of the spokes, serving as the foundation for the tire and tube. The combination of wheels and axles has revolutionized transportation and countless other applications, making tasks more manageable and efficient through the reduction of friction and effortless rotation.

Fig 3. 25 Front Wheel of E-Bike with Disc

3.14 Working of Electric System of Scooter:

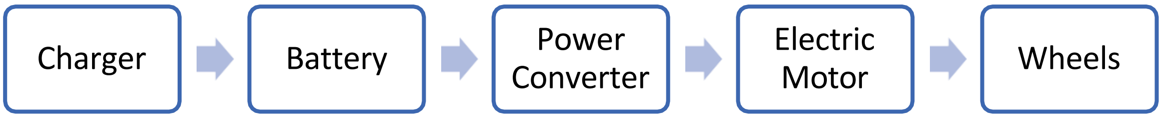

Fig 3. 26 Working of Electrical System

3.15 Throttle:

The throttle is used to boost up the scooter. When the rider presses the throttle, electric powered Signals go from the throttle via wire to the controller, which instructs the battery to launch electric energy to the motor and as a result scooter movement ahead. Throttle is located at the take care of bar. Red: Input, Green: Output, Black: Ground

Fig 3. 27 Throttle used in E-Bike

3.16 Material Selection:

Structural steel is used here to manufacture the chassis. The main reason for using mild steel here is its ability to absorb the impact that occurs during a collision is inexpensive compared to other materials. Excellent strength-to-weight ratio. This means it is stronger and lighter, resulting in better scooter performance. That’s why we would prefer a lithium- ion battery in the Development of our project.

Table 3. 2 Specification of Structural Steel Material

Sr. N0	Material Properties	Value
1	Density	7850 $\frac{kg}{m^3}$
2	Unit Weight	78.5 $\frac{kN}{m^3}$
3	Modulus of Elasticity	21,0000Mpa
4	Shear Modulus	81,000 Mpa
5	Yield Strength	240Mpa
6	Ultimate Strength	420Mpa
7	Possion Ratio in elastic range v	0.30
8	Coefficient of linear thermal Expansion	$12 \times 10^{-6}\ K^{-1}$

Chapter 4

4. Fabrication Process

The fabrication process involved several key steps: sourcing and bending iron pipes to create the frame, joining the handle and integrating existing mounts, disassembling shock absorbers to overcome welding constraints, mounting the front brake, incorporating the hub motor, creating slots for key components, adding handle grips with control buttons, installing a foldable stand, wrapping the frame with sheet metal, grinding and painting for a smooth finish, and finally, wiring the electronic components and insulating the wires. These steps resulted in the completion of the electric bike, ready for use.

4.1 Frame Fabrication:

The frame fabrication process involved purchasing iron pipes of specific gauge and diameter, bending them to desired angles, cutting off excess length, joining the symmetrical sections, and welding them together. By carefully selecting and shaping the pipes, we achieved a well-proportioned and symmetrical frame. The welding process ensured strong and secure connections, resulting in a solid and stable frame structure capable of withstanding operational demands. This step formed the foundation of the electric bike, providing the necessary support and stability for the remaining components.

4.1.1. Purchasing Iron Pipes:

To begin the fabrication of the electric bike's frame body, we sourced iron pipes with a gauge of 16 and a diameter of 2.25 inches from a reliable supplier. These pipes served as the primary material for constructing the frame. It was essential to ensure that the pipes

met the required specifications for strength and durability, so we carefully selected them to match our needs. Additionally, we acquired the necessary quantity of pipes to complete the frame construction.

4.1.2. Bending the Pipes:

Once we had the iron pipes, we proceeded to shape them according to the desired frame design. Using specialized bending tools and techniques, we applied precise measurements and angles to achieve the intended curvature and geometry. It was crucial to maintain consistency in the bending process to create symmetrical sections for both sides of frame that ensured that the frame would have a balanced and visually appealing appearance.

4.1.3. Cutting off Extra Pipe:

After bending the pipes, we carefully trimmed off any excess length to achieve the correct dimensions for the frame. Utilizing appropriate cutting tools, we made clean and accurate cuts to remove the unnecessary portions. Double-checking the measurements before cutting was crucial to prevent any errors that could compromise the frame's integrity. By removing the extra pipe, we ensured that the frame would have a neat and well- proportioned structure.

Fig 4. 1 Cutting of the pipe.

4.1.4. Joining the Symmetric Frame:

To achieve a visually pleasing and well-balanced frame, we had designed symmetry. We replicated the bending process for the left and right halves of the frame, ensuring that the bending angles, lengths, and overall shape were consistent. By carefully matching the shape and dimensions of one side to the other, we designed the symmetrical sections that fit together seamlessly. This attention to symmetry resulted in a frame that not only looked aesthetically pleasing but also provided balanced weight distribution and stability.

Fig 4. 2 With Pipes Final Assembled Frame

4.1.5. Welding the Frame:

Once the symmetrical sections were prepared, the next step involved joining them together through welding. We used appropriate welding technique, that is arc welding, to ensure strong and secure welds. This process involved carefully positioning the sections and applying proper heat control to achieve reliable and durable weld joints. By welding the symmetric parts together, we created a solid and stable frame structure that could withstand the stresses and strains of bike operation.

4.1.6. Adding Supports:

To further reinforce the frame, we incorporated additional support to the base (footrest) and seat portion. This involved welding straight rods or bars in appropriate locations to enhance stability and strength. By carefully positioning and aligning the support elements, we ensured proper weight distribution and rider comfort. These added supports played a vital role in enhancing the overall durability and performance of the frame.

By following these steps, we successfully fabricated the frame body of our electric bike, ensuring it met the necessary strength, symmetry, and stability requirements.

4.2 Handle:

The handle installation involved sourcing a reliable handle, cutting it along with a body patch for welding, utilizing existing mounts for indicators and a headlight, and integrating the front suspension. We carefully selected a suitable handle and incorporated it into our electric bike project. By leveraging the existing mounts, we ensured proper functionality and safety with indicators and a headlight. Integrating the front suspension allowed for the inclusion of disk brakes, enhancing braking performance and rider safety. This step provided a crucial component for steering and control, contributing to the overall functionality and usability of the electric bike.

4.2.1. Sourcing a Reliable Handle:

To proceed with the handle fabrication, we searched for a suitable handle in good condition from a bike in a nearby junkyard. After careful evaluation, we sourced a reliable handle that met our requirements for quality and functionality. This step ensured that we had a sturdy and dependable handle as a crucial component of the electric bike.

