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Techno-Economic Analysis and Environmental Benefit Study of Conversion of Gasoline Motorcycle to Electric

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A PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF BACHELOR'S IN MECHANICAL ENGINEERING

DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a project report entitled " Techno-Economic Analysis and Environmental Benefit Study of Conversion of Gasoline to Electric Motorcycle" submitted by Arpan Pandit Upadhyay, Rupesh Dahal and Tilak Bhusal in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering.

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ABSTRACT

This research compared the environmental, technological, and fiscal advantages of switching from gas-powered to electric bikes. During the analysis, it is established that purchasing a brand-new gasoline motorbike is more expensive than converting a motorcycle to run on electricity. Additionally, compared to a gasoline-powered motorbike, the yearly fuel cost for an electric motorcycle was considerably cheaper, yielding considerable savings over time. The research took into account the environmental advantages of electronic bikes, which don't emit any emissions directly and can run on renewable energy. The findings demonstrated that converting a motorbike from fuel to electricity provided significant financial and environmental advantages. Less than three years were needed for the conversion to pay for itself, and over a ten-year span, there were sizable total savings. While switching from petroleum to electric bikes may help lessen air pollution, greenhouse gas emissions, and our reliance on fossil fuels. According to the established statistics and data collected from different resources and calculating them, converting existing bikes to electric vehicles is a practical choice for lowering emissions associated with mobility and reaching sustainable development objectives.

Keywords: Electric Vehicle, Green House Gases, Emission, Fuel Transition, Techno-Economic Analysis

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LIST OF ABBREVIATIONS

EVs	Electric Vehicles
GHGs	Green House Gases
PM	Particulate Matter
NEA	Nepal Electricity Authority
NOC	Nepal Oil Corporation
NZE	Net Zero Emission
AEPC	Alternate Energy Promotion Centre
GRI	Global Resources Institute
EVAN	Electric Vehicle Association of Nepal
SAARC	South Asian Association for Regional Cooperation
ICE	Internal Combustion Engine
CAD	Computer Aided Design
TTE	Total Tractive Effort
CG	Center of Gravity
BLDC	Brushless Direct Current
SAE	Society of Automotive Engineers
BEV	Battery Electric Vehicle
PHEV	Plug-in Hybrid Electric Vehicle
HEV	Hybrid Electric Vehicle
BMS	Battery Management System
Ah	Ampere Hour

LIST OF SYMBOLS

μ	Rolling resistance coefficient
θ	Inclination angle
Ω	Electrical resistance
C_d	Coefficient of drag
ρ	Density of air
F_d	Drag force
C_r	Coefficient of rolling resistance
v	Velocity
g	Acceleration due to gravity

1 INTRODUCTION

1.1 Background

Dependency in the fossil fuel has been common thing for the transportation from the mid-18th century. In the mid-19th century, electric powered vehicles have become interesting means to propel the vehicle. With the rising environmental concern and limited availability of the fossil fuel, research and development for the electric vehicles has been started. Electric vehicles and fossil fuel powered vehicles have shared history in the last 150 years but today gasoline vehicles are seen most due to technological limitations for the electric vehicle. The most affecting factor for electric vehicles were the energy storage problem which was pushing back the electric vehicles technology. But in today's scenario, due to advancement in battery technology, electric has become common and more promising to sustainable future.

Regarding the prospects of Nepal's topography and definite reach of roadways, transportation activity has been a key facilitator and driver of economic growth and development. Road transportation is regarded as one of the primary sources of urban air pollution and energy consumption in many of South Asian growing cities (Bajracharya and Bhattarai, 2016). In recent years, researchers, and the general public in many parts of the world have become increasingly concerned about the health and environmental consequences of air pollution and climate change. Because urban transportation is one of the major contributors to urban air pollution, this concern has heightened interest in Electric Vehicles (EVs) and other environmentally friendly alternative modes of transportation.

With growing concerns about climate change and an unreliable fuel market, the world is transitioning to an electric-based transportation system, which requires a country to overhaul major infrastructures, establish highly funded research, change government regulations, and adapt available resources to convert its gasoline-based transportation system to an electric one. Transportation accounts for approximately 63 percent of total imported petroleum in Nepal, with the majority consumed in the Kathmandu valley (Water and Energy Commission Secretariat). With high population density along with an ever-increasing number of vehicles, the growth has been haphazardly urbanized. Kathmandu, the capital city of Nepal according to the Numbeo Pollution Index 2022, Kathmandu with a pollution index of 95.37 is ranked as the second most polluted city in the world (NUMBEO, 2022).

Considering the annual standard set by the Environment Protection Agency of PM 2.5 at 15mg per m3 and PM10 at 50mg per m3, the PM 2.5 and PM 10 levels in Nepal's urban areas far exceed the standard (Environment protection Agency, 2019). Today, air pollution is one of the leading causes of death in Nepal, surpassing the violence and natural disasters (National Planning Commission, Government of Nepal, 2020). Nevertheless, due to its huge hydropower potential Nepal has a huge comparative advantage to replace fossil fuels and move toward clean mobility. This climate-resilient pathway will not only have environmental but economic implications as well.

With an estimated 40,000 MW economically viable hydro capacity in the country, hydropower plays an important role not only in Nepal's economic future but also in its clean energy use (International Hydropower Association, 2017). According to the Nepal Electricity Authority (NEA), there are currently 88 hydropower plants in operation with a total capacity of 967.85MW. Because hydropower development in Nepal has been tremendous in recent years, surplus energy can be used as a huge potential, which will be an added advantage to using electrical vehicles instead of diesel and petrol monitored vehicles.

1.2 Problem Statement

Nepal imports all of its fossil fuel needs because there are no natural fossil fuel reserves in Nepal. Nepal is heavily reliant on India for fossil fuels, so the demand for petroleum products is approximately double the price difference from the international market and accounts for approximately 11% of Nepal's primary energy consumption (NOC, 2018). Because of the country's high energy demand, the country's reliance on petroleum imports is growing. The transportation sec2 tor consumes more than 62 percent of all petroleum products. The price of fossil fuels is increasing very rapidly in recent years. In 2002 November, the price of diesel was 26.50 NRs/L, whereas 20 years later in 2022 June, the price of diesel increased to 165.50 NRs/L (NOC, 2022). While calculating the inflation rate of fossil fuels it is found that the total inflation rate from 2002 to 2022 is 53.11% and the average inflation rate from 2002 to 2022 is 2.15% per year. In other words, the price of diesel increased 524.528% in the period of 20 years. But in the same duration, tariff rates of electricity on energy charge up to 250 units was Rs. 7.30 per unit in 2002 while tariff rates of electricity on energy charge up to 250 units is Rs. 9.50 per unit resulting in only an increase of 30.13% in price (NEA, 2022).

The feasibility study for converting petrol bikes to electric bike is being conducted in context of Nepal, there is a policy implemented by Nepal government for the three years plan of conversion of gasoline vehicles to electric powered vehicles. Those bikes which are at the end of their life cycle are just being sold to junk yard and recycled to manufacture other products and probably new vehicles. Nepal has abundant hydropower resources and switching to electricity in energy access is a better option from the point of economic efficiency, energy efficiency, sustainability, and energy security. Nepal Electricity Authority (NEA) is responsible for developing, operating, and distributing hydropower in Nepal. Currently, there is a demand for 1,444 MW of electricity in the country, and 65% of it is supplied by domestic generation, and the remaining 35% is imported to fulfill the demand (NEA 2019). So the new rule that governs the conversion to electric bikes will reduce the import of new petrol bikes and electric scooter making our country more reliable in own means of transportation.

1.3 Objective

1.3.1 Main Objectives

The main objectives of the project is “To convert the gasoline based bike to an electric bike”.

1.3.2 Specific Objective

- To convert petrol bike to electric bike with the optimization of mountings of electric components accessories
- To do the feasibility study and Techno-Economic analysis of the project in context of Nepal.
- To study the environmental benefits of conversion with analysis of different scenarios of energy consumptions, local emissions and GHG emissions.

2 HISTORY AND POLICIES OF EVs IN NEPAL

The history of Electric Vehicles dates back as early as 1975 in Nepal. Though EVs were first introduced in Nepal in the 1970s when the trolley bus operation was started in Kathmandu with Chinese help, the real growth and diversification of EVs did not take place till 1993. In that year, under the Electric Transportation Program, the Global Resources Institute (GRI), with support from the United States Agency of International Development (USAID) introduced three-wheeler electric tempos in Nepal. There were two main reasons behind that initiative: to improve the deteriorating air quality of the Kathmandu valley (GRI) and to develop EVs as a profitable industry in Nepal. 7

However, the Nepal Trolley Bus Service (NTBS) fell bankrupt in 2001 owing to bad governance, corruption, and political intervention, and the electric bus service was formally discontinued in 2009. (Shrestha S., 2015). Another significant step in the direction of EVs in Nepal occurred in 1993, as a result of a gasoline shortage brought on by India's trade embargo. Seven diesel-powered three-wheelers have been converted to electric vehicles and are now used as public transportation in Kathmandu. Global Research Institute and USAID provided funding for this study (Baral A., 2000). In the Kathmandu valley, another 600 electrically driven Tuk-Tuks replaced diesel-powered three-wheelers in 1996. These Tuk-Tuks were dubbed "Safa Tempo," with "Safa" referring to cleanliness and "tempo" referring to a three-wheeler.

According to the Electric Vehicle Association of Nepal (EVAN), there were roughly 21000 electric vehicles in Nepal in 2017, which is a small amount compared to the millions of internal combustion engine vehicles (Bhatta, 2018). In December 2018, the Government of Nepal's National Planning Commission (NPC) became the first government agency to acquire an electric car, in an effort to encourage government agencies to employ EVs to replace fossil fuel-based vehicles. Mr. Swarnim Wagle, the NPC's vice-chairman at the time, spearheaded this endeavor. At NPC's headquarters, a charging station was also built. However, with a change of administration a few months later, the National Planning Commission's Board of Directors changed, and the effort suffered from a lack of consistency.

Early in 1997, Nepal implemented measures to encourage the usage of electric vehicles. The then-Government of Nepal announced an EV Tax in the National Budget with a 23 percent import duty, which was 211 percent lower than the 234 percent import tax on cars powered by petroleum fuels (Shahi, 2017). Despite the 8 fact that EVs were taxed at 10% in 2002, internal combustion engine advocates were successful in convincing the government to reverse its decision and levy the same 240 percent import tax as other cars (Shahi, 2017). With new internal combustion engine automobiles debuting at the same time, this was a significant step backward in Nepal's electric vehicle future.

It took another 13 years for the Nepalese government to reestablish the 1997 EV tax laws. Nepal's 2016/17 budget imposed a 10% import tax on private EVs, cut the tariff on public EVs to 1%, and eliminated the tax on the import of all types of big EVs to be used for public transportation (Ministry of Finance, GON, 2016). Electric vehicles will be free from taxation, according to the Nepalese government's Transportation Management Department. Taxation on automobiles that operate on gasoline or diesel ranges from NPR 8,000 to NPR 15,000 per year, depending on the engine (Transportation Management Department, 2017).

At 238%, Nepal has one of the world's highest automotive import duties. The industry that deals with the disposal of spent batteries and replication will be free from VAT, and just 1% of customs will be charged. The South Asian Association for Regional Cooperation (SAARC), which comprises India, Bangladesh, Sri Lanka, Pakistan, Bhutan, Maldives, and Afghanistan, has put a 7.5% import duty on private electric vehicles. The import duty on private electric vehicles from the rest of the globe, on the other hand, is fixed at 10%. Large electric cars used for public transportation will be free from excise charge and will only be subject to a 1% customs duty. (Upadhya, 2016).

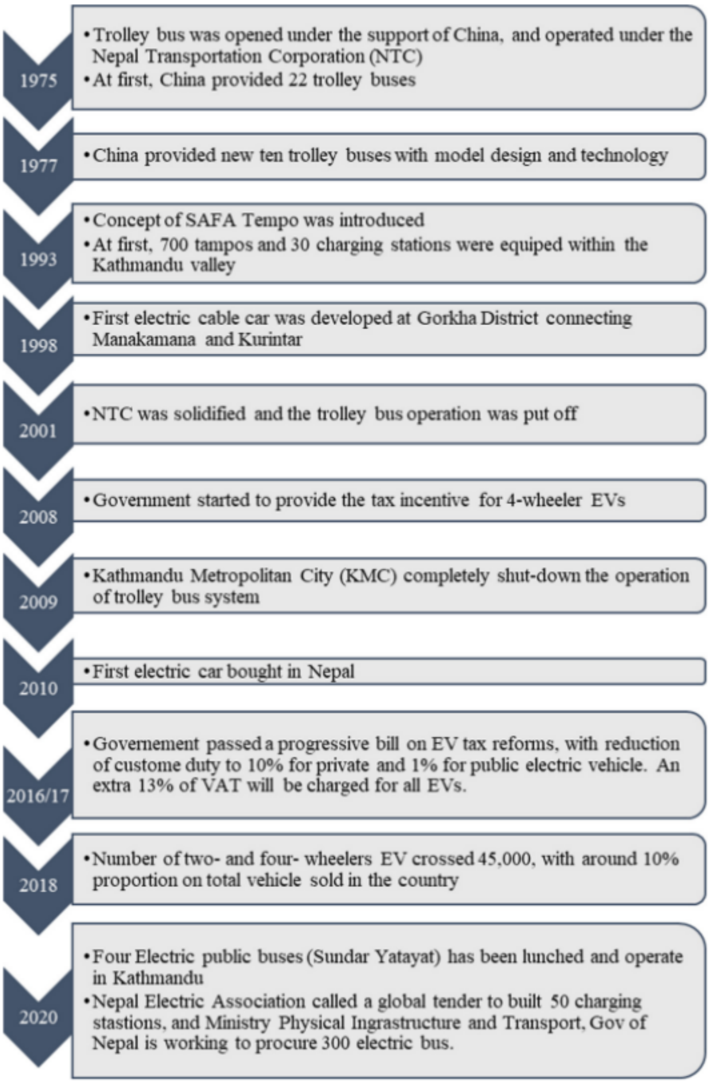

Figure 1: Flowchart of critical events of EVs in Nepal

2.1 Air Pollution Status of Nepal

Nepal is among the top ten nations with the highest outdoor PM2.5 levels in 2019, according to the State of Global Air report 2020. Nepal was ranked second only to India, with an annual average PM2.5 emission of 83.1 micrograms per cubic meter (g/m3). According to the research, which was issued in 2021, over 90% of the world's population had yearly average PM2.5 concentrations that were above the World Health Organization's Air Quality Guideline of 10 g/m3. PM2.5, or particulate matter with a diameter of fewer than 2.5 microns, is one of the most harmful pollutants because it may pass through the nose and neck and into the lungs and even the bloodstream. Since

PM2.5 particles are small, they are also likely to remain suspended in the air for longer, increasing the chances of people inhaling them.

According to the Global Burden of Disease (GBD) research of the Health Effects Institute and the Institute for Health Metrics and Evaluation (IHME), PM2.5 pollution killed 17,900 Nepalis in 2019. Similarly, air pollution was blamed for 42,100 fatalities in Nepal over the same time period. Ischemic heart disease, lung cancer, chronic obstructive pulmonary disease, lower respiratory infections including pneumonia, stroke, type 2 diabetes, and unfavorable birth outcomes are all linked to long-term exposure to PM2.5. Despite multiple national and international assessments indicating poor air quality in Nepal and describing air pollution as a serious public health concern, the study serves as a reminder that Nepalis continue to breathe harmful air.

The World Air Quality Report classified Nepal as the 8th most polluted nation in the world in March, with an annual average PM2.5 of 44.46 g/m^3, down from 54.15 g/m^3 in 2018, when it was still ranked eighth. According to the status of the air report, air pollution surpassed high blood pressure, cigarette use, and poor nutrition as the fourth-largest cause of death globally in 2019, killing 6.67 million people.

2.2 EV Challenges and Opportunities

The Nepalese government is more concerned with the improvement of fundamental requirements than with the acceptance of electric vehicles. EV has not yet realized its expectations as planned, although taking significant initiative in the beginning. In Kathmandu, the development of electric vehicles began with the Trolley bus, and then with the SAFA Tempo. It was one of the most important endeavors in South Asia at the time, but the notion was short-lived, and the activities were quickly abandoned. The SAFA Tempo could not exist in the market because of some technical, operational, and policy issues. Later, various brands started to import and sell the EV in the Nepalese market with modern technologies, and this led to aggressive EV penetration in the market. Until 2018, there were more than 41,000 EVs (including two, three, and four-wheelers) across the country, However, the Nepalese market must do much more to maintain this rapid pace of growth and even move toward a clean transportation mode in the entire nation by a few decades to ensure a better electrical transportation sector. Some of the significant challenges of EVs in Nepal are as follows:

• Cost:

In comparison to industrialized nations, owning a car in Nepal is quite expensive due to a variety of factors such as high taxes, high customs, and high import expenses from other countries, high operation and maintenance costs, and high fuel costs. A middle-class family cannot afford the hefty expenditures of automobile ownership. Because there are no EV manufacturers in the nation and all parts must be imported, operating and maintaining these vehicles is difficult.

