Cost-Efficient Electric Bike as a Sustainable Transportation Alternative for Delivery of Goods

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***Abstract*—The main gist is to give a clear view by bridging the various energy sources available to humanity. The human sensibility for the energetic and environmental problems encourages research in alternative solutions for the automotive field, such as multiple-fuelling, hybridization, and electrification. The project can be considered a synthesis of a broad activity including design, modeling, control, and testing with its leading innovative solutions. In this context, a vehicle like the electrically assisted bike can be considered an excellent alternative vehicle for personal mobility and goods delivery, especially for small and medium distances at an affordable price worth for the common people. The lightweight battery pack, which plugs into any outlet and can charge in just four hours, is located in the center of the bike and can easily be removed for charging. The e-bike can travel up to 20 miles per hour while in throttle mode. A fully sustainable electric motorcycle will be created, which will not only addresses a regular bicycle's drawbacks but includes features to make it more appealing to people that generally would not consider commuting on a bike.**

Keywords—e-bike, motor, battery, controller, ergonomics.

I. INTRODUCTION

A significant contemporary phenomenon that may profoundly impact mobility patterns is the emergence of the electrically assisted cycle or what is more commonly known as the "e-bike". E-bikes typically incorporate a battery, which can be charged at an ordinary domestic power socket linked to an electric motor in the bicycle transmission system. The term "e-bike" is generic and includes a combination of different electrically powered two-wheelers, some of which function by simply turning a throttle. Electric bicycles, like other electric vehicles, use a BLDC motor. This paper presents a way of designing and implementing an electronic module for an e-Bike. The paper shows how low power can be utilized to drive such a motor and manage other useful functions on an e-Bike. E-Bike makes use of these BLDC motors as the propulsion method. Since BLDC motors do not have brushes, they present some advantages over the D.C. brushed motors, from which we remember:

(1) Longer life span
(2) Lower EMI (Electromagnetic interference) radiation
(3) Noiseless operation
(4) Grater torque to motor size ratio.

The premise of this paper is to overcome many of these barriers by technological means at minimal cost to create usable transport for public use.

II. PROBLEM STATEMENT

1) Providing an intermediate solution of e-bike having good comfort and affordable price.

2) To provide a suitable delivery bike option with low investment.

3) Most low-priced e-bike are having Chinese motors, whereas we are providing Indian motors.

III. OBJECTIVES

1) To provide good comfort at an affordable price, we made a fusion of e- bicycle and e-bike.
2) To provide safe transportation in this pandemic situation.
3) To scale back effort in pedaling of the bicycle & to enforce the comfort of consumers along with a clean and energy-efficient vehicle.

4) Delivery bike having carriage capacity of 60-70 kg

5) Product values the factors such as cost, performance, aesthetics, schedule or time-to-market, and quality.

6) Affordable mobility to the common society.

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IV. ABBREVIATIONS

F total = Total tractive force that the output of the motor must overcome to move the vehicle.

F r = force due to Rolling Resistance

F a = Acceleration force

F aerodynamic drag =force due to aerodynamic drag

Crr = coefficient of rolling resistance

M= mass in kg

g= acceleration due to gravity= 9.81 m/s 2

P=Power Required

T=Torque Required

V. METHODOLOGY

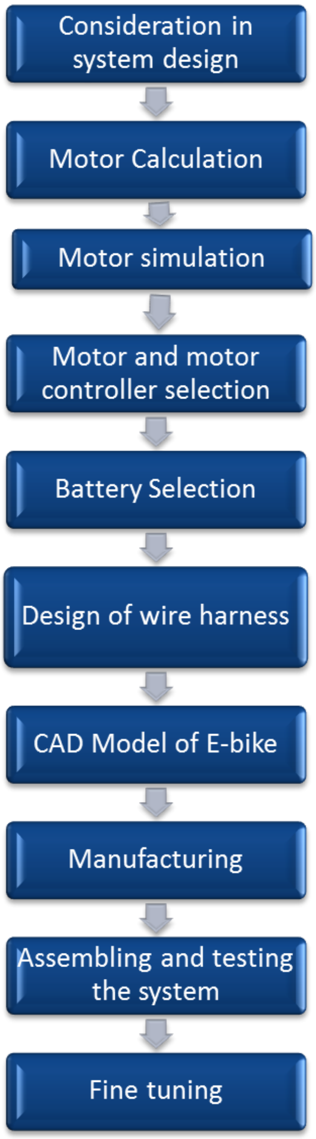

Fig1. Design Flowchart

VI. DESIGN CONSIDERATIONS

1) Max load-carrying capacity -120kg
2) Max speed – 25kmph
3) Rolling resistance for Asphalt/Concrete road-0.04
4) Max inclination of road surface- 2-3degree.