4.2.2. Cutting the Handle and Body Patch:

To facilitate the welding process, we cut the handle along with a patch of the body from the donor bike. This allowed us to easily join the handle with our frame body through welding. By including a section of the body, we also ensured compatibility with existing mounts for side indicators and a headlight, simplifying the integration process.

4.2.3. Utilizing Mounts for Indicators and Headlight:

When working with the handle, we discovered that it already had mounts for side indicators and a headlight. We capitalized on this feature and utilized the existing mounts to attach the indicators and headlights to our electric bike's handle. This ensured proper functionality and enhanced safety by providing adequate lighting and indicator options.

4.2.4. Integrating Front Suspension with the Handle:

We encountered a requirement to introduce the braking system, specifically the inclusion of disk brakes on the front tire. To accommodate this, we needed to integrate the front suspension with the handle. By carefully disassembling the handle and suspension, we were able to effectively combine them. This integration allowed for the proper mounting of the disk brakes, ensuring optimal braking performance and rider safety.

By following these steps, we successfully incorporated the handle into our electric bike project. The sourced handle, along with the integration of mounts and suspension, provided the necessary functionality and compatibility for an efficient and reliable handle system.

Fig 4. 3 Frame mounted with front handle and suspension

4.3 Shock Disassembly:

In the Shock Disassembly step, we joined the frame body and handle, tackled the challenge of integrating the braking system, and disassembled components to address welding constraints. By disassembling the handle and suspension, we created space for modifications and access to critical areas.

We removed the hydraulic container, disassembled the shock absorbers further, and extracted the rubber seals, suspension spring, and fasteners.

These steps allowed us to overcome welding challenges and prepare for the successful incorporation of the braking system into our electric bike.

Fig 4. 4 Rear Shock Absorber

4.3.1. Braking System Challenge:

As we moved on to the next step of introducing the braking system, we encountered a challenge. Although we had disk brakes for the front tire, we lacked the mount required to attach the disc brakes to the frame. This necessitated finding a solution to incorporate the braking system effectively.

4.3.2. Disassembling for Welding Constraints:

To address the welding constraints posed by the presence of rubber seals inside the shock absorbers, we had to disassemble various components. Directly welding the Aluminium plate with the Aluminium shock absorber would have subjected the rubber seals to high temperatures, causing them to melt. Therefore, disassembling became necessary to ensure the integrity of the shock absorbers.

4.3.3. Disassembling the Handle and Suspension:

To facilitate the mounting of the required braking system mount, we started by disassembling the handle and suspension. This step allowed us to gain access to the necessary areas for modification and welding. By carefully removing the components, we created the space required for further disassembly and assembly processes.

4.3.4. Removing the Hydraulic Container and Components:

Continuing the disassembly process, we proceeded to remove the shock absorbers' hydraulic container. This involved carefully disassembling the shock absorbers further to access the hydraulic container. Once the hydraulic container was extracted, we took the additional step of removing the rubber seals, suspension spring, and fasteners from the container for further modifications and adjustments.

By undertaking these disassembly steps, we were able to overcome the welding challenges posed by the presence of rubber seals inside the shock absorbers. This allowed us to proceed with the necessary modifications and advancements required to incorporate the braking system effectively into our electric bike.

4.4 Front Brake Mount:

4.4.1. Aluminum Welding of the Mount with Hydraulic Container:

In this step, we focused on the Aluminum welding process to attach the Aluminum mount with the hydraulic container of the shock absorber. This involved carefully positioning the mount in the desired location and securely welding it to the Aluminum hydraulic container. The welding process ensured a strong and reliable connection between the two components.

4.4.2. Positioning and Marking for Precision:

Before proceeding with the welding, we took the time to specify the exact position where the mount needed to fit. We placed the brakes, tire, mount, and disc in their intended positions and carefully marked the areas for welding. Achieving precision required multiple attempts and adjustments to ensure the accurate alignment of the components.

4.4.3. Aluminum Gas Welding and Heat Treatment:

The next step involved performing Aluminum gas welding to join the mount and hydraulic container. This welding technique allowed us to create a durable and secure bond between the Aluminum components. After completing the welding process, we immediately subjected the part to a heat treatment by dipping it in water. This heat treatment helped to temper the metal and enhance its strength and structural integrity.

4.4.4. Assembling the Hydraulic Container and Shock Absorber:

Following the successful welding of the mount, we proceeded to reassemble the hydraulic container with the shock absorber. This involved carefully aligning and connecting the various components to ensure proper functionality and stability. Once the hydraulic container was securely attached, we then proceeded to assemble the shock absorber with the front handle, ensuring all parts were properly integrated.

By following these steps, we were able to effectively fabricate and integrate the front brake mount into our electric bike. The precise positioning, welding, and assembly ensured the proper functioning and reliability of the braking system, contributing to the overall performance and safety of the bike.

4.5 Modifications:

Integrated hub motor with frame, created slots for key switch and horn, mounted handle grips with control buttons, and added a foldable stand. These modifications improved power delivery, enhanced accessibility, improved grip and control, and provided stability and convenience during parking.

Overall, these enhancements enhanced the functionality and user experience of the electric bike.

4.5.1. Assembly of the Hub Motor with the Frame:

In this step, we focused on integrating the hub motor with the frame of the electric bike. Using welding techniques, we carefully assembled the hub motor onto the designated area of the frame. This ensured proper alignment and secure attachment, allowing the motor to efficiently power the bike.

4.5.2. Creation of Slots for Key Switch and Horn on the Front Handle:

To incorporate essential components, we made appropriate slots on the front handle. These slots were specifically designed to accommodate the key switch and horn. By creating these slots, we provided convenient and accessible locations for these important features, enhancing the functionality and user experience of the electric bike.

Fig 4. 5 Key Switch and Horn Mount

4.5.3. Mounting of Market-Purchased Handle Grips with Control Buttons:

To enhance the grip and control of the handle, we acquired handle grips with integrated control buttons from the market. These handle grips were carefully mounted onto the handlebars, ensuring a comfortable and ergonomic grip for the rider. The control buttons allowed for easy access to essential functions such as acceleration, braking, and other features.

4.5.4. Purchase and Welding of a Foldable Stand to the Frame:

To provide stability and convenience when parking the electric bike, we procured a foldable stand. This stand was then welded securely to the frame. By incorporating a foldable design, the stand could be easily deployed when needed and stowed away during rides, adding practicality and versatility to the bike's overall functionality.

By implementing these modifications, we improved the functionality, usability, and convenience of our electric bike project. The assembly of the hub motor, integration of key components, and addition of a foldable stand contributed to an enhanced riding experience and user satisfaction.

Fig 4. 6 Foldable Stand to Support the frame at standing position.