• Policy and Finance:

In Nepal, there are no clear and well-defined rules for importing and operating electric vehicles. The government has waived the road tax and given EVs a special discount on customs duties, but confusing laws and hefty levies, which deem it a luxury item, have made it difficult to break into the Nepalese market.

• Power availability:

EV charging takes anything from 6 kW to 22 kW of electrical power at today's EV charging stations. In Nepal, the charging time for these charging stations ranges from 1 hour to 12 hours (approximately). As the number of electric vehicles grows, so will the country's energy demand, causing challenges in the electrical industry. EV charging takes anything from 6 kW to 22 kW of electrical power at today's EV charging stations. In Nepal, the charging time for these charging stations ranges from about 1 hour to 12 hours. As the number of electric vehicles grows, so will national energy consumption, causing challenges in the electrical industry. As a consequence, NEA should implement proper measures and policies to tackle this problem.

• Charging station:

Because of the high expense of technology and installation, only a few charging stations owned by private parties may be found in large cities. In the current situation, the vehicle owners are forced to charge their vehicle with the traditional approach at their home or office with low ratings (i.e., single-phase power supply with 16 A or 32 A current limit). Long-distance EV driving is extremely limited due to the scarcity of charging facilities along the roadway.

• Targeted group:

Due to government and infrastructural problems in Nepal, electric vehicles appear to be practical for metropolitan and urban regions but not for rural and long travels. Imported EVs also offer restricted characteristics, such as conventional designs and poor torque, rpm, and range specs. As a result, buyers are encouraged to pick fossil-fueled automobiles over electric ones.

2.3 ADVANTAGES OF EVs OVER EXISTING VEHICLES

• Energy efficient: Electric vehicles convert about 59-62% of the electrical energy from the grid to power at the wheels- conventional gasoline vehicles only convert about 17-21% of the energy stored in gasoline to power at the wheels.

• Environment friendly: EVs emit no tailpipe pollutants, although the power plant producing the electricity may emit them. Electricity from nuclear, hydro-solar, or wind-powered plants causes no pollutants.

• Performance Benefits: Electric motors provide quiet, smooth operation and stronger acceleration and require less maintenance than IC engines.

• Reduce energy dependence: Electricity can be domestically produced and surplus energy can be used for the conduction of EVs in Nepal. EVs however may face significant battery-related challenges.

2.4 GHGs Emissions from Transportation Sector

Carbon dioxide (CO_2) from fossil fuel combustion is responsible for almost all greenhouse gas (GHG) emissions from transportation sources. In 2022 the transport sector added 12 billion metric tons of greenhouse gases (GHGs) to the atmosphere, including CO_2, N_2O, methane, and black carbon. A typical passenger vehicle emits about 4.6 metric tons of carbon dioxide per year. This number can vary based on a vehicle’s fuel, fuel economy, and the number of miles driven per year. A vehicle that operates exclusively on electricity (an EV) will not emit any tailpipe emissions. A fuel cell vehicle operating on hydrogen will emit only water vapour. Private transport modes such as cars, vans, jeeps, and motorcycles will account for 61% of total CO_2 emissions though they will meet only 41% of total passenger travel demand, while high occupancy public transport modes will account for only 12.7% of CO emissions and meet 37.5% of total passenger travel demand.

3 MODELLING AND DESIGN

3.1 Background

The transportation sector is considered as the greatest contributor in air pollution. One of the great source of GHGs emission is ICE which includes cars, buses, motorcycles, etc. With the increasing number of ICE vehicles, there is no doubt the emissions will increase. This problem can be mitigated by the use of electric vehicles which are quiet and free from pollution.

For the conversion, bikes which have been already on the roads for more than twenty years old are given the priority because they emit the most pollutants and prohibited to run by the government of Nepal. As per the report published by the Department of Transport Management in FY 2015/16, there are a total of 23,39,169 vehicles running in the roads of Nepal and that number is ever increasing thus creating trade deficit and huge consumption of fossil fuels which has to be imported from India.

The main aim of this project is the conversion of used gasoline based motorbike to electric. One of the very basic steps includes the selection of motorbike itself. There are a lot of different bikes from different companies available in the market. Based on our surface study, our team found the Hero Splendor as the appropriate bike for this project because of its lightweight build, cost of conversion and availability in the market. There are many such bikes which are already 20 years old and resting in garages. We visited some of the garages within the valley and found Hero Splendor is the best alternative for the conversion.

Electric conversion is the process of creating electric motorcycle by changing the power source from gasoline to electric (A. Habibie & Sutopo, 2020). This can be done using conversion kit available widely. For this, proper modelling and design has to be done in order to meet the functional requirements for the final product. Most of the parts in ICE motorcycle has to be omitted including the engine, transmission box, fuel injection system and exhaust system. They are replaced by electric motor, battery pack and controller. The bike that is to be converted is Hero Splendor old model which is depicted in the figure below.

Figure 2: Hero Honda Splendor old model

3.2 Methodology

The methodology consists the design of technical parameters which include battery pack design, designing appropriate requirements for electric motor, 3D modelling of the domain in order to incorporate all the system and finally studying the emission reduction and techno-economic analysis concludes the project. All of the above mentioned tasks are separately studied by the group of three members. Till now, battery pack design, design of technical parameters of electric motor, 3D modelling have been completed and techno-economic analysis is in progress.

The detail work of the project is depicted by the flowchart given below which includes all the major activities. Literature review and case studies were given first priority in order to design the EV system which include design of electric motor, CAD of geometry and battery pack design. For this wide varieties of articles were recited to develop appropriate model that could fit most of the variables that would encounter during the design process.

(Achmad Habibie et al., 2021) did study about the electric conversion of ICE motorcycles in aspects such as economic, environmental and social aspects in Indonesia. Similarly, the study published by (Mutyala, 2019) gave us the precise ideas that get involved in design and development of electric motorcycle. As per the previous planning, this project is in halfway for completion.

Similarly, the methodology also includes the post-design requirements that include the procurement of motorcycle itself, electric accessories, motor and cells. After the procurement of necessary materials, the fabrication phase starts where all the components related to ICE are dismantled and replaced with their electric counterparts. On completing fabrication, the project heads towards to data collection phase where we collect data pertaining to carbon emission, performance of electric motorcycle and analyse the reduction in emission of GHGs and techno-economic analysis.

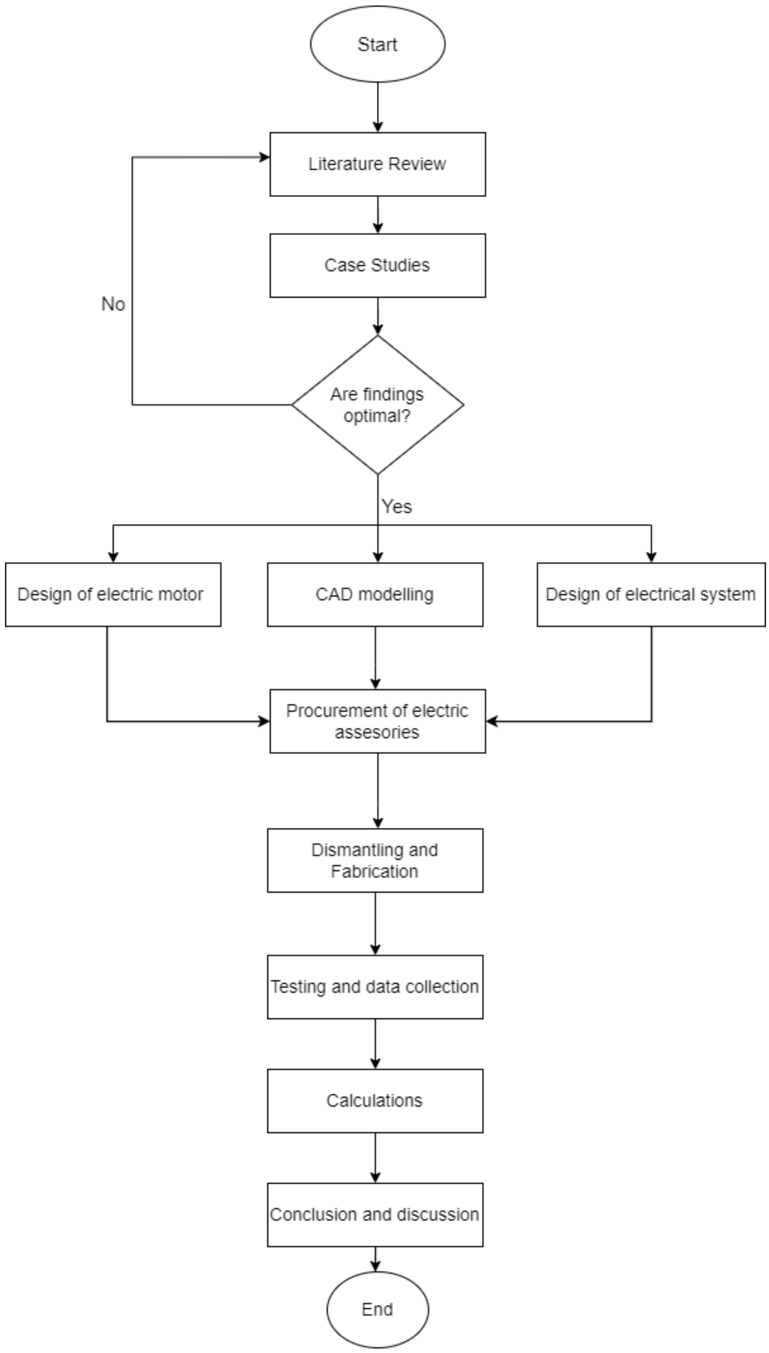

Figure 3: Flowchart showing the methodology

3.3 3D Modelling

The actual replication of physical model is challenging because of the unavailability of proper data. These data are copyrighted and patented so reverse engineering has to be implanted in order to obtain dimensions. This was done using SolidWorks where sketches were developed from the image of the motorcycle. These images were obtained from the official site of manufacturer which is Hero Motorcycles, India. Images were scaled to their original size by measuring the wheelbase, ground clearance and rake angle. After obtaining necessary dimension, the CAD model is built. This paved the way for further planning such as the installation and mounting of motor, battery pack and controller. This process is depicted by the figure below.

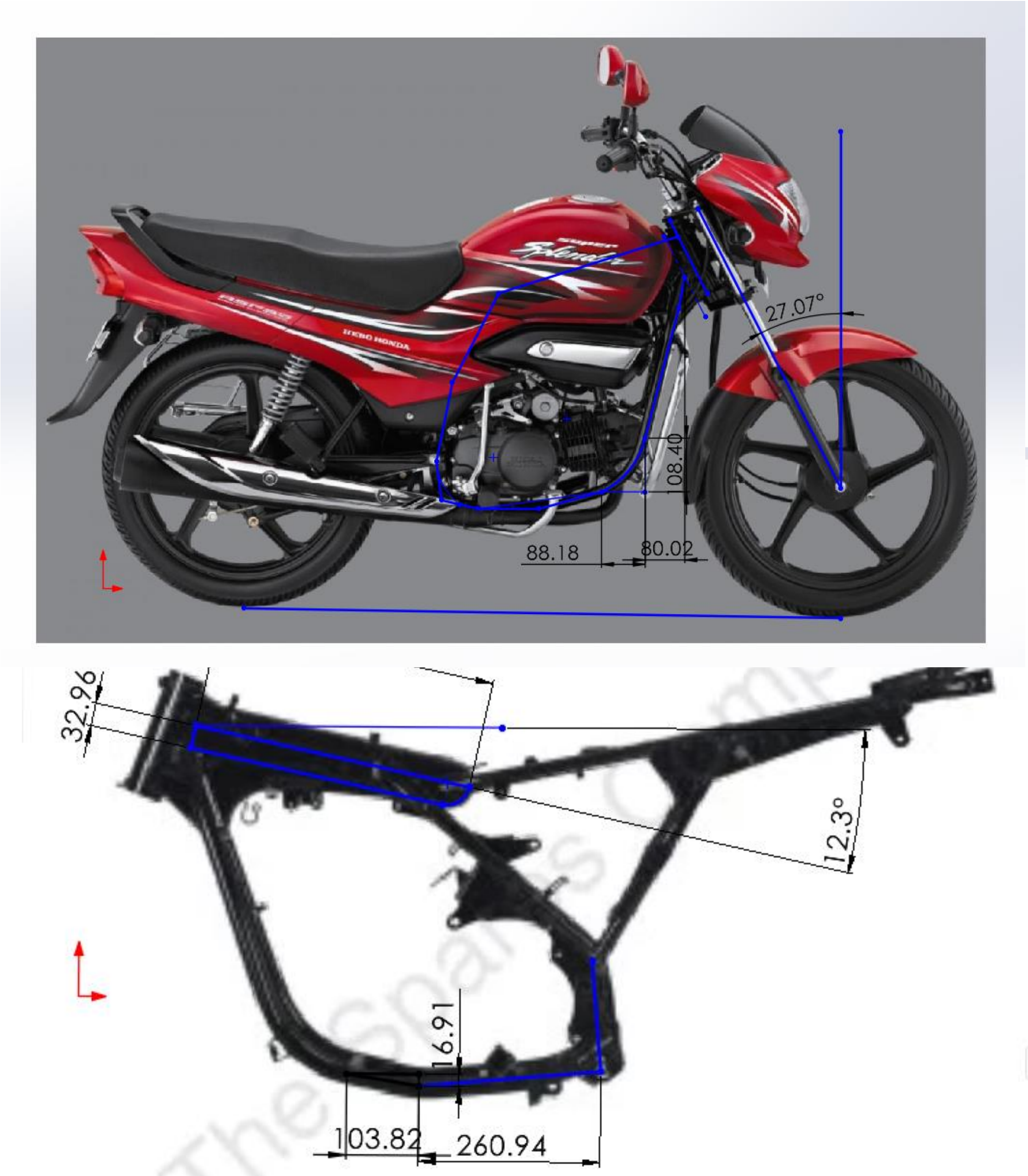

Figure 4: Generating fundamental dimension such as rake angle (top) and chassis elements length (bottom) using Sketch Tool in Solidworks

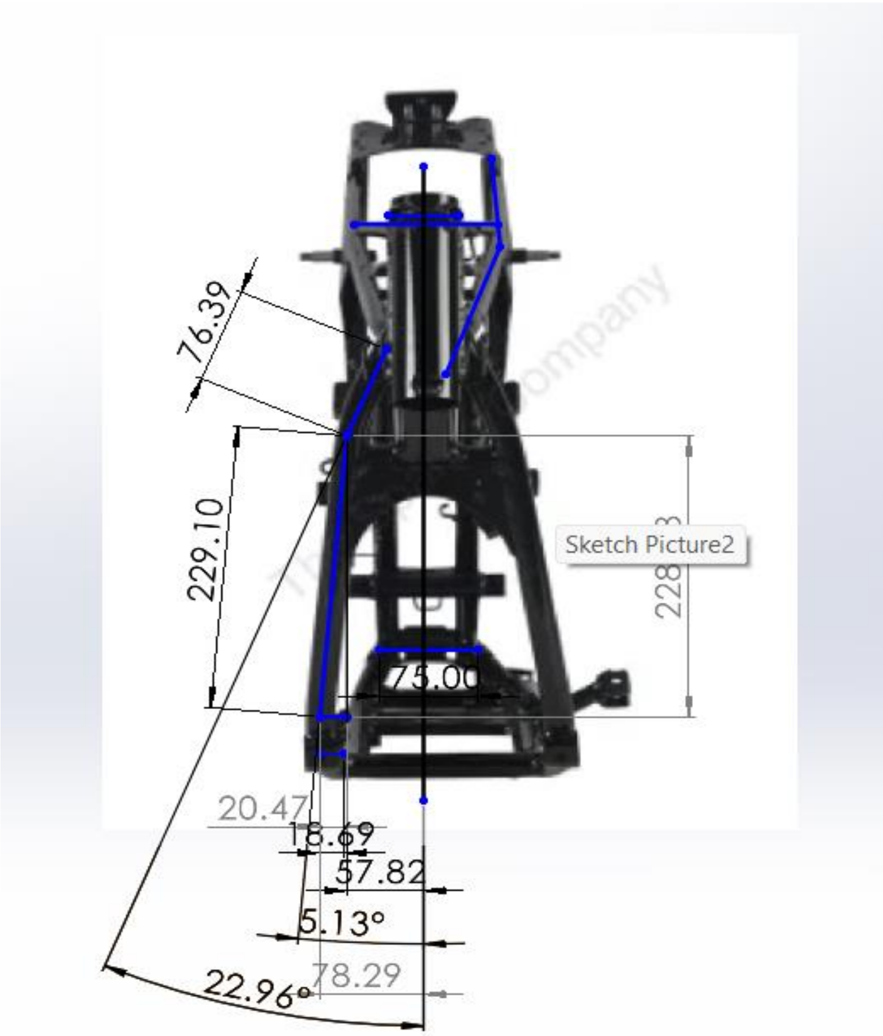

Figure 5: Generating measurement of chassis element from front view.