VII. LITERATURE REVIEW

A steadily growing number of cities worldwide are eager to become cities of bicycles as part of an overall strategy on sustainable development and the desire to become green cities.

Why do we need green mobility:

"Green mobility is sustainable transportation that allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations. Green mobility is affordable, operating efficiently, offering a choice of transport mode, and supporting a vibrant economy". "It limits emissions and waste within the planet's ability to absorb them, minimizes consumption of non-renewable resources, limits consumption of renewable resources to the sustainable yield level, reuses and recycles its components, and minimizes the use of land and the production of noise."

The Benefits of Green Mobility:

- A Less Polluted Environment
- Improved Health
- More Sustainable Economic Development
- Money-Saving

❑ MAJOR FINDINGS

- It was found that most of the customers are not much satisfied with the price of the product.
- It was found that most of the customers were satisfied with the mileage of the Electric bikes and are convinced about the electric bike benefits, and were willing to refer it to their friends.
- It was found that most of the customers are not satisfied with after-sales service. It shows that customers are dissatisfied with after-sale service.
- It was found that the maximum numbers of the customers felt the speed of the electric bikes to be very low and were not satisfied with the current speed of the bikes.
- It was found that most of the respondents feel that the factors such as speed & power, battery life, and appearance of Electric Bikes are the main reasons for its lower market share.

- Essential components in E-bike**:**

A few critical components (battery, controller, motor) and several accessory components (displays, throttles, PAS sensors) make up an electric bike.

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a. Battery pack:

Modern E-bike batteries are almost exclusively lithium-ion. Lithium battery technology matured. It got lighter, more powerful, more reliable, and with an increasingly long cycle life. It is at a point that now a modern lithium battery made with top-tier cells is 8-10 times lighter than the lead batteries of yesteryear, and when not abused, they can be expected to provide well over 5-6 years of regular use.

Fig2. Battery

b. Motor

The electric motor turns electrical energy from the battery into mechanical power to move the bike.

The electric motor is inside either the front or rear bicycle hub in a hub motor, allowing for a reasonably simple conversion where you replace a regular bike wheel with the motorized wheel. These days, nearly all E-bike motors are permanent magnet Brushless DC (BLDC) motors that have 3 phase wires for supplying motor power. In addition to these 3 phase wires to power the hub, they also typically have five hall sensor wires that allow the electronics to determine the motor position to spin smoothly at low speed.

These wires may be split into separate connectors or integrated into a single plug with both the power and signal wires. The motor controller is a component that is unfamiliar to many people. However, it is essential to any bike hardware since you cannot directly connect a brushless motor to a battery pack. The motor controller serves two critical functions.

It converts the D.C. voltage of the battery pack into 3 phase alternating current for the motor windings without which the motor could not spin, and
It can continuously adjust the voltage going to the motor, from 0V up to the total battery pack voltage, in response to the user's throttle signal, pedal sensors, and various current limits.

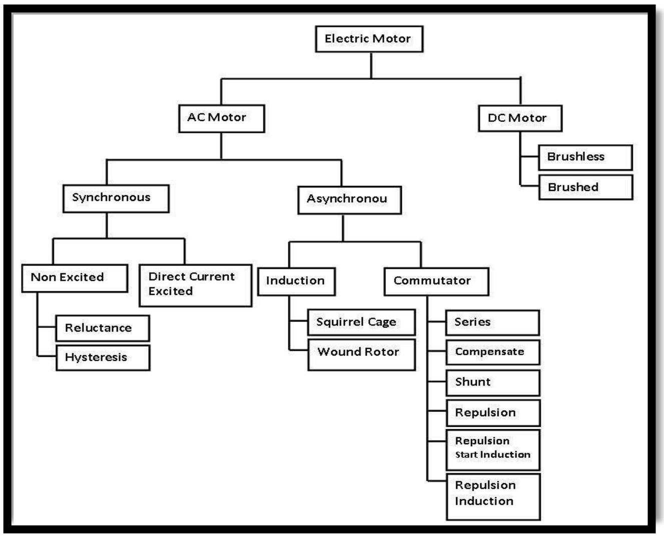

Fig 3. Classification of Motors

Fig4. Hub Motor

c. Throttle

A throttle is the most basic and familiar way of allowing the rider to regulate the amount of power they get from the motor by pressing a throttle lever or twisting a grip mounted on the handlebar. A throttle gives the rider complete control of the amount of power coming from the electric motor at any given time, regardless of how hard they are pedalling.