4.6 Sheetmetal Wrap:

In this step, we acquired a long sheet of steel and welded it onto the entire frame of the bike, improving aesthetics and providing support for feet and seats. We created an opening for the battery compartment and made slots within it to accommodate the microcontroller and battery, ensuring a seamless integration of electrical components.

4.6.1. Acquiring a Long Sheet of Steel:

The initial step involved obtaining a long sheet of steel with a gauge 22 and a width matching the dimensions of our bike. This sheet was sourced from the market, and its dimensions were carefully selected to ensure proper coverage and fit for the frame.

4.6.2. Welding the Sheet onto the Frame:

To enhance both the aesthetics and structural integrity of the bike, we proceeded to weld the sheet of steel onto the entire frame. This process involved skillfully aligning the sheet with the frame and welding it securely in place. The sheet not only enhanced the overall appearance of the bike but also provided additional support for placing feet and seats, improving rider comfort and stability.

Fig 4. 7 Painted Sheetmetal wrap.

4.6.3. Creating an Opening for the Battery Compartment:

Considering the need for a battery compartment, we incorporated an opening in the sheet metal wrap. This opening allowed for the seamless integration of the battery into the frame. By carefully measuring and cutting the sheet, we ensured a proper fit for the battery compartment, enabling easy access and secure placement of the battery.

4.6.4. Making Slots in the Battery Compartment for Components:

To accommodate essential components, such as the microcontroller and battery, we created slots within the battery compartment. These slots were strategically designed to provide secure placements for the microcontroller and battery, ensuring their stability and accessibility. By incorporating these slots, we streamlined the installation process and facilitated proper organization of the electrical components.

Through the sheet metal wrap, we not only improved the visual appeal of the electric bike but also enhanced its functionality and practicality. The welded sheet provided additional support, while the opening and slots within the battery compartment allowed for the

seamless integration of critical components, contributing to the overall performance and usability of the bike.

4.7 Grinding and Painting

In this phase, we focused on achieving a polished and visually appealing look for the electric bike through the processes of grinding and painting. The steps involved were as follows:

4.7.1. Grinding for Smooth Finish:

In this step, we focused on achieving a polished look by meticulously grinding all the welds and joints on the bike. By using grinding tools and techniques, we carefully smoothed out any rough edges and imperfections, ensuring a seamless and professional finish. This process required attention to detail and patience to achieve a uniformly smooth surface.

Fig 4. 8 Grinding Finishing for paint.

4.7.2. Cleaning and Prep:

Before proceeding with the painting phase, thorough cleaning and preparation were essential. We diligently cleaned the entire frame, removing any rust, dirt, or debris that could affect the paint adhesion. Utilizing sandpaper and cleaning solutions, we meticulously eliminated surface contaminants, ensuring an optimal surface for paint application. This step helped us achieve a clean and pristine canvas for our desired paint finish.

4.7.3. Application of Weld Gel Paste:

To further enhance the appearance of the bike, we applied weld gel paste to the curves and welds. This paste served multiple purposes, including filling in any gaps or imperfections in the welded areas, creating a smoother and more refined surface. By carefully applying and blending the gel paste, we achieved a seamless transition between the welded joints and the rest of the frame, resulting in an aesthetically pleasing overall look.

4.7.4. Masking and Spray Painting:

The process of masking and spray painting involved careful planning and precision. We used masking tape and protective covers to isolate specific areas of the bike that required different paint colors or treatments. By masking off sections, we ensured clean paint edges and avoided overspray. Using appropriate spray-painting techniques, we applied multiple coats of paint, allowing for proper drying time between each coat to achieve the desired color depth and consistency.

4.7.5. Sequential Painting of Different Sections:

To ensure a harmonious and cohesive visual appeal, we followed a systematic approach to paint different sections of the bike. By dividing the bike into manageable sections, we applied paint in a sequential manner, maintaining consistency in color application and ensuring an even finish throughout. This method allowed us to focus on each section individually, addressing any specific requirements or intricacies, resulting in a balanced and visually pleasing overall appearance.

Fig 4. 9 Final appearance after assembly and paint

4.7.6. Oil Painting:

As a final touch, we opted for oil paint to coat the main frame of the bike. Oil paint offered a durable and glossy finish, providing an added layer of protection and enhancing the bike's visual appeal. With careful brushwork and attention to detail, we applied the oil paint to achieve a smooth, lustrous finish that complemented the overall design of the electric bike.

Through meticulous grinding and careful painting, we were able to transform the bike's appearance, achieving a smooth finish, removing imperfections, and creating a visually appealing design that complemented the overall project.

4.8 Wiring:

The wiring process involved purchasing a dedicated wiring kit, placing electronic components, joining, and insulating wires, making connections, tapping and painting wires, resulting in a seamlessly integrated electrical system for the bike's optimal performance. The electric bike is now fully equipped and ready to provide an exhilarating ride experience.

4.8.1. Purchasing the Wiring Kit:

To ensure a reliable and efficient electrical system, we acquired a dedicated wiring kit designed specifically for bikes. This kit contained all the necessary wiring components and connectors required for our electric bike project, ensuring compatibility and ease of installation.

4.8.2. Placement of Electronic Components

With the wiring kit in hand, we strategically positioned the electronic components at their appropriate locations on the bike. This included the placement of the battery, microcontroller, motor controller, and other electrical modules, considering factors such as accessibility, weight distribution, and overall functionality.

4.8.3. Joining and Insulating Wires:

To establish the electrical connections, we carefully joined the wires from the wiring kit with the respective components. We ensured proper alignment, correct polarity, and secure connections by using suitable connectors and crimping techniques. Additionally, each connection was meticulously insulated to prevent short circuits and ensure electrical safety.

4.8.4. Wiring Connections with Electronic Components:

Once the individual wires were joined and insulated, we proceeded to make the necessary connections between the wiring and the electronic components. This involved identifying the correct terminals and pins on the components and establishing reliable electrical pathways. We double-checked each connection to guarantee proper functionality and adherence to the electrical system's requirements.

4.8.5. Tapping and Painting of Wires:

To integrate the wiring seamlessly with the bike's frame, we tapped the wires along the frame body. This process involved carefully securing the wires in place using suitable clips or adhesive tapes while ensuring they were neatly arranged and concealed. Additionally, we painted the tapped wires to match the color and finish of the bike's frame, creating a clean and cohesive appearance.

With the completion of the wiring process, all electrical components were properly connected and integrated into the bike. The comprehensive wiring system allowed for the efficient flow of electrical power, enabling the bike to function smoothly and reliably. At this stage, the electric bike was ready to hit the road and deliver an electrifying ride experience.