The Sketch Picture technique uses pictures in any format (.bmp, .gif, .jpg, .jpeg, .png, .psd, etc.) on a sketch plane as an underlay for creating 2D sketches and convert raster data to vector data using Autotrace (Solidworks, 2022) helps to grasp importance dimension in 1:1 ratio from and side view. This is quite painstaking yet popular technique in CAD to reverse engineer any kind of physical model. Finally, incorporating all the dimensions available from the Sketch Tool, simple and approximate chassis can be built. The final chassis sketch and model is presented in the figure below.

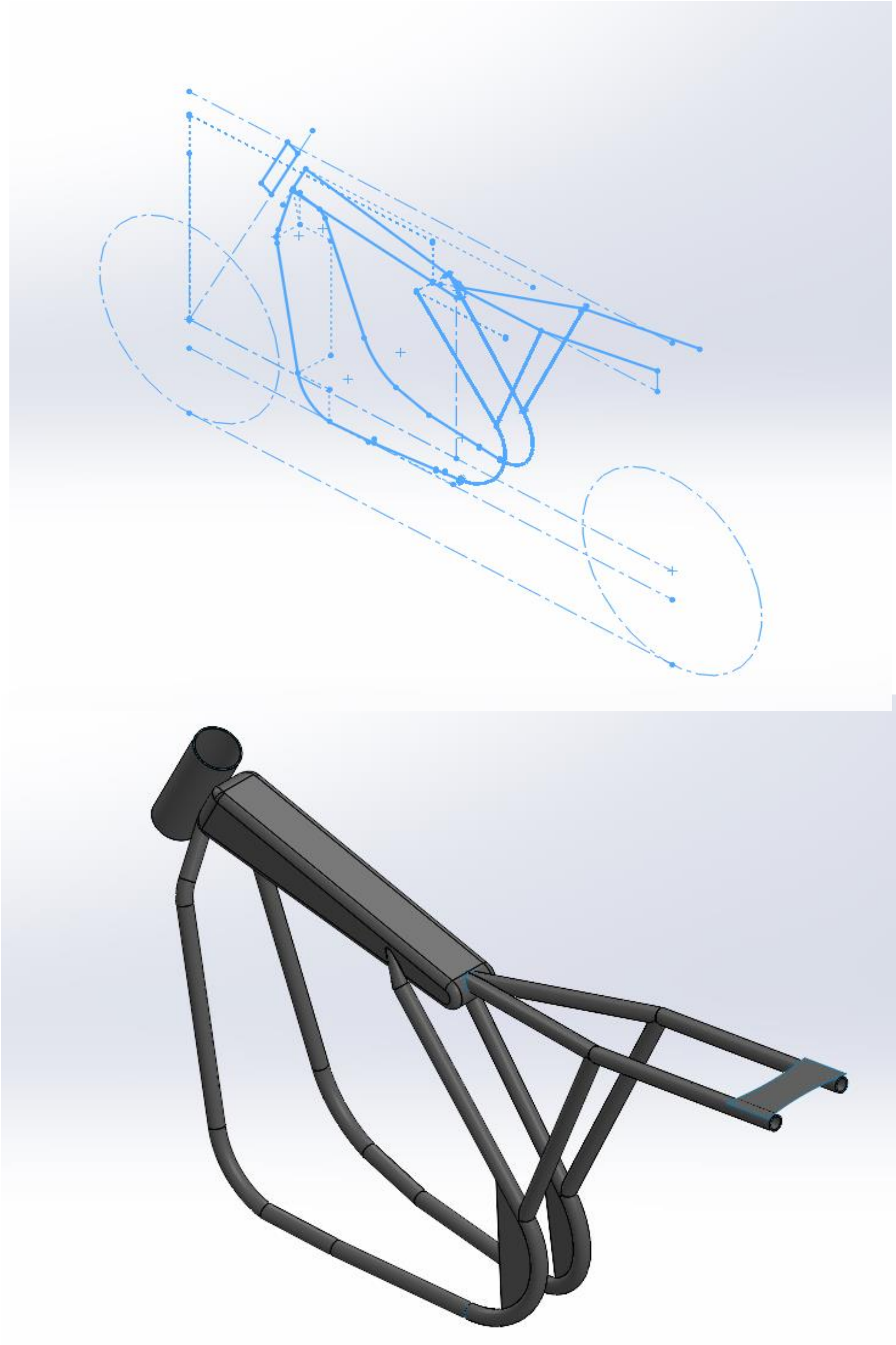

Figure 6: 3D sketch (top) and model (bottom) of chassis

Final 3D model consists of different arrays of parts such as wheels, suspension system, motor, battery pack, controller, swingarm. Using the Sketch Picture technique and available blueprint from internet, most essential parts to build the skeleton of bike are modelled in Solidworks. The final assembly is shown in figure below.

Figure 7: Front view (top) and isometric view (bottom)

3.3.1 Things to consider while remodeling

Converting a gasoline-powered motorcycle to an electric vehicle requires model modifications to be made. There are several reasons why it may be necessary to modify a gasoline motorcycle before converting it to an electric vehicle. Here are some of the reasons:

- Space: Converting a gasoline motorcycle to an electric vehicle requires adding a battery pack and an electric motor, which may not fit within the existing frame of the motorcycle. Modifications may be necessary to make room for these components.
- Weight Distribution: The weight of the battery pack and electric motor may alter the weight distribution of the motorcycle, which could impact handling and stability. Modifications may be necessary to ensure that the motorcycle handles properly and remains stable.
- Cooling: Electric components generate heat, and it is important to ensure that they are properly cooled to prevent damage. Modifications are required to enable proper cooling that can handle the increased heat generated by the electric components.

Similarly, there are different parameters which need to be considered in electric motorcycle to obtain the same power output before and after conversion. Some of the factors are:

- Battery Capacity: One of the most important modifications when converting a gasoline bike to electric is the battery capacity and placement. The battery needs to be large enough to provide sufficient range, but also small enough to fit in the motorcycle frame. The placement of the battery is also important to maintain the center of gravity and weight distribution of the motorcycle.
- Motor Selection: The motor selection is another important factor to consider. The motor needs to be powerful enough to provide sufficient acceleration and top speed. The placement of the motor is also important to maintain the balance and weight distribution of the motorcycle.
- Cooling and Thermal Management: Cooling and thermal management is another important factor to consider. The battery and motor generate heat during operation, and proper cooling and thermal management are necessary to prevent damage to the components.

- Charging: Converting a gasoline bike to electric requires a charging facilities to be put in place. This can include installing charging stations at home or incorporating on-board charger to make charging available anywhere anytime.
- CG relocation: The location of the center of gravity (CG) in a converted electric motorcycle is an important factor that affects stability, safety, maneuverability, braking and overall performance.

Figure 8: Location of Center of Gravity (CG) in converted motorcycle

The importance of considering these factors when converting a gasoline bike to electric is to ensure that the converted motorcycle is safe, reliable, and performs as expected, to prevent damage to the components, ensure longevity and practical for daily use.

3.4 Design of motor

Electric drive for the modern EVs are fundamental aspect of transportation technology. Transportation sector has long seen the development of ICE vehicles but the short history of EVs will outperform ICE vehicles in near future. Motor should be designed in such a way that offers high performance in every conditions. This can be achieved by including load requirements and resistance encountered during driving. This section addresses the design of motor for electric motorcycle.

3.4.1 Calculation of Total Tractive Effort (TTE)

When designing motor for the EV, a number of factors must be taken into account to determine the maximum torque required. Taking reference from (Chauhan, 2015) and (Dorrell & Popescu, 2012), the approximate mathematical equation can be developed to calculate the torque required at wheel.

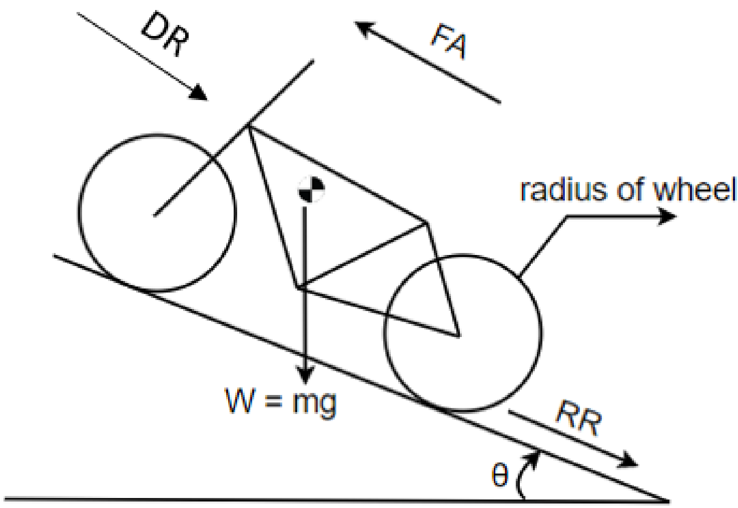

Figure 9: Bike schematic

TTE = Rolling Resistance (RR) + Grade Resistance (GR) + Acceleration Force (FA) + Drag Resistance (DR)

i. Rolling Resistance (RR)

RR = Total weight (W)* Rolling coefficient of friction (μ)

Where, Total Weight = Weight of vehicle + Weight of rider

Mass of vehicle= 90 kg

Mass of rider = 140 kg

[Considering two riders in a bike weighing 70 kg each]

$\mu = 0.017$

∴ W = Total mass * acceleration due to gravity (g)

= (90+140)*9.81

= 2256.3 N

Table 1: Coefficient of rolling resistance for different surfaces

Contact Surface	C_{rr}
Concrete(good/fair/poor)	0.010/0.015/0.020
Asphalt(good/fair/poor)	0.012/0.017/0.022
Macadam(good/fair/poor)	0.015/0.022/0.037
Snow(2 inch/4 inch)	0.025/0.037
Dirt(smooth/sandy)	0.025/0.037
Mud(firm/medium/soft)	0.037/0.090/0.150
Grass(firm/soft)	0.055/0.075
Sand(firm/soft/dune)	0.060/0.150/0.300

Therefore, RR = 2256.3*0.017

= 38.35 N

ii. Grade resistance (GR)

GR = Total weight (W) * sin(θ)

where,

θ is the grade or inclination angle

Table 2 Grade for different road conditions

Detail	Ruling	Limiting	Exceptional
Plain or Rolling Area	1 in 30	1 in 20	1 in 15
	(3.3%)	(5.0%)	(6.7%)
Mountainous Area	1 in 20	1 in 16.7	1 in 14
	(5.0%)	(6.0%)	(7.0%)
Steep Area	1 in 16	1 in 14.3	1 in 12.5
	(6.0%)	(7.0%)	(8.0

sin(θ) = 1 in 20 [From the table below]

= 2256.3*1/20

∴GR = 113 N

iii. Acceleration Force (FA)

FA = total mass (m) * acceleration of a vehicle (a)

Assuming the bike moves 0-60 m/s in 10 seconds, then acceleration can be calculated as:

$$a = \frac{v-u}{t}$$

$$= \frac{60-0}{10}$$

$$= 6\ m/s^2$$

FA = (90+140)*6

∴FA = 1380 N

iv. Drag Resistance (DR)

The drag coefficient is defined by:

$$C_d = \frac{2F_d}{\rho v^2 A}$$

Where, C_d = Coefficient of drag [0.6 for normal motorcycle (Schultz, 2016)]

A = Area [0.36 m^2 for normal motorcycle (Wilson, Spring 2003)]

v = Speed of motorcycle [Assuming max. speed of 70 km/h]

ρ = Density of air [1.2 kg/m^2]

F_d= Drag force

Then, the DR can be calculated as:

$$DR = F_d = \frac{1}{2} * C_d * A * d * v^2$$

$$= {}^{1}/_{2} * 0.6 * 0.36 * 1.2 * 19.44^2$$

= 49 N

Finally,

TTE = RR+GR+FA+DR

=38.35+113+1380+49

∴ **TTE = 1580 N**

Similarly, total torque required is:

$T = R_f * TTE * r_{wheel}$

where, R_f = Frictional losses between bearing and axle

r_{wheel} = radius of wheel

R_f = 1.15

Rear wheel sixe of hero splendor = 457.2 mm

∴ T = 1.15*1580*0.4572/2

=415 N.m

This is the torque required at wheel of the motorbike.

4 RESULTS and DISCUSSION

4.1 Chassis Dynamometer Test Analysis

A chassis dynamometer test is a type of test where a vehicle, such as a motorcycle, is mounted onto a specialized machine called a dynamometer, which measures the vehicle's performance under controlled conditions. The dynamometer consists of a set of rollers that are connected to a computer and various sensors, which measure the vehicle's speed, power, torque, and other performance parameters. Since, the motorcycle is very old, it is necessary to know the existing power of motorcycle before conversion. This will help to tally the power of motorcycle before conversion and after conversion. The picture below shows the test in Vehicle Fitness Test Center (VFTC) in Teku, Kathmandu.

Figure 10: Chassis dynamometer test performed in Vehicle Fitness Test Centre (VFTC), Teku

In the case of a motorcycle chassis dynamometer test, the motorcycle is placed on the rollers of the dynamometer, and the rear wheel is driven by the rollers as if the motorcycle were being ridden on the road. The dynamometer then measures the performance of the motorcycle under controlled conditions, while the rider makes various throttle and gear changes. The purpose of the chassis dynamometer test is to provide accurate and precise measurements of the motorcycle's performance, such as power, torque, and speed, under controlled conditions. This allows for a more accurate and objective evaluation of the motorcycle's performance, which helps in design of electric motor during conversion.

After performing motorcycle chassis dynamometer test, a plot was obtained which shows the variation of engine power, power and torque at wheel and drag power as shown in the figure below.

Each of the parameters and their significance are explained below.

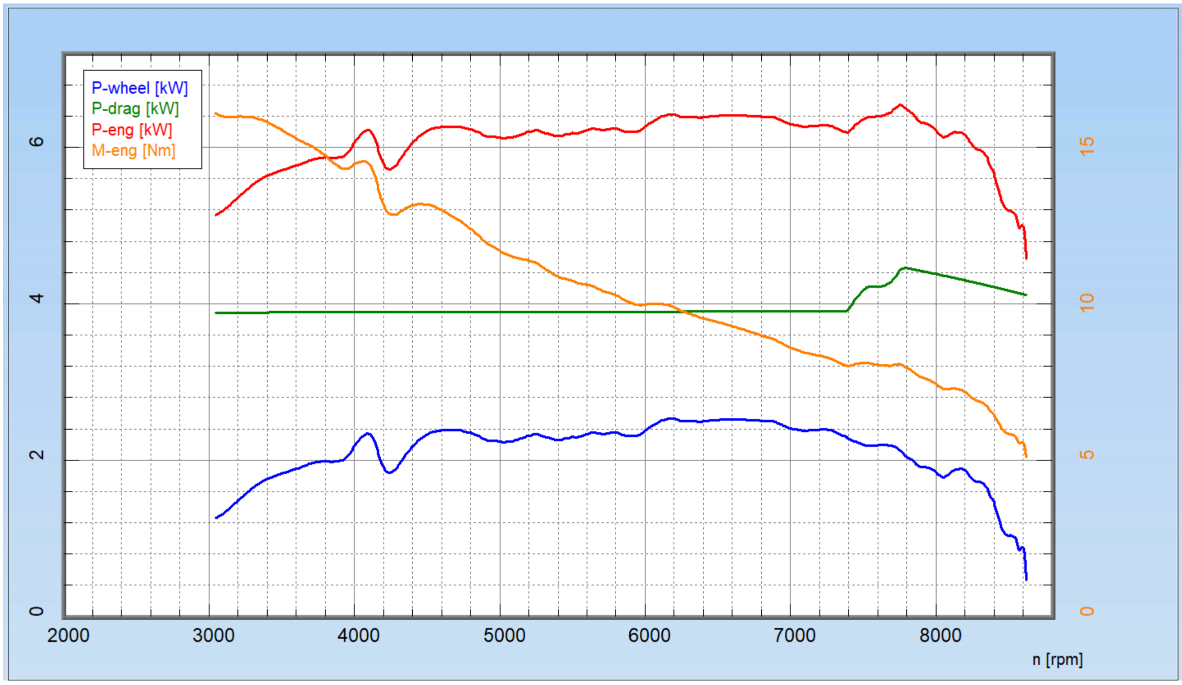

Figure 11: A power and torque plot obtained from chassis dynamometer test which shows wheel power, drag power, engine power and torque available at wheel

- Wheel power: This is the power that the motorcycle is actually delivering to the road via the rear wheel. It takes into account all the losses in the drivetrain (such as frictional losses in the chain or belt) and gives us an idea of how much power is actually available for acceleration and top speed.
- Engine Power: This is the power that the engine is producing at the crankshaft. It is calculated based on the torque produced by the engine and the speed at which it is

spinning. This is an important parameter as it gives an idea of the maximum power that the engine is capable of producing.

- Wheel Torque: This parameter tells how much twisting force (torque) is being applied to the rear wheel by the engine at different engine speeds (RPM). This can provide an idea of the low-end and mid-range torque characteristics of the engine, as well as the maximum torque output at high RPM.

The engine power accrues from the wheel power plus the drag power, which is automatically determined after the clutch is disengaged.

The table showing the peak value of engine power, wheel power, drag power, RPM at which maximum power is attained, maximum torque and RPM is shown below which are found to be 6.5 kW, 2.1 kW, 4.4 kW, 7760 RPM, 16.1 N.m at 2040 RPM and 8625 RPM respectively.