Chapter 5

5. Results and Discussion

5.1 Results and Discussion of FEA Analysis with Different Mesh Size:

After performing static structural analysis in ANSYS at various mesh sizes (10mm, 9mm, 8mm, and 7mm), it was observed that the solution was becoming increasingly independent of mesh size as the element size decreased. However, it was found that the solution became sufficiently mesh-independent at an element size of 8mm.

This means that further refinement of the mesh beyond 8mm does not significantly improve the accuracy of the solution. Therefore, an 8mm mesh size can be considered as an appropriate balance between computational efficiency and accuracy for the given problem.

It is important to note that achieving mesh independence is crucial in finite element analysis because it ensures that the results obtained are not significantly affected by the mesh size, and thus, can be considered reliable and accurate.

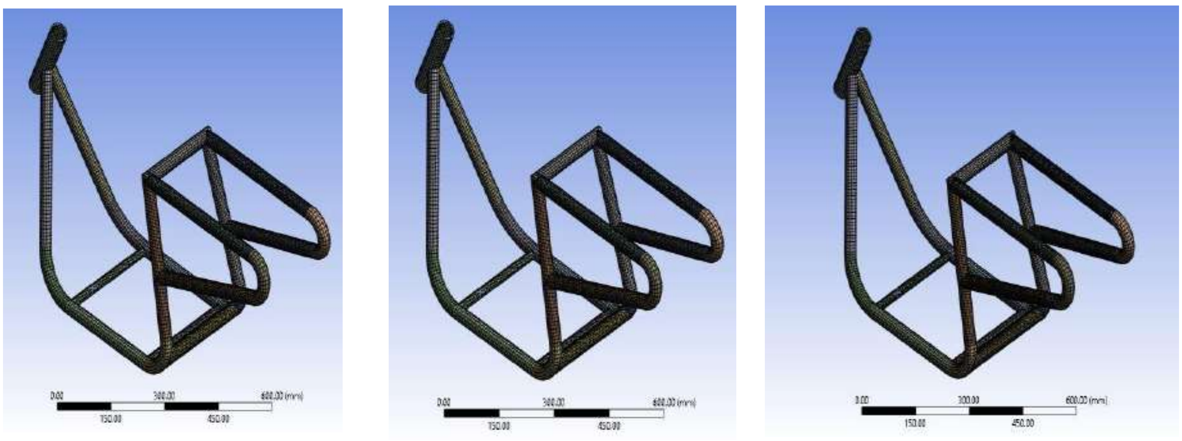

Fig 5. 1 Structural Analysis with Mesh Size 10mm

Upon conducting a static structural analysis with a 10mm element size mesh in ANSYS, the resulting deformation was found to be 5.28mm under a load of 90kg. The Equivalent Elastic Strain was calculated to be 5.6e-3, while the Equivalent Stress was 95.4MPa.

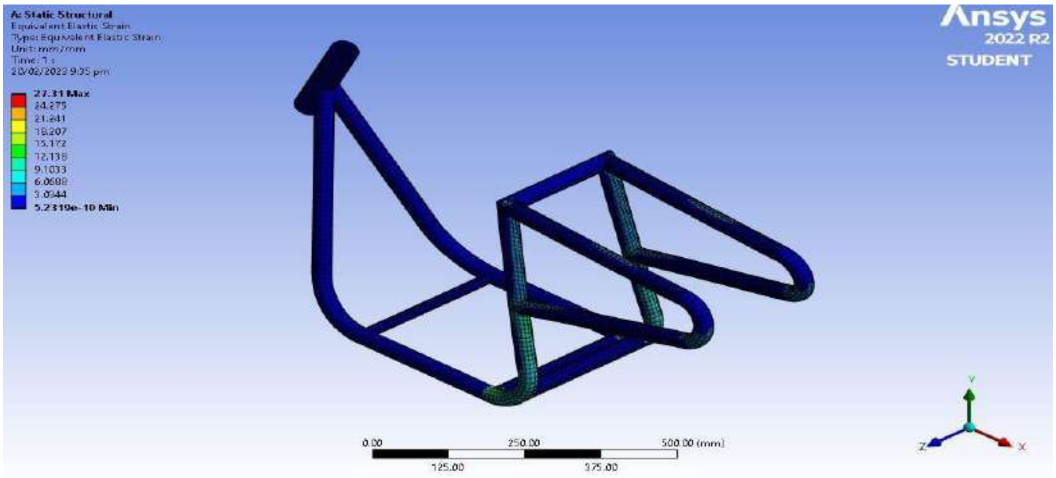

Fig 5. 2 Equivalent Elastic Strain

To ensure that the design meets the required safety standards, the Factor of Safety (FOS) was also calculated. Based on the results, the FOS for this design was found to be 4.569, indicating that the design is safe and has a reasonable margin of safety against failure.

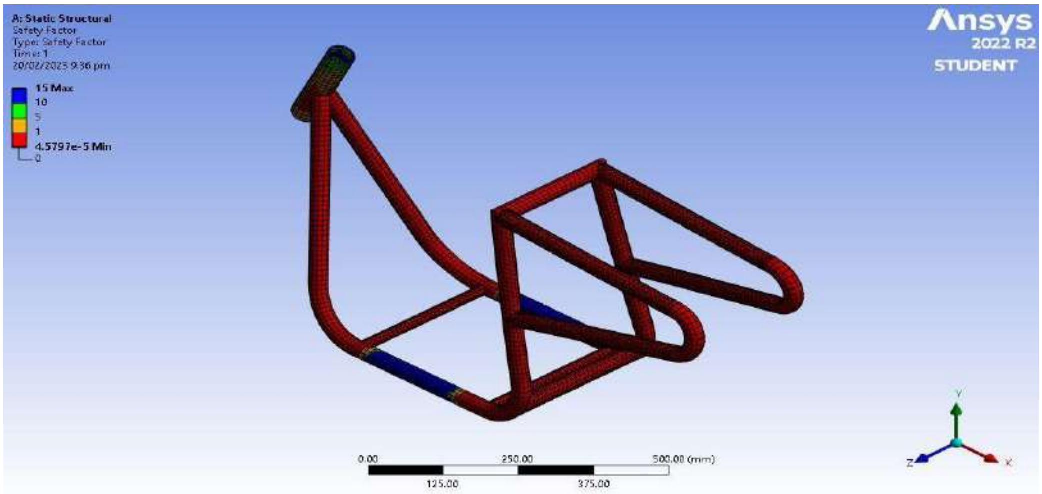

Fig 5. 3 FOS with mesh size 10mm

It is important to note that these results are subject to mesh dependency and may not accurately represent the true behavior of the structure. Therefore, further analysis with refined mesh sizes may be necessary to achieve mesh independence and ensure the accuracy of the results.