Table 3 Power data obtained from the test

Power data						
Corrected power 1)	P_{Norm}	----.-	kW	/	----.-	BHP
Engine power	P_{Eng}	6.5	kW	/	8.9	BHP
Wheel power	P_{Wheel}	2.1	kW	/	2.9	BHP
Drag power	P_{Drag}	4.4	kW	/	6.0	BHP
Max. power at		7760	rpm	/	88.2	km/h
Torque 1)	M_{Eng}	16.1	Nm			
Max. Torque at		3040	rpm	/	34.6	km/h
Max. attained RPM		8625	rpm	/	98.1	km/h

1) No power correction
Correction factors: Q_V = 0.00 %

4.2 Motor Selection

After calculating the torque required at wheel, the next task is to select the motor from internet offered by different vendors. There are a lot of products which offer wide range of power and torque but come with great cost. It is very difficult to find the actual model which could satisfy the requirements as per the design. After weeks of searching, we found the correct vendor selling motor which meets the requirements. QS MOTOR is the leading manufacturer of bicycle and scooter motor. It manufactures hub motors as well as mid-drive motors which offer ultra-high efficiency, long life and lowest repair rate. These motors are used by famous electric motor manufacturing companies such as NIU, Super SOCO, GEELY and VMOTO.

The purpose of selecting mid-drive motor is they offer higher performance and torque when compared to a similarly powered traditional hub motor. Mid-drive motors are designed to make maintenance and service extremely easy. Similarly, mid-drive motor is stationed close to the bike's CG and low to the ground. This helps improve the handling of electric motorbike by distributing the weight of the vehicle.

The 2000 W BLDC electric mid-drive motor manufactured by QS MOTOR is ideal for this product as it meets the torque requirement and higher efficiency. This is an ideal solution for e-Bike, Motorbike, Scooter, etc. This motor can be fitted with pulley or sprocket (14 T) which become more advantageous in context of electric conversion. This will allow to use which old motorcycle chain with the motor without requiring to replace sprocket and chain. Further details of the motor are tabulated below.

S.N.	**Specifications**	Value
1.	Model	QS Motor 2000W 120 70H Mid Drive Motor
2.	Motor Design	Single axle
3.	Magnet	Strong V magnet 70H
4.	Diameter	143 mm
5.	Length	211 mm
6.	Rated power	2000 W (maximum power 4600 W)
7.	Rated Voltage	72 V
8.	RPM	2800 rpm – 5000 rpm
9.	Maximum torque	20 N.m to 49.6 N.m
10.	Efficiency	91%
11.	IP rating	IP54
12.	Weight	8.8 kg

Table 4: Motor specifications table

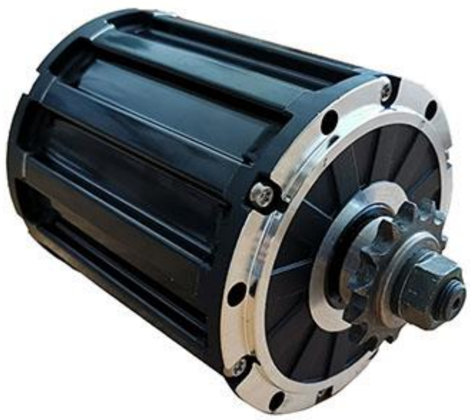

Figure 12: 2000 W mid-drive QS Motor

4.3 Motor Controller

A motor controller is a device which regulate the operation of an electric motor. Motor controllers often include a manual or automatic means for starting and stopping the motor, selecting forward or reverse rotation, speeding up or slowing down, and controlling other operational parameters.

The ND72490B is the compatible controller supplied by the QS Motor itself. It can be used with other type of motors as well. The details of the controller is tabulated below.

Table 5: Controller specifications table

Specifications	Value
Rated DC current	270 A
Rated Voltage	72 V
Protect Phase Current	490 A
Adapter motor	5-6 kW
IP rating	IP67
Weight	2.14 kg

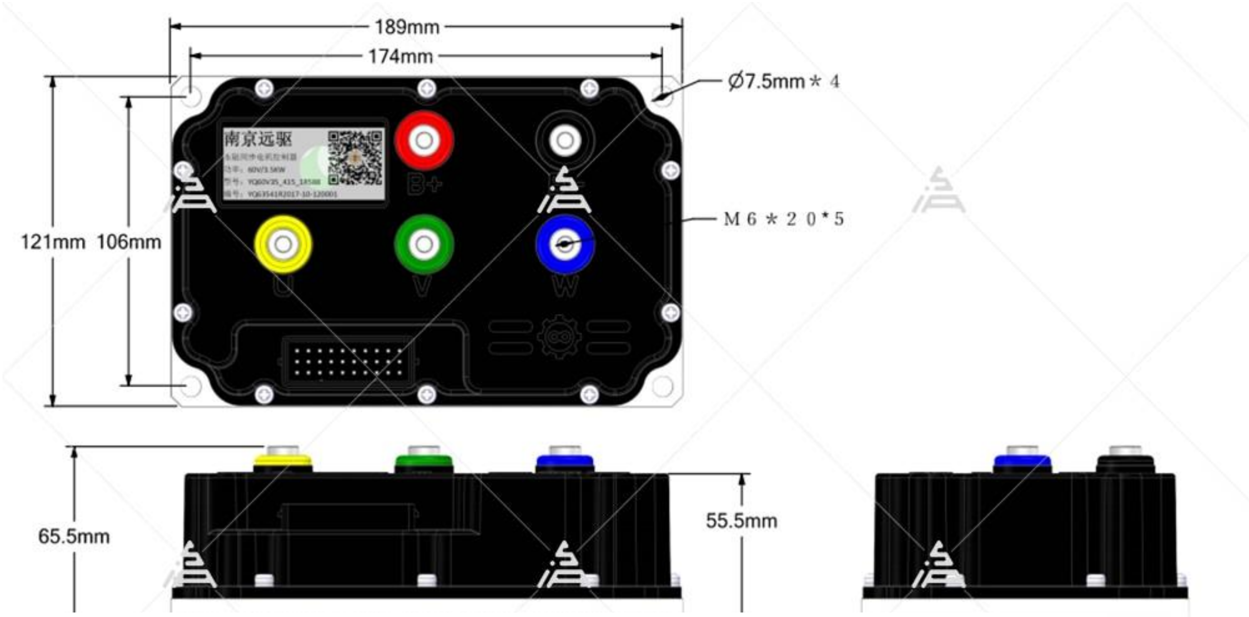

Figure 13: ND72490B controller

4.4 BMS

In EVs, a BMS plays a pivotal role in overall functioning of the system. It is much more demanding than the battery pack itself. It has to interface with a number of other on-board systems, it has to work in real time in rapidly changing charge/discharge conditions as the vehicle accelerates and brakes, and it has to work in harsh and uncontrolled environments. The BMS must manage the system over the entire operating cycle of the EV/HEV vehicle, and has to ensure the following functions.

1. Collecting information from sensors in the battery: current, voltage, temperatures, etc.
2. Controlling the charger to ensure proper charge of the battery.
3. Managing cell balance to ensure optimum performance of the battery.
4. Safety control: avoids overcharge or over discharge or other major anomalies that can occur in case of failure of the battery.
5. Reporting the battery state: communication of information (alarms, gauge, etc.) to the user and to other on-board equipment via the communication bus.
6. Thermal management of the battery: the BMS monitors the temperature of the cells in all modes of operation.
7. Communication with the vehicle: vehicle computer and BMS exchange data via the communication bus (CAN 2.0B).

8. Maintenance via the BMS: users will have the ability to connect maintenance and diagnostic tools to undertake necessary operations for the maintenance of the battery.
9. Data transfer to a laptop PC, which can monitor and store the battery measurement data collected by the BMS.

The famous name in BMS is Daly BMS. Dongguan Daly Electronics Co. Ltd. was established in 2015 and specializes in Lithium BMS manufacturing such as LiFePO4, NMC and LTO. The specifications of Daly BMS are 3S-32S, 12V – 120 V and 5A – 500 A.

RoHS and CE certified BMS are embedded with BT and NTC temperature sensor that could be connected with the smartphone to monitor the battery parameters. Daly can supply the BMS as per our design of 60 V 17 S and 150 A.

Figure 14: Daly BMS (20S, 72V and 150 A)

4.5 Throttle and Speedometer

YY V3 Throttle and DKD speedometer comes along with the motor and controller. They helps to drive the vehicle smoothly and provide the information about the speed, battery condition, charge available and any warning displayed by the system.

Figure 15: DKD Speedometer (Top) and YY V3 Throttle (Bottom)

4.6 Wires and accessories

Connection wires are needed to make two way connection with motor, controller and BMS. Motor supplier will supply Relay, Flasher, 72V to 12V 15A DC converter, Ignition, suitable for QS165 encoder motor and QS180 encoder motor.

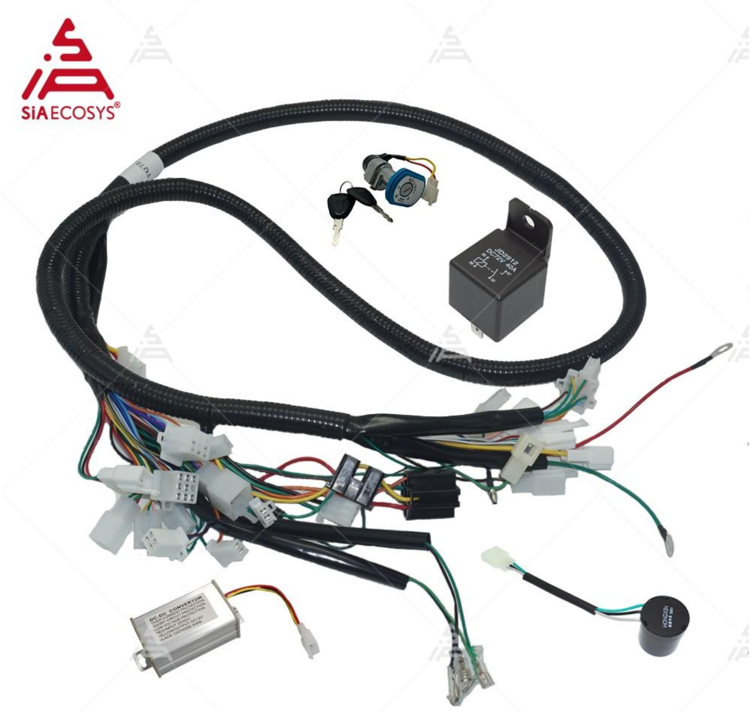

Figure 16: Wires and accessories

4.7 Li-ion 21700 NMC cell

Lithium-ion batteries become one of battery technology with the best energy-to-weight ratio. NMC is the short name of this lithium-ion battery type that comes with a mixture of Cobalt, Manganese, and Nickel. The unique mix of materials has made this battery long-lasting. 21700 batteries are the size designation for the rechargeable lithium-ion battery which are first made popular by electric cars and scooters. 21700 batteries as the name implies measures 21 millimeters in diameter and 70 millimeters long compared to an 18650 battery which we are more familiar with which is 18 millimeters in diameter and 65 millimeters long. The big advantage of these cells is an increased maximum energy capacity. For example, an 18650 battery mazes out at 3,600 mAh whereas a 21700 battery can hold as much as 5000 mAh which give longer run times while still maintaining similar body tube.

Table 6: Specifications for 21700 NMC cell

Specifications	Value
Diameter/Height	21 mm/ 70 mm
Nominal Voltage	3.6 V
Charge Voltage	4.2 V
Cut-off Voltage	2.5 V
Nominal Capacity	5 Ah
Current	4 A
Internal Resistance	1000 Hz,≤ 30 mΩ
Maximum charge current	1 C
Maximum discharge current	3 C
Weight	<70 g

Figure 17: A typical Li-ion NMC 21700 cell

4.8 Design of Battery Pack

4.8.1 Basic Terminology

The main focal point during the designing and figuring out the size of a battery system, there needs to be understanding for the basic terminology surrounding it. One good source for understanding many of the different terms, and one that is far more complete, is the signification from the Society of Automotive Engineers (SAE) J1715 (Sreejith & Rajagopal, 2017).

4.8.2 Vehicle and Industry Terms

An Electric Vehicle (EV) is a vehicle that is fully electrified and does not have an internal combustion engine (ICE). All power is provided by the electric battery, which powers one or more electric motors that provide propulsion and power to all other systems on the vehicle. These are also known as battery electric vehicles (BEVs), and the terms are used interchangeably. However, the same abbreviation EV is also used to refer to Electrified Vehicles (EVs), which include vehicles with all types of electric power support, such as micro hybrids, hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and battery electric vehicles (BEVs).

The term HEV refers to the most common type of electrified vehicle configuration. These can range from mild to powerful hybrids. A mild hybrid has a smaller battery, usually less than one kilowatt hour (kWh), and provides less power to the system. A strong hybrid, on the other hand, will have a slightly larger battery, often around 1.5kWh, and will provide some minimal electric propulsion in addition to powering some of the auxiliary systems. The term hybrid refers to the act of combining an ICE with a battery-powered electric system, resulting in a dual-power system. In the hybrid car, the electric motor will generally provide the power support throughout the operating cycle, but does not provide electric driving capability (mild hybrid) or at best only minimum electric drive capability (strong hybrid).

Another term that is occasionally used in relation to electric vehicles is Light Electric Vehicle (LEV). LEVs include two- and three-wheeled electric motorcycle platforms, as well as electric bicycles. The LEV market is the world's largest electric vehicle market, with between 25 and 30 million LEVs sold globally each year. The vast majority of these are electric bicycles (e-bikes), pedelecs (electric assist bicycles), and electric scooters sold in Asia, but demand for this type of technology is growing rapidly in Western markets.

A Stop/Start (S/S) system is referred to as a micro hybrid (HEV). A very small battery, often a lead acid or a very small lithium-ion battery, powers the vehicle systems when the control system automatically shuts off and then restarts the engine when the vehicle stops in this type of hybrid. Because the battery is too small to capture the amount of energy that would be regenerated back into it, most of these systems do not support regenerative braking. However, larger batteries (typically >750-1000Wh) may include regenerative braking capability and on-board power support for electrically powered systems such as power steering, power brakes, entertainment system, HVAC, and vehicle lighting while the engine is turned off. This configuration is gaining much popularity in all regions around the world due to the low cost and general simplicity of this system.

4.8.3 Battery Terms

These are the common understanding for some of the basic terminology surrounding the battery which are the explanation for the most common terms usually used in the lithium-ion industry.

- Ampere: Often referred as the shortened form 'Amp', this is a unit of measurement of the battery current.
- Anode: Anode is the negative terminal inside the battery cell through which conventional current enters the device. It is typically a thin piece of highly conductive aluminum or copper that is coated with graphite, carbon or other similarly conductive material.
- Battery Management System: The battery management system (BMS) is the control system within the battery pack that consists of one or more electronic controllers that manage charging and discharging, monitor temperature and voltage, communicate with the vehicle system, balance the cells, and manage the battery pack's safety functionality.
- Beginning of Life (BOL): The term refers to the battery energy, capacity and power when it is first built or is at the beginning.
- C-rate: The term C-rate is important because it refers to how quickly a battery can charge or discharge all of its energy (or power). In other words, it describes how

quickly a battery can accept a charge or lose power (discharge). C-rate is defined in terms of a one-hour discharge, so 1C-rate is the rate at which a battery is fully discharged (or charged) in one hour. Similarly, 2C-rate would be equal to the rate at which a battery is fully discharged in 30 minutes (60min/2C=30min). If the C-rate number increases, the discharge time decreases, and vice versa. As a result, a 0.5C discharge rate corresponds to a 2 h discharge period (60min/0.5C=120min or 2h).

- Capacity: Capacity is measured in Ampere hours (Ah) and is a measure of amount of energy in the system.
- Cathode: Cathode is the opposite of the anode; it is the positive terminal inside the battery cell.
- Current: Current is the measurement of the flow of the electrical charge, which may be carries by electrons moving through a wire or circuit board and by ions moving through an electrolyte between the anode and cathode and is measured in Amperes.
- Cycle: The process of discharging and then charging a battery is referred to as a cycle. One cycle is defined as a complete discharge followed by a charge. Depending on the application, a cycle may run at various levels of power and/or voltage, or even at a constant rate of charge and discharge. A cycle can be full, which means completely discharging and then charging the cell, or partial, which means only discharging to a certain level and then charging back up to the starting level.
- Depth of Discharge (DoD): The DOD is a measurement of how much of the cell or pack energy will be used for that application. You will typically use lithium-ion battery only somewhere between 20% and 90% of the total amount of energy in order to prevent overcharge at the top and manage low end voltage. So if we think of the battery as a 10-gallon gas tank PHEV, it may only use 60%, or 6gallons, of its energy—so the DoD would be 80%. For a HEV or micro-HEV, the battery may only use 30–50% of the available energy or 3–5gallons in this example. And an EV may use 80–90% of the total energy available, about 8–9gallons in this example. During system development one design decision that is commonly made, especially for hybrid applications, is to reduce the Depth of Discharge (DOD) during operation in order to achieve greater cycle life and improve safety in the energy storage system.