Details of "Fatigue Tool"	
Domain	
Domain Type	Time
Materials	
Fatigue Strength Factor (Kf)	1.
Loading	
Type	Fully Reversed
Scale Factor	1.
Definition	
Display Time	End Time
Options	
Analysis Type	Stress Life
Mean Stress Theory	Mean Stress Curves
Stress Component	Max Shear
Life Units	
Units Name	cycles
1 cycle is equal to	1. cycles

Fig 5. 4 Details of fatigue Load

5.2.1 Stress Strain Graph

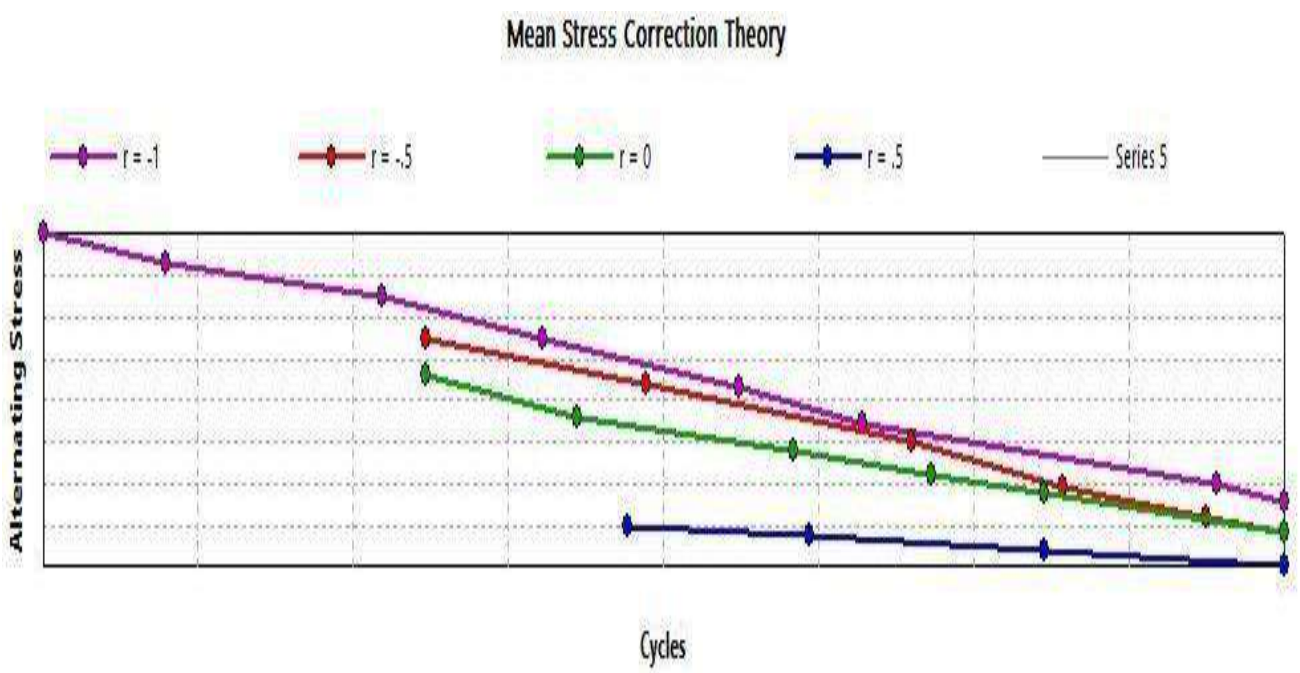

Fig 5. 5 Stress Strain Graph of Scooter Frame

5.2 With 8mm size:

After refining the mesh size to 8mm and performing a static structural analysis in ANSYS, the resulting deformation was found to be 5.32mm under a load of 90kg. The Equivalent Elastic Strain was calculated to be 5.8e-3, while the Equivalent Stress was 96.5MPa.

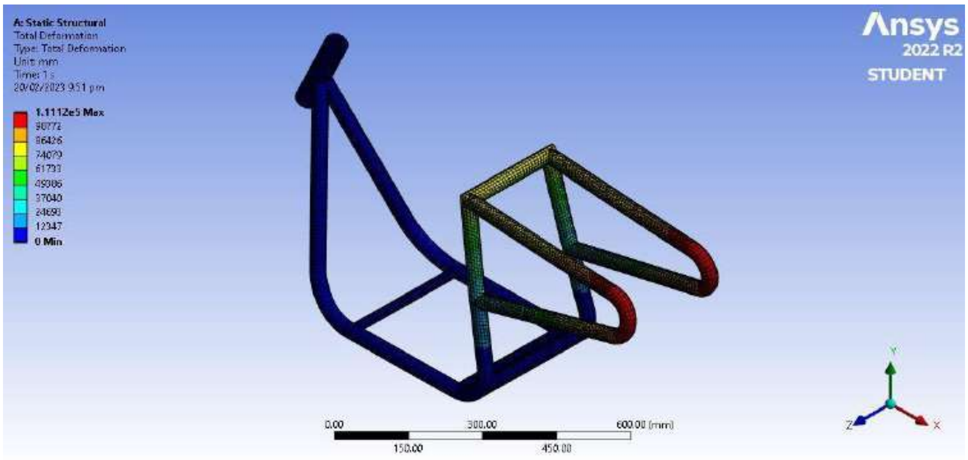

Fig 5. 6 Static Structural Analysis with 8mm

To ensure that the design meets the required safety standards, the Factor of Safety (FOS) was also calculated. Based on the results, the FOS for this design was found to be 4.4, indicating that the design is safe and has a reasonable margin of safety against failure.

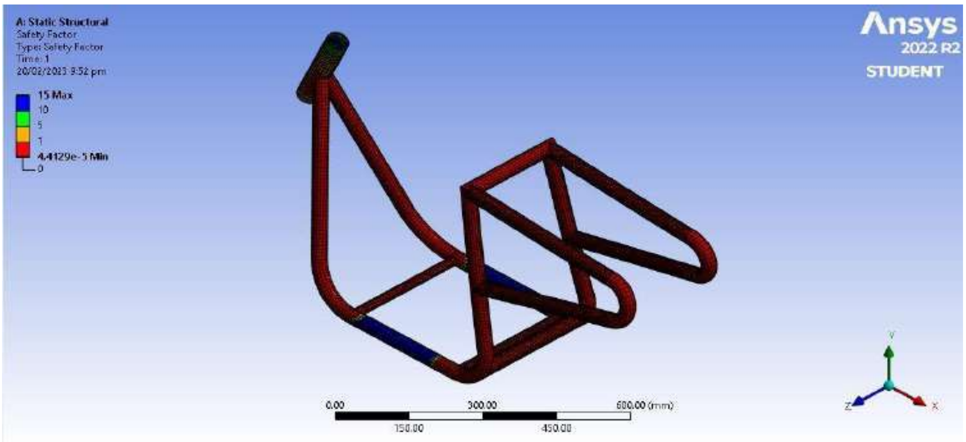

Fig 5. 7 FOS with mesh size 8mm

It is important to note that achieving mesh independence is crucial in finite element analysis because it ensures that the results obtained are not significantly affected by the mesh size, and thus, can be considered reliable and accurate. In this analysis, it was found that further mesh refinement beyond 8mm does not significantly improve the accuracy of the results, indicating that 8mm is an appropriate mesh size for this problem.

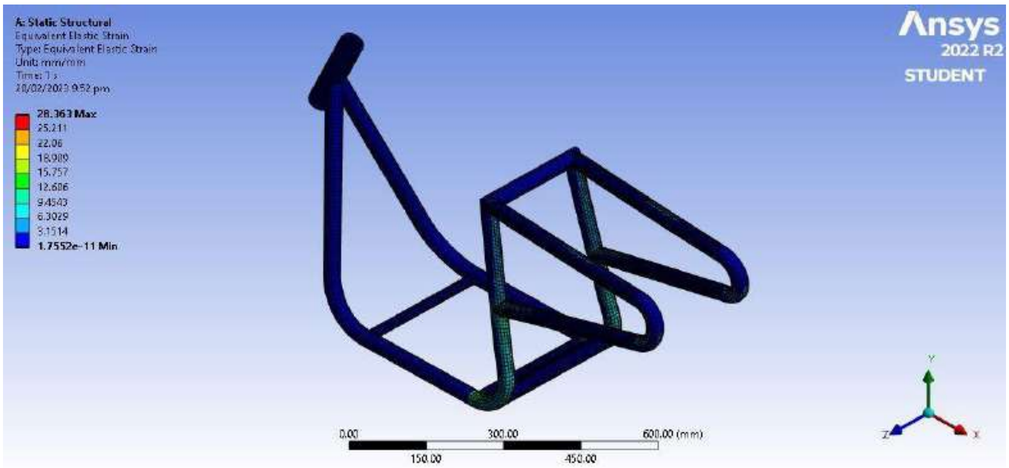

Fig 5. 8 Equivalent Elastic Stress Strain Analysis with mesh size 8mm

The Mean Stress Theory is a commonly used approach for predicting the failure of ductile materials under multiaxial loading conditions. The theory predicts that the material will fail when the maximum principal stress reaches a critical value that depends on the mean stress.

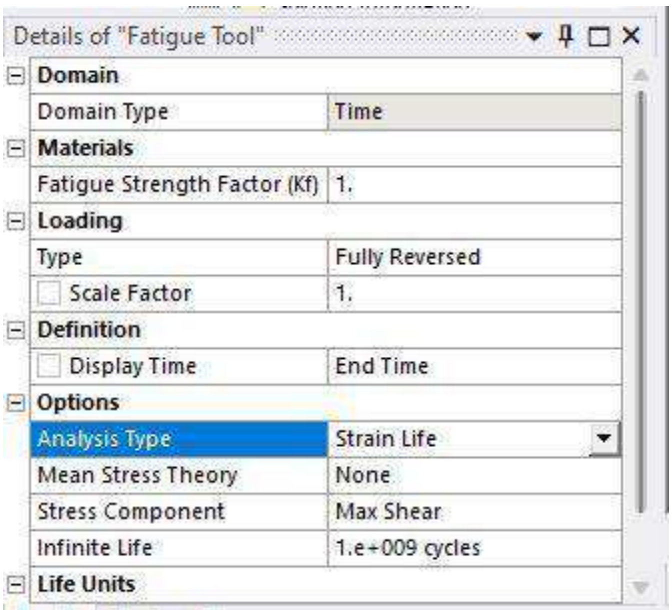

Fig 5. 9 Details of Fatigue Load

5.2.1 Stress Strain Graph Generated with 8mm mesh size:

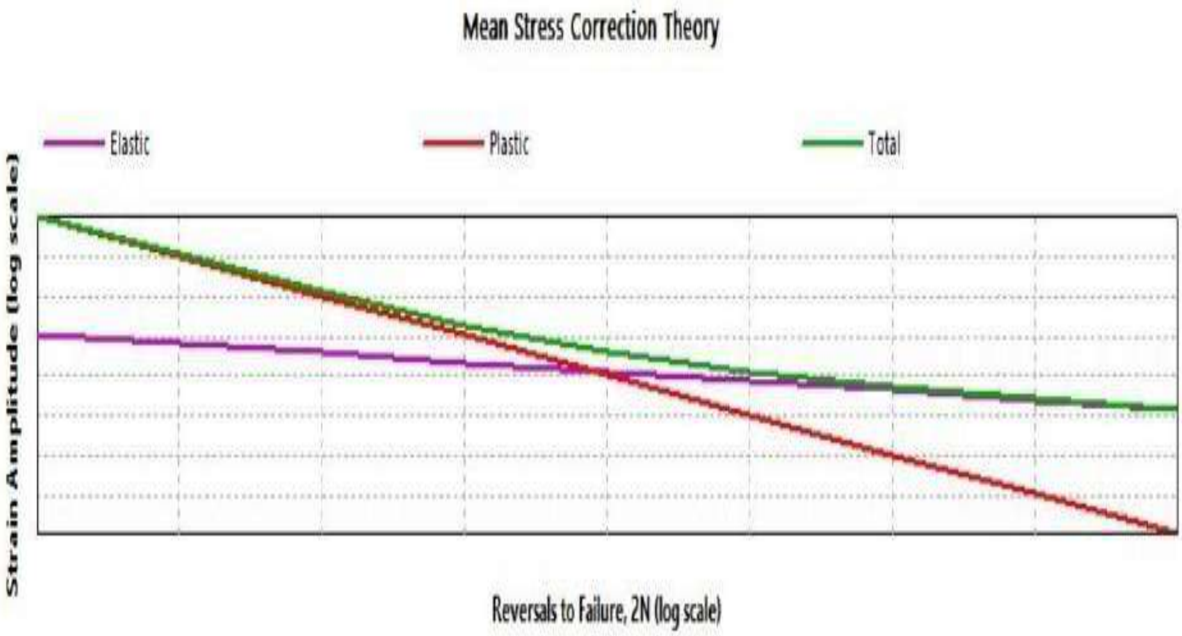

Fig 5. 10 Stress Strain Graph with 8mm Mesh Size

To better visualize this concept, we can plot the maximum principal stress (S1) against the mean stress (Sm) using a 2D graph. The graph will typically take the form of an ellipse, with the major axis representing the failure criteria for pure axial loading (Sm=0) and the minor axis representing the failure criteria for pure shear loading (S1=−S2). The center of the ellipse represents the failure criteria for hydrostatic stress (Sm=(S1+S2+S3)/3). The Mean Stress Theory is a commonly used approach for predicting the failure of ductile materials under multiaxial loading conditions.