- Electrodes: The term electrodes refer to the combined pair of anode and cathode when it is assembled in a battery cell.
- Electrolyte: Electrolyte is liquid or gel used in battery which contains ions and can be decomposed by electrolysis and used as the medium to transfer the lithium ions and forth between the anode and cathode.
- End of life (EOL): The EOL of a battery is reached when the maximum power and energy of the battery have been reduced to approximately 80% of their BOL measurements. The 80% rule is based on either power or energy that has declined to the point where acceleration (power) or range (energy) is no longer "satisfactory" to the consumer. However, depending on the application, a shorter EOL may be appropriate.
- Energy: The term energy refers to the amount of energy that a battery will store, which is analogous to the size of the gas tank. Energy is usually measured in kilowatt hours (KWh).
- Energy Storage System: The term ESS is used in a variety of contexts, but it generally refers to the entire battery pack system. The ESS is a collection of mechanically and electrically connected cells, as well as the necessary thermal, electronic, and mechanical structures to house the entire unit. It is, in essence, everything "in the battery box."
- High Voltage (HV): Any system with a voltage greater than 60V is considered "high voltage" and must include appropriate safeguards (HVIL, safety disconnect, orange cabling, etc.) to protect workers and anyone else who may come into contact with the system.
- Power Density—Measured in either kilowatt per kilogram (kW/kg) or kilowatt per Liter (kW/L). Similar to energy density, power density is the comparison of a battery’s power in relation to its weight or volume.
- Parallel: A battery with parallel connections is made up of cells that are linked in parallel (e.g., positive to positive, negative to negative, etc.). In a parallel connection, you feed current into all of the cells at the same time as you pull current out of them. The system capacity is increased by connecting cells in parallel. The following example represents three cells: assume they are 3.6V and 5Ah; in a parallel configuration, the voltage would remain at 3.6V but the capacity would increase to 15Ah (5Ah3 cells).

- Series: A series configuration is a collection of cells that are connected in series (e.g., negative to positive, etc.). Connecting cells in series raises the overall voltage of the system. The following example represents three cells in series, each of which is 3.6V and 5Ah, as in our previous example. This configuration would result in 10.8V (3.6V3 cells), but the capacity would remain at 5Ah. Putting lithium-ion cells in series is similar to connecting multiple garden hoses end to end; the batteries are in series as well. The difference is that connecting batteries in series increases the voltage but not the capacity; connecting garden hoses in series has the opposite effect.
- Short Circuit: When the positive and negative poles or electrodes of a battery are connected, a short circuit occurs. A short circuit, in essence, creates a circular connection within a cell, driving all of the current back into the cell or pack, eventually, and usually very quickly, resulting in a catastrophic failure. This could happen inside the cell as a result of the growth of dendritic materials that connect the anode and cathode electrically. If it happens inside the cell, it is an internal short but if the electrical connection is made between the poles outside the cell, it is referred to as an external short.
- State of Health (SOH): SOH is an intriguing measure because there is no "standard" definition; different battery companies, control companies, and application users may have different definitions. In general, SOH refers to the battery's current state of health as compared to its beginning of life measurement. In other words, SOH is intended to tell you how long the battery will last before it dies (EOL). SOH is a measure of internal resistance, capacity, voltage, self-discharge, the battery's ability to accept charge, and the total number of charge-discharge cycles completed at that time. The state of health calculation is an algorithm that is programmed into the main controller of the battery management system.
- Voltage (v): Voltage is the potential of the charge in a battery.

4.8.4 Lithium-ion Cell Chemistry

Batteries are usually classified into two categories: primary or secondary. The main distinct feature of these batteries is whether they are rechargeable or not. Primary batteries are rechargeable and are single use batteries which must be discarded after they have been discharged. Secondary batteries are rechargeable, that can be charge and use multiple times over the period of time. The amount of life, or use, in a rechargeable battery is dependent on the chemistry and operating profile.

Li-ion was introduced to the market in 1990, and sales of lithium ion increased in demand from 1991 to the early 2000s, becoming the highest volume cell manufactured in the world. Because it had a much higher energy density than comparable cells on the market, lithium-ion quickly became the battery of choice for most small electronics. Energy flow is created in a lithium-ion battery when lithium-ions in the cathode are transferred through an electrolyte medium into the anode; this is referred to as a charging event. For most of us, this appears counterintuitive, but when the battery discharges, ions pass from anode to cathode. A charging event is depicted in the diagram below, with lithium-ions passing from the cathode material through the electrolyte to the separator and then back through the electrolyte and to the anode material. In a closed-circuit loop, this action causes a voltage flow up the copper current collector and to the positive current collector.

The higher voltage is another advantage of lithium-ion chemistries over nickel- and lead-based batteries. Typical NiMh and NiCd rechargeable cells have a nominal voltage of 1.2-1.5V, whereas lithium-ion cells have a nominal voltage of 3.2-3.8V. A higher voltage is important because it means that you can connect fewer cells in series to achieve your desired pack voltage. A NiMh battery pack with 350V, for example, may require 292 cells to achieve that voltage (350V/1.2V = 292 cells). A lithium-ion battery pack, on the other hand, would only require about 98cells to achieve the same system voltage (350V/3.6V = 98 cells).

In addition to having a higher voltage and energy density, lithium-ion batteries have a lower rate of self-discharge. This means that its natural capacity loss during storage is less than that of other chemistries, with many lithium-ion chemistries losing only a fraction of their capacity 1% to 5% per month. There are two types of capacity loss during storage: reversible and permanent. Reversible capacity loss refers to energy that is lost during storage but will be recovered once the storage is completed. The battery is cycled once more. Permanent loss is the portion that can never be recovered. Almost all lithium-ion chemistries experience some degree of reversible capacity loss over time. Some of which is almost always permanent.

Lithium-ion chemistries have a significantly longer cycle life than the other chemistries. Whereas PbA may only get 300-500 cycles before its end of life (EOL), lithium-ion can get thousands of full discharge cycles before its EOL during 100% depth of discharge (DOD) cycles. In terms of partial cycles, as the DOD is reduced, the lithium-ion battery will be able to achieve tens of thousands of cycles. For example, a typical lithium-ion chemistry may achieve 1000 cycles using 100% DOD, but if we take that same cell and only use 80% of its total usable energy, we can now achieve several thousand cycles.

4.9 Mathematical Modelling of Battery Pack

Electric vehicles (EVs) require accurate prediction and mathematical modeling. In this regard, the most important parameters are forces, power requirements, energy usage, and cell parameters. The development of a mathematical model to estimate these performance parameters for various hypothetical future batteries will necessitate the consideration of fundamental vehicle dynamics equations. Inputs to the model include vehicle attributes such as mass, dimensions, gear ratio, wheel base speed, motor power, and so on, and the vehicle must perform well in order to meet the target of a current IC engine vehicle. Another critical factor for EVs is their range. A mathematical model is developed to calculate the range of vehicle based on the type of battery and its capacity.

4.9.1 Power Consumption by a Vehicle

A vehicle must overcome four opposing forces while running: motion - aerodynamic drag, rolling resistance, a component of its weight depending on the gradient, and inertia. Because power consumption is calculated by multiplying force by velocity, and because the velocity of the vehicle changes continuously during movement. Simulators are typically used to estimate power consumption at each simulation step. Integrating the power consumption values over time.

(Chen et al., 2017) have introduced a parametric approach for estimating vehicle energy consumption. Their model is known as Parametric Analytical Vehicle Energy Consumption (PAMVEC). The basic idea behind this method is to separate the total tractive forces into two distinct categories. The first consists of non-recoverable aerodynamic drag and rolling resistance. The other consists of gradient-related force and inertia, which cause a change in the vehicle's potential or kinetic energy and can be recovered. A driving cycle, according to Simpson et al., can be represented by four parameters: average speed, root mean cubed velocity, velocity ratio, and characteristic acceleration.

4.9.2 Electric Vehicle Load Modeling

Energy or power demanded by a vehicle is obtained by determining the various forces acting on the vehicle that opposes its motion. The vehicle is modeled as a road load and various longitudinal forces acting on it derived from Newton's second law of motion. During the process different vehicle parameters are specified on the basis of the prototype that we are modeling. During the modeling the maximum speed (v) to be achieved by the electric bike is assumed to be 70 km/hr (19.45 m/s).

The rolling/friction force and drag force is required to propel the vehicle forward for which the vehicle mass parameters are given by:

i. **Vehicle total mass (Kg)**

For the overall calculation of the vehicle the total mass of the vehicle is assumed with the passenger along with it. The design specification of the bike is made to adjust the mass of two people considering one rider and one passenger. As the two-passenger seat is more abundant and used in the peripheral of Nepalese automotive market, the design is based on the reference on that aspect.

$$\boldsymbol{M} = \boldsymbol{Mv} + \boldsymbol{Mp} = 230kg$$

Where,

$\boldsymbol{Mv}$ = Vehicle mass =90 kg

$\boldsymbol{Mp}$ = Total number of passengers × 70 = 140 kg

During the calculation the average mass of each passenger is assumed to be 70 kg.

ii. **Rolling/ friction force**

The calculative equation for the rolling/friction force is given by

$$\boldsymbol{F_f} = \boldsymbol{C_r} \times \mathbf{M} \times \mathbf{g} = 38.35 \text{ N}$$

$\boldsymbol{where}$,

$\boldsymbol{C_r}$ = Coefficient of rolling resistance = 0.016 is assumed for the tires of bike

$\boldsymbol{M}$ = Total mass of the vehicle

$\boldsymbol{g}$ = Acceleration due to gravity

iii. **Drag force**

$$\boldsymbol{F_d} = \boldsymbol{{}^1/_2} \times \boldsymbol{C_d} \times \boldsymbol{A_f} \times \boldsymbol{d} \times \boldsymbol{v^2}$$

$\boldsymbol{where}$,

$\boldsymbol{C_d}$ **=** Coefficient of drag = 0.6 for bike

$\boldsymbol{d}$ **=** Fluid density = 1.2 kg/m^3 (Air)

$\boldsymbol{A_f}$ **=** Frontal area of bike = 0.36 m^2

The assumptions for the numerical data for the bike are speculated from the current factual data set derived from the existing ICE powered bikes.

$$\boldsymbol{F_d} = \boldsymbol{{}^1/_2} \times \boldsymbol{0.6} \times \boldsymbol{0.36} \times \boldsymbol{1.2} \times \boldsymbol{19.44^2}$$

$$= 49\ N$$

iv. **Net force and power**

$$\boldsymbol{F_{net}} = F_f + \boldsymbol{F_d} = \boldsymbol{38.35 + 49 = 87.35\ N}$$

From the basic calculations of rolling and drag force the total net force of the bike is found to be 79.16N through which the power required for the bike to accelerate in the specified velocity is calculated.

$$\boldsymbol{P} = \boldsymbol{F_{net}} \times \boldsymbol{v} = 87.35 * 19.44 = 1.53 \text{ KW}$$

v. **Energy usage**

After the calculations for the load and the power requirement the energy usage requirement for the battery to be modelled is calculated with respect to range covered and time to cover that distance.

$$\boldsymbol{E} = \boldsymbol{P} \times \boldsymbol{T} = 1.53 * 1.42 = 2.172 \text{ kWh}$$

$$\boldsymbol{T} = \boldsymbol{D}/\boldsymbol{v} = 100/70 = 1.42\ hr$$

$\boldsymbol{where}$,

$$\boldsymbol{D} = range\ or\ distance\ covered$$

$$\boldsymbol{T} = time\ required\ to\ cover\ that\ distance$$

4.10 Cell requirements and battery parameters

Based on the chosen power and the change in energy consumed, the basic requirements for the calculation parameters of battery are fulfilled. During the design of the battery the Lithium-ion battery is considered with the view of targeting it towards the electric bike where 21700 batteries came in surface. For the cell parameters the basic cell capacity of electric bike is assumed to be 2.5 Amp-hr and cell voltage is assumed to be 3.7V. From this data, the basic parameters for the design of battery are given by,

i. **Battery parameters**

$$\boldsymbol{V_b} = Battery\ Voltage = 72\ V$$

$\boldsymbol{where}$,

$$\boldsymbol{C_b} = Battery\ capacity = E/V_b = 30.16\ \ Ah$$

ii. **Cells required**

After the calculation of pre-requisite of chemistry, cells parameters, voltage and capacity of the battery the total number of cells required for the arrangement for series or parallel is calculated.

$$C_t = S_c \times P_c$$

$\boldsymbol{where}$,

$\boldsymbol{S_c} = \boldsymbol{V_b}/\boldsymbol{V_c} = 72/3.6 = 20\ cells$

$\boldsymbol{S_c} = Cells\ in\ series\ combination$

$\boldsymbol{P_c} = \boldsymbol{C_b}/\boldsymbol{C_c} = 30/5 = 6\ cells$

$\boldsymbol{C_t} = 20 * 6 = 120\ cells\ required$

$\boldsymbol{P_c} = Cells\ in\ parallel\ combination$

$\boldsymbol{C_t} = Total\ cells\ required$

iii. **Total battery pack capacity**

$$Series\ count = 20$$

$$Parallel\ count = 6$$

Battery parameters

$$Nominal\ capacity\ =\ 5000\ mAh\ =\ 5Ah$$
$$Nominal\ Voltage\ =\ 3.6\ V$$

As there are 20 cells in series, therefore total voltage would be

$$\boldsymbol{V_t}\ =\ 20\ \times 3.6\ =\ 72\ V$$

As there are 6 cells of parallel strings, therefore total current would be

$$\boldsymbol{I_t} =\ 6\ \times 5\ =\ 30\ Ah$$

So, total battery pack capacity will be

$$\boldsymbol{E}\ = \boldsymbol{V_t}\ \times\ \boldsymbol{I_t}\ =\ 72 * 30\ =\ 2.1\ kWh$$

All these calculations assumed that we can use 100% of the battery to achieve that range, in reality we may only be able to use about 80-90% of that battery depending on the cell selection and usage profile.

4.11 Arrangement and stacking techniques of cells

4.11.1 Cells in Parallel, the P count

If you connect several cells with the same type of electrodes in parallel, they will all behave as if they were one large cell. Also, when you first connect them, they must be at the same charge level. The positive electrode is called the Cathode, and the negative electrode is called the Anode. The positive is represented by a red plus sign in the images below, while the negative is represented by a black dash]. If the fully charged cell is in parallel to a cell that is low, the high cell will try to charge up the low cell in just a few seconds, since there is no built-in resistance between them across the connecting bus to slow things down.

The P-count determines the capacity of the pack in amp-hours (Ah), as well as the amount of current that the pack can produce in amps. In this example, we'll use a factory-rated 5 Ah nominal voltage cell. If we connect four parallel packs, the total range will be 20 Ah (4P X 5-Ah = 20-Ah).

4.11.2 Cells in series, the S count

When we connect the cells in series, we don't change the amps or capacity; we simply increase the voltage of the pack. When you connect them in a series, you connect the positive end of one cell (or P-group) to the negative end of the other.

The lithium-NCA or lithium-NCM chemistry is used in the most popular cylindrical 18650-format cells (18mm in diameter, 65mm long) (the cathode uses Nickel-Cobalt-Aluminum or Nickel-Cobalt-Manganese). Those chemistries have a nominal (average) voltage of 3.7V, and to get the most life out of the pack, set the Low-Voltage-Cutoff (LVC) to 3.3V per series-cell and the fully-charged target to 4.1V. The common max charge is 4.2V per cell, but when cells rest (for any length of time) at that high of a voltage, it will significantly degrade their life. Charge the pack to 4.1V times the series number.

4.12 Battery Management System

A battery management system (BMS) is any electronic system that manages a rechargeable battery (cell or battery pack), such as protecting it from operating outside its safe operating range, monitoring its state, calculating secondary data, reporting that data, controlling its environment, authenticating it, and/or balancing it. BMS has two primary functions when it comes to a battery pack its two primary functions are to keep the battery operating safely and keeping it operating reliably and if we think about it all the advanced features than we can see in a BMS really at its core boiled down to one of these two features is it keeping the battery pack safe or is it maintaining reliable operation. So it’s helpful to stay in the context of what the purpose of that feature. Black box model of battery management system is a system that takes a number of inputs. For example, the black box takes in a number voltages, every cell voltage, pack voltage and number of temperature sensors typically which sprinkled throughout the pack to get a sense of temperature distribution of the cells sand it also takes as in input the current flowing into or out of the packs. BMS detect the battery pack charging or discharging, what magnitude within the BMS it’s running number of algorithms to try to generate an accurate estimation of the following outputs so one of the primary outputs is what’s called a SOC or state of charge.

4.13 Calculation validation using Drive Cycle

A drive cycle is a standardized test procedure plot used to evaluate the performance of a vehicle under specific operating conditions. It is an important tool used in the design and development of electric vehicles, as it allows to evaluate the vehicle's energy efficiency, range, and overall performance using real case scenario. The drive cycle is typically a set of specific driving conditions, such as speed, acceleration, and deceleration that the vehicle must undergo during the test. The test may also include periods of idling or coasting, to simulate real-world driving conditions.