Another useful graph for visualizing the Mean Stress Theory is the Goodman diagram, which plots the maximum stress amplitude (Sa) against the mean stress (Sm). The diagram typically includes a line representing the material's endurance limit under fully reversed cyclic loading conditions, as well as lines representing the material's ultimate strength under purely tensile or purely compressive loading conditions.

5.2.2 Graph Generated

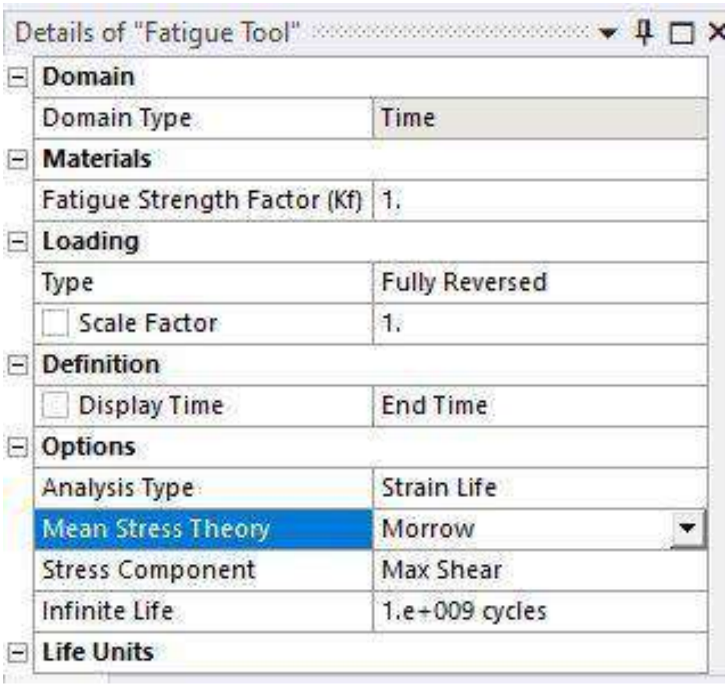

Fig 5. 11 Details of Fatigue Load

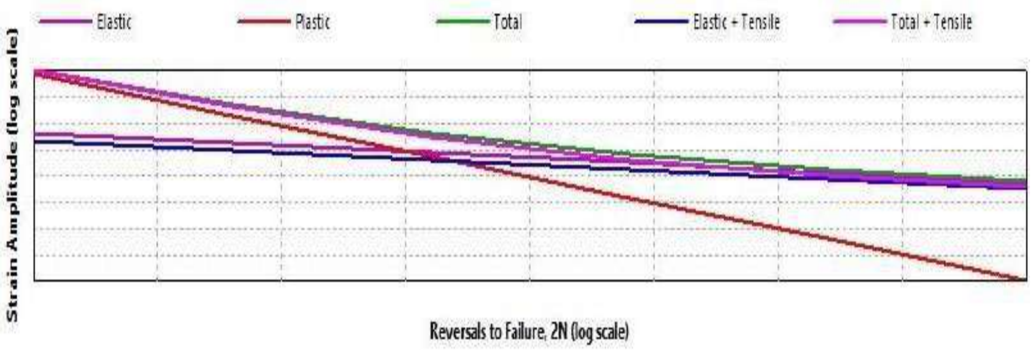

Fig 5. 12 Stress Strain Graph Generated with 7mm Mesh Size

By analyzing these graphs, we can gain insight into the failure mechanisms of the material under different loading conditions and predict the point of failure based on the maximum and mean stress levels experienced by the material. These graphs are invaluable tools for engineers designing components and structures subjected to complex loading conditions.

Table 5. 1 FEA Results

Sr. No.	**Element size**	**Max Deformation**	**Equivalent Stress (MPa)**	**Equivalent Elastic Strain (mm/mm)**	**FOS**
1	10mm	8mm	5.6609	27	4.8
2	8mm	8.2	5.609	27.3	4.6
3	7mm	8.24mm	5.61	27.37	4.4

Chapter 6

6. Conclusion & Recommendation

6.1 Conclusion:

The E-Scooter project is a significant initiative aimed at advancing eco-friendly transportation solutions, replacing traditional petrol engines with greener alternatives. This project plays a crucial role in promoting sustainability, reducing pollution, and contributing to a cleaner environment. Through the use of ANSYS analysis, employing an 8mm mesh size, we ensure both efficiency and accuracy in validating the safety and reliability of the e-bike frame. The static structural analysis further confirms that the e-bikes meet essential safety standards, providing a reasonable margin of safety (Factor of Safety or FOS ranging from 4.4 to 4.8) against potential failure. By implementing a gear-hub-motor and lithium- ion battery, we achieve improved power efficiency, reduced fabrication components like the chain and sprocket mechanism, and ultimately create cost-effective and eco-friendly E- bikes. This pioneering approach has the potential to revolutionize urban mobility and significantly benefit the environment. Throughout this challenging project, we have gained valuable knowledge and expertise in project planning, procurement, assembling, and machining, which has further enriched our capabilities in engineering field.

6.2 Future Recommendations

Enhance Power Efficiency: Continuously work on optimizing the powertrain system to improve energy conversion and reduce power losses. This can be achieved using more efficient motors, advanced motor control algorithms, and lightweight components.

Integrate Smart Connectivity Features: Incorporate smart technology into e-bike design, enabling connectivity with smartphones and other devices. This could include features such as GPS navigation, ride tracking, theft prevention mechanisms, and integration with smart city systems.

Focus on Safety and Ergonomics: Continuously prioritizing safety in e-bike design involves implementing advanced braking systems, improving suspension for better stability, and enhancing rider visibility through integrated lighting systems.

By implementing these recommendations, the design and fabrication of e-bikes can be further enhanced, offering improved range, efficiency, safety and contribute to the widespread adoption of e-bikes as a viable and eco-friendly mode of transportation.

References

[1] A. S. T. A. Sharma, "Design and Fabrication of Electric Scooter," Mechanical Project, Ghaziabad, 125-126, 2018.

[2] Manmohan Guota Nishant Halder, "Design AndFabrication of Low Cost Electric Scooter," International Journal of Multidisciplanary Research and Publication(IJMRAP), vol. 1, pp. 12-14, 2019.

[3] "Design And Fabrication of mini Hybrid Electric Scooter," ICMMEE, vol. 1, pp. 22-24, 2021.

[4] "Design And Development of Electric Scooter," International Journal of Academic Multidisciplanary Research (IJAMR), vol. 5, no. 8, pp. 63-69, 2021.

[5] W.G.S.C.S.&.S.X.Sun, "Impact of Road Conditions on Electric Scooter Safety," A Case Study of China Sustainbility, vol. 11, p. 6215, 2021.

[6] S. M. P. &. A. Lukic, "Energy autonomous solar/battery auto rickshaw," Journal of Asian Electric, pp. 1135-1143, 2008.

[7] J. S. a. K. J. J. Doe, " IEEE Transactions on Energy Conversion," Solid-State
Electrolyte Battery Technology for Electric Scooters, vol. vol. 33, pp. 1256-126, 2018.

[8] Y. a. M.J.Kim, "Travelling Performance Test of a small Electric Vechicle equipped the Gradient Response," J. of KSMT, vol. 17, pp. 1116-1120, 2015.

[9] W. Kwon, "Proceeding of KSPSE," Development of a Portable and Foldable Electric Scooter, vol. 7, pp. 145-147, 2017.

[10] Y. K. a. H. Eu, "J.of the KSM," Development of a portable Electric Scooter Mode, vol. 19, pp. 427-432, 2018.

[11] G. Giacobone and G. Mincolelli, "Hman-Centered Design for Automotive Styling Design,," Conceptualizing a Car from QFD to ViP, vol. 7, pp. 59-65, 2020.

[12] T. F. A. K. a. A. S. Q. Sun, "Modal shift implications of e-bike use in the Netherlands," Transp. Res. Part D Transp. Environ, vol. 8, pp. 114-119, 2022.

[13] I. W. a. M.-C. Pan, "Internal Resistance Based Assessment Model for the Degradation of Li-Ion Battery Pack," ASME International Mechanical Engineering Congress and Exposition, American Society of Mechanical Engineers, vol. 84560, pp. 112-114, 2022.

[14] Sheu, K. B., Hsu, T. H., & Hsu, "Y. Y.A novel parallel hybrid motorcycle transmission," n Materials science forum. Trans Tech.

[15] S. H. D. W. F. L. C. &. H. Y. P. Hsu, "Novel integrated management system design of electric," American Control Conference, vol. Proceedings of the 2004.IEEE, 2004, June.

[16] K. D. S. C. Huang, " A new parallel-type hybrid electric-vehicle," Applied Energy, pp. 51-64, 79, 2004.

[17] W. V. &. G. .Yan, " Power flow control for a series hybrid electric vehicle," e IEEE International Symposium on Industrial Electronics, 2005, June.

[18] C. D. Z. D. &. B. T. H. Quinn, "An valuation of state-of-charge limitations and actuation signal," IEEE Transactions on Smart Grid, pp. 483-491, 2012.

[19] S. M. P. &. A. Lukic, "Energy autonomous solar/battery auto rickshaw," Journal of Asian Electric, pp. 1135-1143, 2008.

[20] N. E. W. L. S. S. I. Brand, "Investigation of an Electric Assisted Bicycle and Determination of Performance".

[21] C. Newson and L. Sloman, "The Case for a UK Incentive for E-Bikes," Bicycle Association: London, UK, 2019.

[22] H. Sundfør, A. Fyhri and H. Bjørnarå, "E-bikes—Good for public health?,"

Advances in Transportation and Health, p. 251–266, 2020.

[23] Q. Sun, T. Feng, A. Kemperman and A. Spahn, "Modal shift implications of e-bike use in the Netherlands," Transp. Res. Part D Transp. Environ., 2022.

[24] I. Wulandari and M.-C. Pan, "Internal Resistance Based Assessment Model for the Degradation of Li-Ion Battery Pack.," ASME International Mechanical Engineering Congress and Exposition, American Society of Mechanical Engineers, pp. Volume 84560, p. 008, November 2020.

[25] G. Giacobone and G. Mincolelli, "Human-Centered Design for Automotive Styling
Design," Conceptualizing a Car from QFD to ViP, p. pp. 59–65, 2020.

[26] A. Hasibuan, L. Parinduri, O. Sulaiman, A. Suleman, A. Harahap, M. Hasibuan, F. Rupilele, J. Simarmata, N. Kurniasih and G. Daengs, "Service quality improvement by using the quality function deployment (QFD) method at the government general hospital.," Physics: Conference Series; IOP Publishing: Bristol, UK, pp. Volume1363, p. 012095., 2019.

[27] Y.W. Kwon and H.S. Eu, "Development of a portable Electric Scooter Model," J.of the KSMT,, vol. 19, pp. 427-432, 2017.

[28] Y.W. Kwon et. al 4, "Development of a Portable and Foldable Electric Scooter," Proceeding of KSPSE., vol. 7, pp. 145-146, 2015.

[29] Y. a. M.J.Kim, "Travelling Performance Test of a small Electric Vechicle equipped the Gradient Response CVT," J. of KSMT, vol. 17, pp. 1116-1120, 2015.

[30] A. F. a. H. B. H. Sundfør, "E-bikes—Good for public health," Advances in Transportation and Health, vol. 19, p. 251–266, 2020.

[31] S. M. P. &. A. Lukic, "Energy autonomous solar/battery auto rickshaw," Journal of Asian Electric, pp. 1135-1143, 2018.

[32] W. V. &. G. .Yan, "EEE International Symposium on Industrial Electronics," Power flow control for a series hybrid electric vehicle, vol. 3, pp. 312-313, 2005, June.

[33] C. Newson and L. Sloman, "he Case for a UK Incentive for E-Bike," *Bicycle Association: London, UK,*, vol. 2, pp. 87-89, 2019.

[34] .. D. Z. D. &. B. T. H. Quinn, "IEEE Transactions on Smart Grid," *An evaluation of state-of-charge limitations and actuation signal*, vol. 6, pp. 483-491, 2012.

[35] Q. L. C. Z. H. &. Z. Y. Wang, "A review of lithium-ion battery thermal management systems for electric vehicle applications," *Journal of Energy Storage,*
vol. 30, p. 1001, 2020.

Annexure

Annexure (if any) should be placed at the end of the project report