The importance of the drive cycle in designing electric vehicles lies in its ability to simulate real-world driving conditions, and to evaluate the vehicle's performance under these conditions. The drive cycle is a great tool to optimize the design of the vehicle's drivetrain, battery, and other components, to maximize energy efficiency and range. For example, during the drive cycle test, we may measure the energy consumption of the vehicle, as well as the amount of power that the battery can deliver under different operating conditions. This information can be used to optimize the design of the battery and motor, to ensure that the vehicle can deliver the desired range and performance under a variety of driving conditions. Additionally, the drive cycle can be used to evaluate the vehicle's emissions, including greenhouse gas emissions and pollutants such as nitrogen oxides and particulate matter. This information is important for meeting regulatory requirements and ensuring that the vehicle meets environmental standards. Similarly, drive cycle plot helps to validate the theoretical calculation and produce vehicles that are more efficient, more reliable, and better suited as per our requirements. The MATLAB simulation conducted a comprehensive analysis of the electric bike's performance over a 600-second drive cycle. The simulation produced three plots, each of which provided valuable insights into different aspects of the bike's performance. The first plot, which shows the total power consumption of the electric bike over time, is an essential metric for evaluating the bike's energy efficiency.

The y-axis of the plot represents power consumption in kW, while the x-axis represents time in seconds. This plot revealed that the electric bike initially consumed no power at the start of the simulation and gradually increased its power consumption as the drive cycle progressed. At the end of the 600-second drive cycle, the total power consumed by the bike was 0.085 kW. By analyzing this plot, the power requirements of the bike under different driving conditions can be determined, and areas where energy efficiency could be improved can be identified.

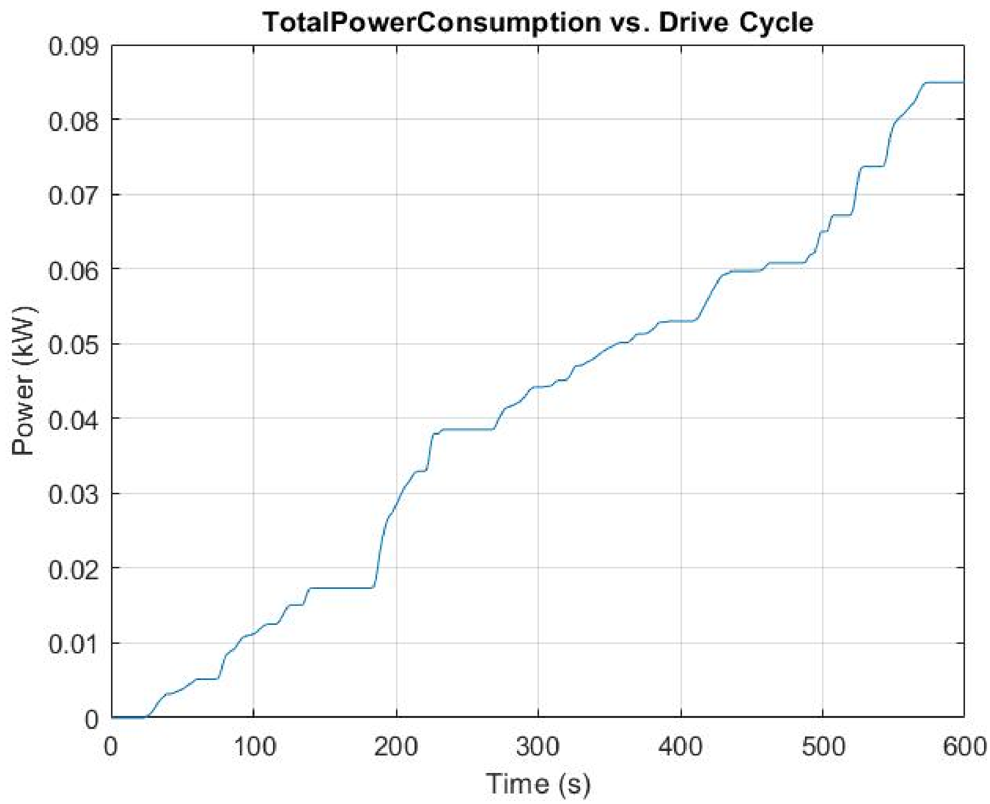

Figure 18: Total power consumption vs drive cycle

The second plot, which shows the tractive power required to move the electric bike forward, provides insights into the bike's acceleration and speed characteristics. The y-axis of the plot represents tractive power in kW, while the x-axis represents time in seconds. This plot illustrated that the electric bike required a peak power of 5 kW to move forward at certain times during the drive cycle. The peak power required to move the bike forward is a crucial parameter for selecting the motor and battery capacity of the electric bike, and for optimizing the bike's performance under different driving conditions.

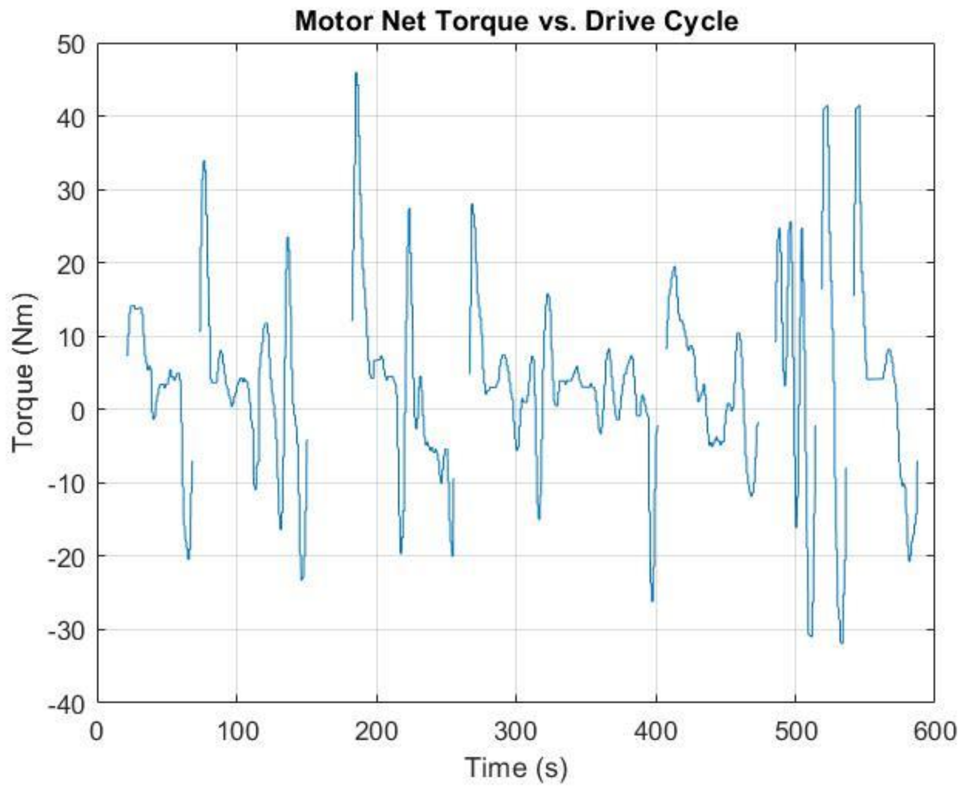

Figure 19: Motor net torque vs drive cycle

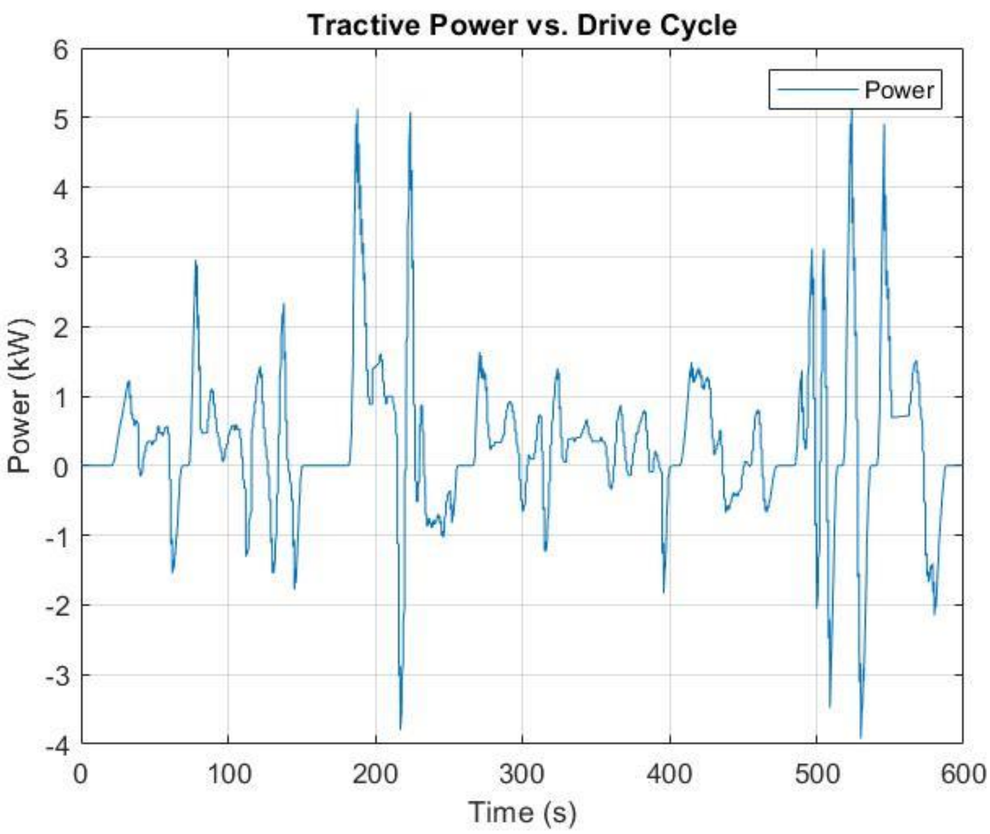

Figure 20: Tractive power vs drive cycle

The third plot, which shows the net torque required to move the electric bike forward, provides insights into the bike's ability to overcome resistance and climb hills. The y-axis of the plot represents net torque in Nm, while the x-axis represents time in seconds. This plot revealed that the electric bike required a maximum net torque of 47 Nm to move forward at certain times during the drive cycle. By analyzing this plot, the torque requirements of the bike under different driving conditions can be identified, and the appropriate motor and gearing can be selected to optimize the bike's performance. These three plots provide valuable information for optimizing the design of the electric bike to improve its performance and efficiency under different driving conditions. By improving the bike's energy efficiency, acceleration, and torque characteristics, its overall performance can be enhanced, and it can become more competitive in the marketplace. These insights can be used to fine-tune the design of the electric bike, leading to a more effective and efficient transportation solution.

4.14 Environmental Benefits

Considering electric vehicles, another aim is to study the direct emission reduction by converting to electric bike. A study done by (Ellingsen, 2017) provides data on environmental impact that energy require to manufacture a vehicle is equivalent to driving that same vehicle for 30,000 miles and energy required to manufacture a battery to drive that vehicle will be equivalent to drive that vehicle for another 15,000 miles. This data shows manufacturing any electric bike with will increase environmental pollution with extra energy consumption. So, our project aims to tackle this problem by converting any petrol bike to electric bike without creating it from scratch and saving energy and carbon equivalent to 30,000 miles drive.

For the study of environmental benefits that we are getting with the conversion is measured with the tail pipe emission test which was done in Vehicle Fitness Testing Center. The tailpipe emission test system was used to measure the CO, CO_2, and HC emissions from the exhaust of the project bike. This test system is designed to accurately measure the level of pollutants emitted by a vehicle's exhaust.

The principle of the tailpipe emission test is based on the fact that the exhaust gases from a vehicle contain pollutants that can be harmful to the environment and human health. The test system works by measuring the concentration of these pollutants in the exhaust gases. The exhaust gases were then sampled from the tailpipe and analyzed for the concentration of CO, CO_2, and HC using a gas analyzer. The test was repeated three times to obtain a more accurate average of the emissions. The data obtained from the test can help evaluate the effectiveness of emission reduction by converting it to electric one. The results can also be used to compare the emission levels of the bike before and after any modifications or conversions.

In the tail pipe emission test, three data of CO (% Vol), CO_2 (%Vol), and HC (% Vol) were taken for our project bike. The average of these values was calculated to further understand the emission level. These values were then compared with the Euro standard 5, which defines the maximum amount of pollutants that a vehicle can emit. The data obtained from the VFTC which is presented in below table.

Figure 21: Emission being measured in Vehicle Fitness Test Centre (VFTC), Teku

Table 7 Emission obtained from Emission Test

Pollutants	CO (% Vol)	CO_2 (%Vol)	HC (% Vol)
Test 1	0.9	3.34	0.0217
Test 2	0.8	2.86	0.0246
Test 3	0.61	1.96	0.025
Average	**0.77**	**2.72**	**0.0237**

Before the conversion, the bike emitted 0.77% volume of CO and 2.72% volume of CO_2, which were higher than the Euro standard 5 limit of 0.5% and 0.64%, respectively. The emission level of HC was within the limit at 0.0237% volume.

After the conversion, the emission level of all three pollutants reduced to 0% volume, which means that the bike now complies with the Euro standard 5 and emits no harmful pollutants which is shown in below table.

Table 8 Emission comparison for different conditions

Pollutants (% Vol)	Euro standard 5	Before Conversion	After Conversion
CO	0.5	0.77	0
CO_2	0.64	2.72	0
HC	0.01	0.0237	0

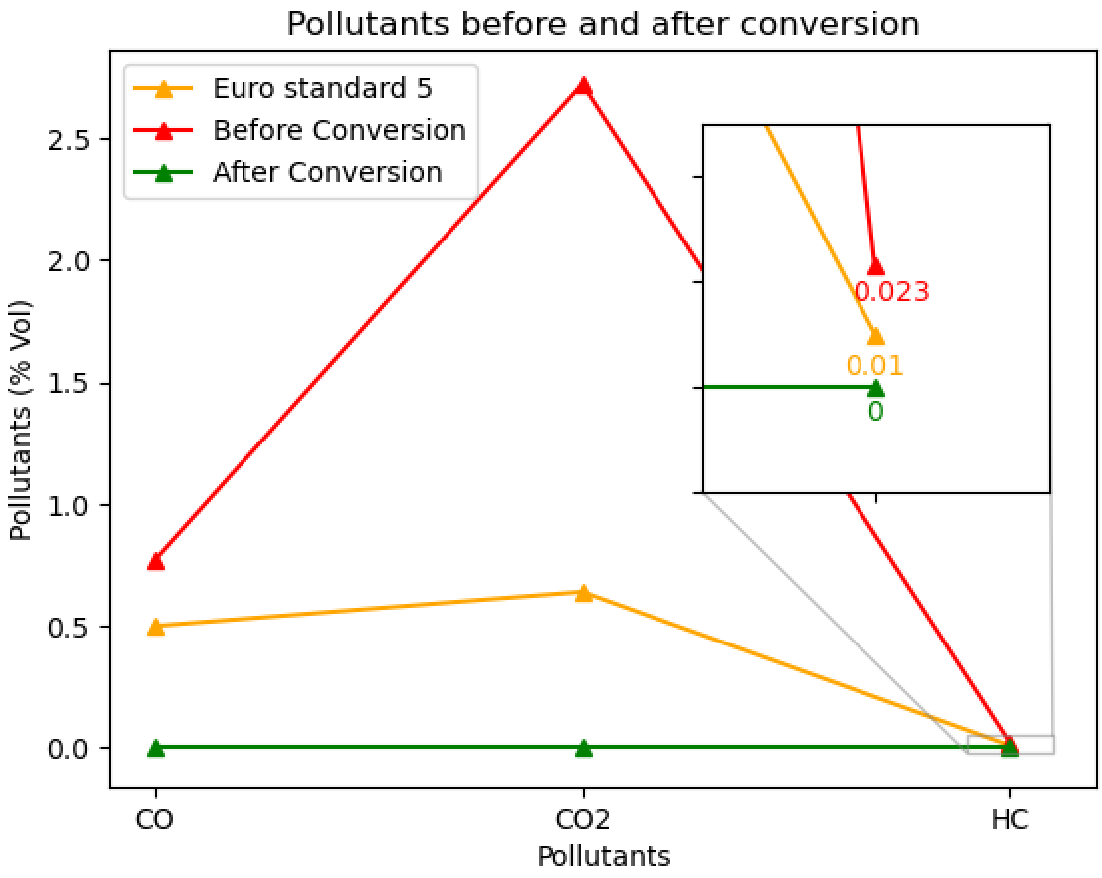

Figure 22: Plot for different emission conditions

A line chart was also plotted to visualize the change in emission levels before and after the conversion. The chart shows a significant drop in the emission level of all three pollutants after the conversion.

Table 9 Total emission saved during the lifetime of electric vehicle

Pollutants	Euro Standard(g/km)	Quantity (g/km)	Avg Distance Per Day (km)	Total Distance in Lifetime (km)	Total Saved Emissions (Kg)
CO	1	1.77	40	146000	258.42
CO_2	1.14	3.124	40	146000	456.104
HC	0.1	0.2376	40	146000	34.6896

The above table presents information on the emissions of three pollutants - CO (carbon monoxide), CO_2 (carbon dioxide), and HC (hydrocarbons) - and their corresponding Euro standards, which are emissions standards for vehicles set by the European Union. Main aim of the table is to study the carbon saved during the lifetime of the vehicle. The second column lists the Euro standard for each pollutant, expressed in grams per kilometer (g/km). The third column shows the quantity of each pollutant emitted per kilometer of driving, measured in grams per kilometer. The fourth column represents the average distance traveled per day in kilometers, assumed to be 40 km. The fifth column shows the total distance a vehicle would travel over its lifetime, which is assumed to be 146,000 km.

It shows the total amount of emissions saved by using a vehicle that meets the Euro standard, measured in kilograms (Kg). This calculation is based on the difference between the actual emissions of the vehicle and the emissions that would be produced if the vehicle met the Euro standard for each pollutant. The total emissions saved are the sum of the savings for each pollutant.

CO, CO_2, and HC are pollutants that are commonly found in vehicle exhaust. These pollutants are harmful to the environment and human health. Carbon monoxide (CO) is a colorless and odorless gas that can be deadly at high concentrations. It is formed when the fuel in the engine is not completely burned. CO can reduce the amount of oxygen that the body can absorb, leading to headaches, dizziness, and even death in severe cases.

Carbon dioxide (CO_2) is a greenhouse gas that contributes to climate change. It is produced when fossil fuels are burned and is one of the main drivers of global warming. High levels of CO_2 can cause a range of environmental problems, including sea-level rise, ocean acidification, and extreme weather events. Hydrocarbons (HC) are a group of pollutants that are formed when fuel is burned incompletely. They can cause smog and other air pollution problems. HC emissions can contribute to the formation of ground-level ozone, which can cause respiratory problems and other health issues.

Reducing the levels of CO, CO_2, and HC emissions in vehicle exhaust has several benefits for the environment. When these pollutants are reduced to zero, it can significantly improve the air quality and reduce the risk of health problems associated with exposure to these pollutants. It can also help mitigate the impacts of climate change by reducing the amount of greenhouse gases released into the atmosphere. Additionally, reducing emissions can help meet environmental regulations and reduce the overall carbon footprint of transportation. Overall, reducing emissions is crucial to creating a cleaner and healthier environment for everyone.

The Euro 5 emissions standards set limits on the maximum permissible emissions of various pollutants from passenger cars and light commercial vehicles sold in the European Union.

The specific limits for CO, CO_2, and HC emissions under Euro 5 are as follows:

- CO emissions: The limit for carbon monoxide (CO) emissions under Euro 5 is 0.5% volume, which means that the concentration of CO in the vehicle's exhaust gases cannot exceed 0.5% of the total volume of the exhaust gases.
- CO_2 emissions: Euro 5 does not set a specific limit for carbon dioxide (CO_2) emissions, but it does set limits on the average CO_2 emissions across a manufacturer's fleet of vehicles. For example, in 2015 the average CO_2 emissions of all new cars sold by a manufacturer could not exceed 130 grams per kilometer.
- HC emissions: The limit for hydrocarbon (HC) emissions under Euro 5 is 100 parts per million (ppm) by volume, which means that the concentration of HC in the vehicle's exhaust gases cannot exceed 100 ppm by volume.

It's worth noting that emissions standards can vary by vehicle type, engine size, and other factors. Additionally, newer Euro 6 standards have superseded the Euro 5 standards, which were introduced in 2009.

4.14.1 Total emission savings

The trend of bike import in Nepal is tabulated below. This shows that every year the number of bike import has been increasing which is due to increase of disposable income and inadequate public transport. This skyrocketing import has led to traffic congestion, air pollution, and safety concerns.

It is important for policymakers to consider the potential impacts of bike imports on the economy and the environment, and to develop policies and regulations that balance the benefits and risks of this trend.

Older bikes tend to have lower fuel efficiency compared to newer models, which means they consume more fuel to travel the same distance. This results in higher fuel consumption and increased cost to the owner. Additionally, older bikes may require more frequent maintenance and repairs, which can further increase fuel consumption and costs. Over time, the increased fuel consumption of older bikes can have a significant impact on the overall fuel consumption of the transportation sector. Similarly, older bikes also tend to produce higher levels of emissions compared to newer models. This is because older bikes are often equipped with outdated engine technology and emissions control systems, which can result in higher levels of pollutants such as carbon monoxide, hydrocarbons, and nitrogen oxides. These emissions can contribute to air pollution and have negative impacts on public health and the environment. In some countries, older bikes may not meet current emissions standards and may be required to undergo emissions testing or be retired from service.

To address the negative impacts of older bikes on fuel consumption and emissions, many countries have implemented policies and regulations aimed at encouraging the retirement of older vehicles and the adoption of newer, more fuel-efficient and cleaner models. These policies may include incentives for scrapping older bikes, mandatory emissions testing, and age limits on the registration of bikes. By encouraging the replacement of older bikes with newer, more efficient and cleaner models, countries can help reduce fuel consumption, emissions, and their negative impacts on the environment and public health.

Table 10 Trend of bike import in Nepal

SN	Year	No. of imported bikes	SN	Year	No. of imported bikes
1	046/47	34576	17	062/63	44610
2	047/48	5697	18	063/64	72568
3	048/49	9336	19	064/65	68667
4	049/50	8513	20	065/66	83334
5	050/51	10550	21	066/67	168707
6	051/52	11401	22	067/68	138907
7	052/53	12357	23	068/69	145135
8	053/54	15739	24	069/70	175381
9	054/55	12306	25	070/71	163945
10	055/56	17090	26	071/72	196383
11	056/57	19755	27	072/73	267439
12	057/58	29291	28	073/74	354071
13	058/59	36117	29	074/75	341623
14	059/60	29404	30	075/76	374371
15	060/61	26547	31	076/77	406225
16	061/62	31273	32	077/78	428512

Figure 23: Plot depicting the bike import trend in Nepal

Based on the above fact, we can calculate the total emission savings from old motorcycles which are running in our streets. Most motorcycle last for 10-15 years which is equivalent to 1, 46, 000 km.

Motorcycles which have been serving for ten to fifteen years are taken into account.

No. of old motorcycles = 6, 77, 318

(Rith et al., 2019) has calculated the vehicle survival rate using the Weibull distribution which is 0.5. So, using this survival factor we can calculate the motorcycles which are 10-15 years of age still running in roads.

Therefore, No. of running motorcycles = 0.5*Number of old motorcycles

= 0.5 * 6, 77, 318

= 3, 38, 659

Using this data, we can calculate the total emission saved by vehicles running in our roads.

Based on the emission result obtained from Vehicle Fitness Test Center for a single motorcycle, we can calculate the total savings from old motorcycles which is depicted in following table.

Table 11 Total emission savings

Pollutants	Total possible Conversion	Emission saved/conversion(kg)	Total possible emission savings (tonne)
CO	338659	258.42	87516.25878
CO_2	338659	456.104	154463724.5
HC	338659	43.689	14795673.05

4.15 Techno-Economic Analysis

Techno-economic analysis of conversion of petrol bike to electric bike is done using techno economic model which will represent then whole conversion process and cost related to the conversion of bike to final product. It consists of following elements to be considered. Techno economic analysis has been used in different project for the evaluation of economic feasibility/viability of Lithium-Ion Battery for motorcycle development.

Steps of techno-economic analysis (Kurniyati et al., 2016).

4.15.1 Process Design

A process flow diagram is a diagram representing sequence of general flow of the total process which involves the process from raw materials to final product. It mainly focuses on the major process, equipment and components. In gasoline to EV conversion process flow diagram shows the steps and process that will take place during the conversion which is shown in figure below.

4.15.2 Process Modeling

Process modelling is used to fully define the system with material balance calculation. This will help to analyze system on the basis of engineering calculations which corresponds to the process flow diagram. It follows the mass balance principal which can be written as:

$$\text{Mass Input} = \text{Mass Output} + \text{Mass Accumulation}$$

4.15.3 Equipment Sizing

Now from the process model, the estimation of sizing parameters for each equipment that will be used in in bike will be calculated. This will also account for the motor size, battery size, outer bike design and all the components that will be used throughout the conversion process

4.15.4 Capital Cost estimation

After completing all the modelling and equipment sizing, the capital cost of the total project should be calculated for the understanding of economic viability. The capital cost that will be invested for each piece of material that will be used is done using major equipment factored approach (Bates et al., 1997). All the purchase cost will be estimated from the equipment sizing table. This includes all the necessary items that will be purchased during the conversion process.

As Nepal does not manufacture diesel or electric vehicles, purchasing these vehicles represents the total production cost. This also applies to the cost of converting petrol bikes to electric bikes, representing the total cash outflow from the country. For example, the Yatri Project One electric bike has a market price above NRs. 5, 55,000, and this cost represents a significant outflow of cash from the country. In Nepal, the customs duty rate on petrol bikes is 50% of the customs value, and the VAT rate is 13% of the customs value plus the customs duty. Meanwhile, the customs duty rate on electric bikes is only 10%, with a 13% Value Added Tax (VAT) applied to both the customs duty and the customs value. These import taxes and fees contribute significantly to the overall cost of importing vehicles and significantly impact the economics of the transportation industry in Nepal.

In addition to the high customs duty and VAT rates on imported bikes, it is also important to consider the difficulty of importing and assembling bike components in Nepal. Due to the lack of a robust local manufacturing industry, many components must be imported from abroad, adding to the cost and complexity of the conversion process. Importing and assembling bike components in Nepal can be a particularly challenging task due to various factors, including inadequate infrastructure and complex regulatory procedures. These factors can lead to delays in the importation process, resulting in higher costs for importers and increased lead times for production. Furthermore, the lack of a well-established local supply chain can make it difficult to obtain the necessary components, and the availability of skilled labor can also be a challenge. These factors can increase the cost of the conversion process and hinder the development of a thriving local industry.

The high customs duty and VAT rates on imported bikes, coupled with the challenges of importing and assembling components in Nepal, make it difficult and costly to produce electric and diesel bikes locally. Addressing these challenges will be critical to developing a sustainable and thriving transportation industry in Nepal that can support economic growth and reduce reliance on fossil fuel imports. The following parameters are listed in the table considering the tentative budget plan are the key factors included while further progressing our project:

Table 12 Bike conversion cost

Bike Conversion Cost				
S.N.	Particulars	Quantity	Unit Cost (Rs.)	Amount (Rs.)
1.	BLDC Motor (2 kW, 72 V)	1 nos	88,000	88,000
2.	Li-ion NMC 21700 Battery Pack (72V, 42Ah)	1	1,20,000	1,20,000
5.	BMS (17S 60V)	1 nos	15,000	15,000
7.	Controller	1 nos	10,000	10,000
8.	Extension wire	1 unit	5,000	5,000
9.	Throttle and LED Display	1 nos	15,000	15,000
10.	Miscellaneous			5,000
			Total Amount	Rs. 2,58,000

4.15.5 Operating cost estimation

The table provided above offers an in-depth estimation of the bike conversion cost involved in a project, which does not comprise computational work, data collection, and instrumental rental charges. While exploring the Nepalese market scenarios and the price tariffs, the computational cost amounts to Rs 25,000, encompasses the expenses incurred in using computers and other technological equipment for processing data or carrying out simulations. The data collection cost, on the other hand, comes to Rs 20,000, representing the cost of collecting data from different sources like surveys, interviews, or experiments. Furthermore, the instrumental rental charges are Rs 40,000, which signifies the expenses incurred in renting specialized equipment or instruments for the project, such as laboratory equipment, sensors, or measuring devices. Lastly, the "others" category has a cost of Rs 15,000 as an estimation, covering other miscellaneous expenses, such as travel costs, communication expenses, or other overhead costs.

4.15.6 Comparative Analysis

The main aim of this techno-economic analysis is the study of commercialization and feasibility of the Petrol bike to EV conversion in context of plain region of Nepal. While analyzing the comparative analysis the advantages and disadvantages of each option in terms of cost, environmental impact and other factors should be considered. Ultimately, the decision to buy a petrol bike or convert it to an electric bike will depend on a variety of factors, including individual needs and preferences and budget. A thorough comparative analysis of cost, and drawbacks of few of the options are discussed below that aligns to help the goal and their strategies:

4.15.7 Based on fuel cost over the period of 5 years

The given factors represent a comparative analysis of a petrol bike before conversion and an electric bike after conversion.

Before conversion, the petrol bike has a mileage of 30 km/liter and a fuel unit cost of Rs. 178/liter. After conversion to an electric bike, the mileage decreases to 13.22 km/hr, and the fuel unit cost reduces to Rs. 10/KWh. The comparison of the two factors reveals that the electric bike has a lower mileage than the petrol bike. However, the fuel unit cost for the electric bike is significantly lower than that of the petrol bike. This means that the electric bike is more cost-efficient in terms of fuel consumption compared to the petrol bike.

It's worth noting that the electric bike's lower mileage is compensated for by its lower fuel unit cost. The cost per kilometer of the electric bike might be lower than the petrol bike, despite its lower mileage. The analysis suggests that converting from a petrol bike to an electric bike can be economically beneficial in terms of fuel consumption costs.

The above analysis clearly shows that the fuel cost for an electric bike is significantly lower than that of a petrol bike. Considering the distance traveled of 40km per day, the annual fuel cost for a petrol bike is NPR 75,085.71, whereas it is only NPR 10,950 for an electric bike. This amounts to a savings of NPR 64,135.71 per year, which is a considerable amount. Over a period of 5 years, the savings from using an electric bike becomes even more significant, with a total savings of NPR 3, 20,878.57 compared to a petrol bike.

Given the increasing concern for environmental pollution and the limited resources of Nepal, it is important to consider the long-term economic and environmental benefits of electric bikes over petrol bikes. With the rising fuel prices and limited availability of fossil fuels, electric bikes present a viable alternative for the transportation sector in Nepal. Additionally, the low operating cost of electric bikes makes it an attractive option for people who rely on transportation for their daily activities.

Therefore, in the context of Nepal's transportation scenario, electric bikes are more suited than petrol bikes due to their lower fuel cost and environmental benefits. With the advancement of technology and infrastructure, the use of electric bikes can be promoted and encouraged for a sustainable transportation system in Nepal.

4.15.8 Based on the payback period over the 10 years

Table 13 Fuel savings after conversion

	Before Conversion	**After Conversion**
	Petrol Bike	**Electric Bike**
Milage	30 km/liter	13.22 km/kWh
Fuel Unit Cost	Rs. 178 /liter	10 Rs/kWh
Distance Travelled	40 km/day	
	14,600 km/year	
	73,000 km/5 year	
Fuel Cost	NPR. 205.71 /day	NPR. 30 /day
	NPR. 75085.71 /yr	NPR. 10,950 /yr
	NPR. 3,75,428.57 /5 yrs	**NPR. 54,750 /5 yrs**

$$Payback\ period = Initial\ investment/Total\ savings$$

$$= 2,58,000/(75,085.71 - 10,950)$$

$$= 4.023\ years$$

Table 14 Economic analysis of buying new gasoline bike, converted bike and new electric bike using Net Future Value

Economic Analysis			
	Buying New	**Conversion**	**Buying New**
	Petrol Bike	**To Electric Bike**	**Electric Bike**
Buying/Converting Cost	300,000.00	258,000.00	479,000.00
	Fuel Cost Each year		
Year 1	75,085.71	10,950.00	10,950.00
Year 2	75,085.71	10,950.00	10,950.00
Year 3	75,085.71	10,950.00	10,950.00
Year 4	75,085.71	10,950.00	10,950.00
Year 5	75,085.71	10,950.00	10,950.00
Battery Replacement Cost	0.00	120,000.00	120,000.00
Year 6	75,085.71	10,950.00	10,950.00
Year 7	75,085.71	10,950.00	10,950.00
Year 8	75,085.71	10,950.00	10,950.00
Year 9	75,085.71	10,950.00	10,950.00
Year 10	75,085.71	10,950.00	10,950.00
Net Future Value	**2,249,396.60**	**1,755,790.67**	**2,442,172.47**

While breaking down the above statistics, for instance, a new petrol bike costs around NRs. 300,000, while converting it to an electric bike costs NRs. 258,000 initially. The annual fuel cost for a petrol bike is NRs. 75,085.71 for the first five years, while an electric bike will cost only NRs. 10,950.00 per year during the same period. In the fifth year, the petrol bike will not require a battery replacement, whereas the electric bike will cost NRs. 120,000 for a new battery. Between the sixth and tenth years, the fuel cost for a petrol bike will be NRs. 75,085.71 per year, whereas an electric bike will cost only NRs. 10,950 per year.

Calculating the net future value of both vehicles over a ten-year period, the cost of owning and operating a petrol bike will be approximately NRs. 2,249,396.60, while converting a petrol bike to an electric one will cost only NRs. 1,755,790.67. The payback period for converting a petrol bike to an electric is 4.23 years, considering the initial investment and total savings over ten years of use, which amounts to NRs. 493,606. In addition to fuel and battery costs, savings can also be realized through reduced maintenance costs, such as lubricating oil, clutch plates, air filters, and spark plugs. These factors contribute to the overall economic advantages of converting to an electric bike.

5 CONCLUSION and RECOMMENDATIONS

The conversion of gasoline-based bikes to electric bikes is an emerging trend in the transportation industry. This project aims to analyze the economic, environmental, and design aspects of such a conversion in the context of Nepal. This discussion focuses on the findings of the project and the implications for the transportation industry in Nepal. Firstly, the environmental benefits of converting a gasoline-based bike to an electric bike are significant.

The emissions of CO, CO_2, and HC reduce to zero after the conversion. This indicates a significant reduction in pollutants emitted by the vehicle, leading to a cleaner environment. The line chart visualizes the reduction in emissions levels before and after the conversion, which further highlights the positive environmental impact of the conversion. The reduction in emissions is particularly important in the context of Nepal, where air pollution is a significant problem, especially in urban areas. Therefore, the conversion to electric bikes can contribute to a cleaner and healthier environment in Nepal. However, the economic analysis of the conversion presents some challenges. Nepal does not manufacture diesel or electric vehicles, and therefore, the total production cost is the purchasing cost.

The Yatri Project One electric bike, for example, has a market price above NRs. 5, 75,000, which represents a significant outflow of cash from the country. In addition, the high customs duty and VAT rates on imported bikes and the difficulty of importing and assembling bike components in Nepal add to the cost and complexity of the conversion process. These factors can increase the cost of the conversion process and hinder the development of a thriving local industry. Despite the economic challenges, electric bikes offer several advantages over petrol bikes. The low operating cost of electric bikes makes it an attractive option for people who rely on transportation for their daily activities.

The rising fuel prices and limited availability of fossil fuels in Nepal make electric bikes a viable alternative for the transportation sector in Nepal. Furthermore, the promotion and encouragement of electric bike use can contribute to a sustainable transportation system in Nepal. In terms of design, the conversion process can be complex due to the lack of a robust local manufacturing industry. Many components must be imported from abroad, adding to the cost and complexity of the conversion process. Therefore, the availability of skilled labor and the establishment of a well-established local supply chain are crucial for the success of the conversion process.

Moreover, the drive cycle plot is an important tool in the design and development of electric vehicles. It allows for the evaluation of the vehicle's energy efficiency, range, and overall performance using real-world driving conditions. The drive cycle helps to optimize the design of the vehicle's drivetrain, battery, and other components, to maximize energy efficiency and range. It also helps to evaluate the vehicle's emissions, including greenhouse gas emissions and pollutants such as nitrogen oxides and particulate matter. This information is important for meeting regulatory requirements and ensuring that the vehicle meets environmental standards.

In conclusion, the conversion of gasoline-based bikes to electric bikes presents significant environmental benefits in terms of reduced emissions. However, the economic analysis presents some challenges due to the high cost and complexity of the conversion process. Despite the challenges, electric bikes offer several advantages over petrol bikes, including low operating costs, which make it an attractive option for the transportation sector in Nepal. Therefore, with the advancement of technology and infrastructure, the use of electric bikes can be promoted and encouraged for a sustainable transportation system in Nepal.

There are some short comings to this project and therefore, we suggest the following recommendations for future work.

1. Before starting the project, it's important to define the scope and objectives clearly. This will help to identify the key requirements, deliverables, and timelines.
2. The success of the project largely depends on selecting the right components for the electric motor and battery pack. The motor should be powerful enough to provide sufficient torque and speed, while the battery should be able to provide enough energy to drive the motorcycle for a reasonable distance. It's important to research and select components that are reliable, efficient, and cost-effective.
3. Design of electrical components require specialized knowledge in electrical engineering and mechanical engineering. It's important to follow established design practices and safety standards.
4. It is recommended to use locally available components rather than importing from abroad as far as possible.
5. While preparing the budget, detailed cost analysis of the components, labor, overhead cost, government tariffs and custom charge should be included which could make a project expensive.

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APPENDIX

1. Python code for emission plot

```
import matplotlib.pyplot as plt

from matplotlib.pyplot import *

# Data

pollutants = ['CO', 'CO2', 'HC']

euro5_std = [0.5, 0.64, 0.01]

before_conversion = [0.77, 2.72, 0.023]

after_conversion = [0, 0, 0]

# Plotting

fig, ax = plt.subplots()

ax.plot(pollutants, euro5_std, label='Euro standard 5',marker='^',color='orange')

ax.plot(pollutants, before_conversion, label='Before
Conversion',marker='^',color='red')

ax.plot(pollutants, after_conversion, label='After
Conversion',marker='^',color='green')

# Add labels and legend

ax.set_xlabel('Pollutants')

ax.set_ylabel('Pollutants (% Vol)')
```

```
ax.set_title('Pollutants before and after conversion')

ax.legend()



# Zoom in on the HC part

axins = ax.inset_axes([0.6, 0.4, 0.35, 0.5])

#axins.plot(pollutants, before_conversion, label='Before Conversion')

#axins.plot(pollutants, after_conversion, label='After Conversion')

axins.set_xlim(1.9, 2.1)

axins.set_ylim(-0.02, 0.05)

axins.set_xticklabels('')

axins.set_yticklabels('')

ax.indicate_inset_zoom(axins)

# plot the Euro standard 5 line in the zoomed area

axins.plot(pollutants, euro5_std, label='Euro standard 5',marker='^',color='orange')

axins.plot(pollutants, before_conversion, label='Euro standard
5',marker='^',color='red')

axins.plot(pollutants, after_conversion, label='Euro standard
5',marker='^',color='green')



axins.text(2, 0.004, str(0.01), ha='center', va='center',color='orange')
```

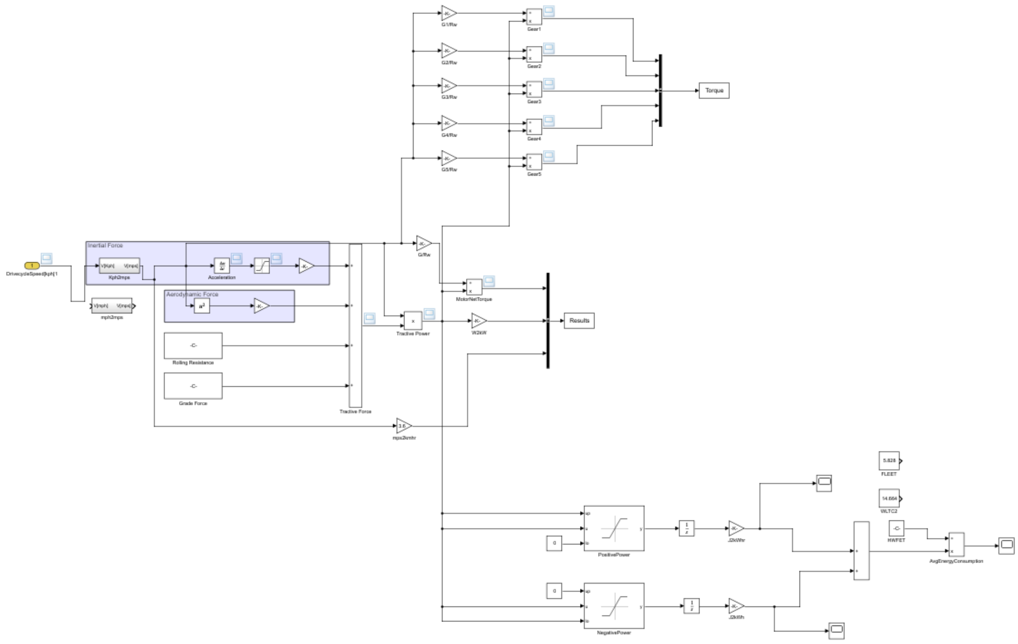
```
axins.text(2.01, 0.018, str(0.023), ha='center', va='center',color='red')

axins.text(2, -0.005, str(after_conversion[2]), ha='center', va='center',color='green')

grid()

plt.show()
```

2. Matlab Simulink Model for the Drive cycle Analysis



3. VFTC testing

Figure 24: Chassis dynamometer test

Figure 25: Emission test using flue gas analyzer

4. Drive Cycle Test Data

Part	version	time in s	v in km/h	time in s	v in km/h	time in s	v in km/h	time in s	v in km/h	time in s	v in km/h
1	8	1	0	61	29.7	121	31	181	0	241	38.3
1	8	2	0	62	26.9	122	32.8	182	0	242	36.4
1	8	3	0	63	23	123	34.3	183	2	243	34.6
1	8	4	0	64	18.7	124	35.1	184	6	244	32.7
1	8	5	0	65	14.2	125	35.3	185	12.4	245	30.6
1	8	6	0	66	9.4	126	35.1	186	21.4	246	28.1
1	8	7	0	67	4.9	127	34.6	187	30	247	25.4
1	8	8	0	68	2	128	33.7	188	37.1	248	23.1
1	8	9	0	69	0	129	32.2	189	42.5	249	21.2
1	8	10	0	70	0	130	29.6	190	46.6	250	19.5
1	8	11	0	71	0	131	26	191	49.8	251	17.8
1	8	12	0	72	0	132	22	192	52.4	252	15.2
1	8	13	0	73	0	133	18.5	193	54.4	253	11.5
1	8	14	0	74	1.7	134	16.6	194	55.6	254	7.2
1	8	15	0	75	5.8	135	17.5	195	56.1	255	2.5
1	8	16	0	76	11.8	136	20.9	196	56.2	256	0
1	8	17	0	77	18.3	137	25.2	197	56.2	257	0
1	8	18	0	78	24.5	138	29.1	198	56.2	258	0
1	8	19	0	79	29.4	139	31.4	199	56.7	259	0
1	8	20	0	80	32.5	140	31.9	200	57.2	260	0
1	8	21	0	81	34.2	141	31.4	201	57.7	261	0
1	8	22	1	82	34.4	142	30.6	202	58.2	262	0
1	8	23	2.6	83	34.5	143	29.5	203	58.7	263	0
1	8	24	4.8	84	34.6	144	27.9	204	59.3	264	0
1	8	25	7.2	85	34.7	145	24.9	205	59.8	265	0
1	8	26	9.6	86	34.8	146	20.2	206	60	266	0
1	8	27	12	87	35.2	147	14.8	207	60	267	0.5
1	8	28	14.3	88	36	148	9.5	208	59.9	268	2.9
1	8	29	16.6	89	37	149	4.8	209	59.9	269	8.2
1	8	30	18.9	90	37.9	150	1.4	210	59.9	270	13.2
1	8	31	21.2	91	38.5	151	0	211	59.9	271	17.8
1	8	32	23.5	92	38.8	152	0	212	59.9	272	21.4
1	8	33	25.6	93	38.8	153	0	213	59.8	273	24.1
1	8	34	27.1	94	38.7	154	0	214	59.6	274	26.4
1	8	35	28	95	38.4	155	0	215	59.1	275	28.4
1	8	36	28.7	96	38	156	0	216	57.1	276	29.9
1	8	37	29.2	97	37.4	157	0	217	53.2	277	30.4
1	8	38	29.8	98	36.9	158	0	218	48.3	278	30.5
1	8	39	30.3	99	36.6	159	0	219	43.9	279	30.3
1	8	40	29.6	100	36.4	160	0	220	40.3	280	30.2
1	8	41	28.7	101	36.4	161	0	221	39.5	281	30.1
1	8	42	27.9	102	36.5	162	0	222	41.3	282	30.1
1	8	43	27.5	103	36.7	163	0	223	45.2	283	30.1
1	8	44	27.3	104	36.9	164	0	224	50.1	284	30.1
1	8	45	27.3	105	37	165	0	225	53.7	285	30.1

1	8	46	27.4	106	37.2	166	0	226	55.8	286	30.1
1	8	47	27.5	107	37.3	167	0	227	55.8	287	30.2
1	8	48	27.6	108	37.4	168	0	228	54.7	288	30.4
1	8	49	27.6	109	37.3	169	0	229	53.3	289	31
1	8	50	27.7	110	36.8	170	0	230	52.2	290	31.8
1	8	51	27.8	111	35.8	171	0	231	52	291	32.7
1	8	52	28.1	112	34.6	172	0	232	52.1	292	33.6
1	8	53	28.6	113	31.8	173	0	233	51.8	293	34.4
1	8	54	28.9	114	28.9	174	0	234	50.8	294	35
1	8	55	29.2	115	26.7	175	0	235	49.2	295	35.4
1	8	56	29.4	116	24.6	176	0	236	47.4	296	35.5
1	8	57	29.7	117	25.2	177	0	237	45.7	297	35.3
1	8	58	30.1	118	26.2	178	0	238	43.9	298	34.9
1	8	59	30.5	119	27.5	179	0	239	42	299	33.9
1	8	60	30.7	120	29.2	180	0	240	40.2	300	32.4
1	8	301	30.6	361	27.1	421	34	481	0	541	0
1	8	302	28.9	362	26	422	35.4	482	0	542	2.7
1	8	303	27.8	363	25.4	423	36.5	483	0	543	8
1	8	304	27.2	364	25.5	424	37.5	484	0	544	16
1	8	305	26.9	365	26.3	425	38.6	485	0	545	24
1	8	306	26.5	366	27.3	426	39.7	486	1.4	546	32
1	8	307	26.1	367	28.4	427	40.7	487	4.5	547	37.2
1	8	308	25.7	368	29.2	428	41.5	488	8.8	548	40.4
1	8	309	25.5	369	29.5	429	41.7	489	13.4	549	43
1	8	310	25.7	370	29.4	430	41.5	490	17.3	550	44.6
1	8	311	26.4	371	28.9	431	41	491	19.2	551	45.2
1	8	312	27.3	372	28.1	432	40.6	492	19.7	552	45.3
1	8	313	28.1	373	27.2	433	40.3	493	19.8	553	45.4
1	8	314	27.9	374	26.3	434	40.1	494	20.7	554	45.5
1	8	315	26	375	25.7	435	40.1	495	23.6	555	45.6
1	8	316	22.7	376	25.5	436	39.8	496	28.1	556	45.7
1	8	317	19	377	25.6	437	38.9	497	32.8	557	45.8
1	8	318	16	378	26	438	37.5	498	36.3	558	45.9
1	8	319	14.6	379	26.4	439	35.8	499	37.1	559	46
1	8	320	15.2	380	27	440	34.2	500	35.1	560	46.1
1	8	321	16.9	381	27.7	441	32.5	501	31.1	561	46.2
1	8	322	19.3	382	28.5	442	30.9	502	28	562	46.3
1	8	323	22	383	29.4	443	29.4	503	27.5	563	46.4
1	8	324	24.6	384	30.2	444	28	504	29.5	564	46.7
1	8	325	26.8	385	30.5	445	26.5	505	34	565	47.2
1	8	326	27.9	386	30.3	446	25	506	37	566	48
1	8	327	28.1	387	29.5	447	23.4	507	38	567	48.9
1	8	328	27.7	388	28.7	448	21.9	508	36.1	568	49.8
1	8	329	27.2	389	27.9	449	20.4	509	31.5	569	50.5
1	8	330	26.7	390	27.5	450	19.4	510	24.5	570	51
1	8	331	26.6	391	27.3	451	18.8	511	17.5	571	51.1
1	8	332	26.8	392	27	452	18.4	512	10.5	572	51
1	8	333	27	393	26.5	453	18	513	4.5	573	50.4
1	8	334	27.2	394	25.8	454	17.5	514	1	574	49

1	8	335	27.4	395	25	455	16.9	515	0	575	46.7
1	8	336	27.5	396	21.5	456	16.4	516	0	576	44
1	8	337	27.7	397	16	457	16.6	517	0	577	41.1
1	8	338	27.9	398	10	458	17.7	518	0	578	38.3
1	8	339	28.1	399	5	459	19.3	519	2.9	579	35.4
1	8	340	28.3	400	2.2	460	20.9	520	8	580	31.8
1	8	341	28.6	401	1	461	22.3	521	16	581	27.3
1	8	342	29	402	0	462	23.2	522	24	582	22.4
1	8	343	29.5	403	0	463	23.2	523	32	583	17.7
1	8	344	30.1	404	0	464	22.2	524	38.8	584	13.4
1	8	345	30.5	405	0	465	20.3	525	43.1	585	9.3
1	8	346	30.7	406	0	466	17.9	526	46	586	5.5
1	8	347	30.8	407	0	467	15.2	527	47.5	587	2
1	8	348	30.8	408	1.2	468	12.3	528	47.5	588	0
1	8	349	30.8	409	3.2	469	9.3	529	44.8	589	0
1	8	350	30.8	410	5.9	470	6.4	530	40.1	590	0
1	8	351	30.8	411	8.8	471	3.8	531	33.8	591	0
1	8	352	30.8	412	12	472	1.9	532	27.2	592	0
1	8	353	30.8	413	15.4	473	0.9	533	20	593	0
1	8	354	30.9	414	18.9	474	0	534	12.8	594	0
1	8	355	30.9	415	22.1	475	0	535	7	595	0
1	8	356	30.9	416	24.7	476	0	536	2.2	596	0
1	8	357	30.8	417	26.8	477	0	537	0	597	0
1	8	358	30.4	418	28.7	478	0	538	0	598	0
1	8	359	29.6	419	30.6	479	0	539	0	599	0
1	8	360	28.4	420	32.4	480	0	540	0	600	0

Source: Worldwide Harmonised Motorcycle Emissions Certification Procedure