Fig5. Electronic Throttle

d. Controller

The motor controller is a component that is unfamiliar to many people. However, it is essential to any bike hardware since you cannot directly connect a brushless motor to a battery pack. The motor controller serves two critical functions.

- It converts the D.C. voltage of the battery pack into 3 phase alternating current for the motor windings without which the motor could not spin.
- It can continuously adjust the voltage going to the motor, from 0V up to the total battery pack voltage, in response to the user's throttle signal, pedal sensors, and various current limits.

Motor controllers usually have a specific voltage range they will work in, and they will also have a current limit that defines the maximum amperage that they will draw from the battery pack. A small low current motor controller might be rated for 14 amps, which means it will only draw a maximum of 14 Amps from the battery pack. When the motor attempts to draw more current than this, the controller automatically reduces the voltage provided to the motor to keep the battery current drawn right at the limit. If you use a low amperage motor controller with a large hub motor, the system will work fine, but you will not be getting nearly as much power from the motor as it is capable of. Conversely, if you use a high amperage motor controller with a small motor, you risk overheating and damaging the motor or stripping the internal gears or clutch.

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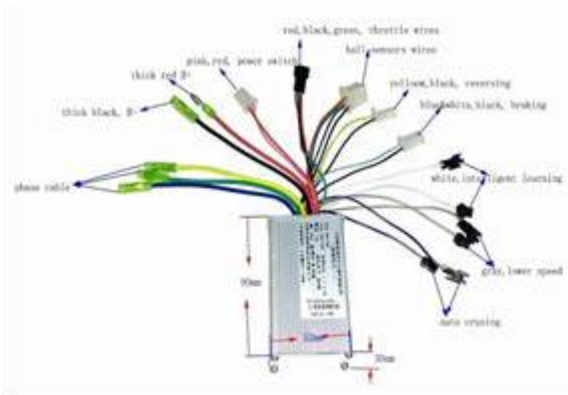

Fig6. Controller

• ERGONOMICS AND ANTHROPOLOGY

The International Ergonomics Association defined ergonomics as a scientific discipline to design and optimize human well-being while interacting with industrial products. The fundamental aim of ergonomics is to eliminate the discomforting symptom, which causes low satisfaction, limits motion, and long-term disability. The research method of ergonomics dealing with measuring the human body's posture and physical characteristics is known as Anthropometry. Ergonomics tells the producer the optimum output for sitting and the comfort while riding the bike.

The principles of ergonomic design are considered in five levels are determined below :

1. An equipment/machinery must be safe while in contact with human beings.
2. An equipment/machinery must not produce harmful effects in human beings over more extended periods.
3. An equipment/machinery must be physically comfortable. That is, it should not require excessive efforts, both physical and mental or visual.
4. An equipment/machinery should provide mental satisfaction or give pleasure to the human being using the same. This must also include the cost price of equipment against the function of the same.
5. Determining the degree of modernity of equipment/machinery ergonomic considerations must constitute an essential factor of the social profitability of the equipment/machinery. Even at establishing the design assumptions of equipment/machinery, it is necessary to introduce both ergonomic.

VIII. DESIGN PROCEDURE

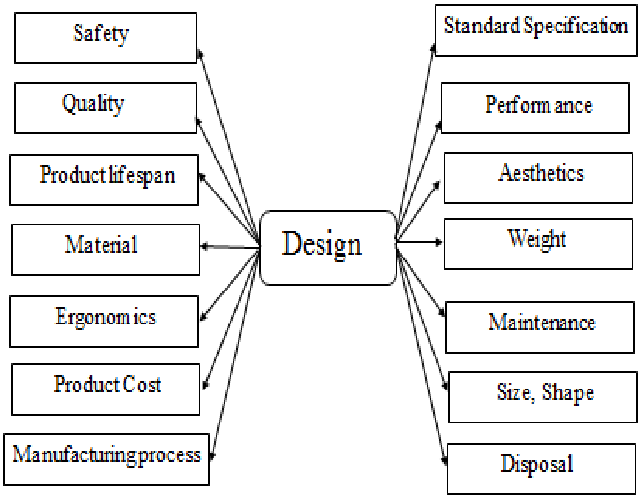

Fig7. Design Procedure

IX. MOTOR TORQUE CALCULATION

The electric vehicle has several components like a charging module, converters, controllers, batteries, electric motor, and the block diagram of power flow in an electric vehicle is shown in Figure.

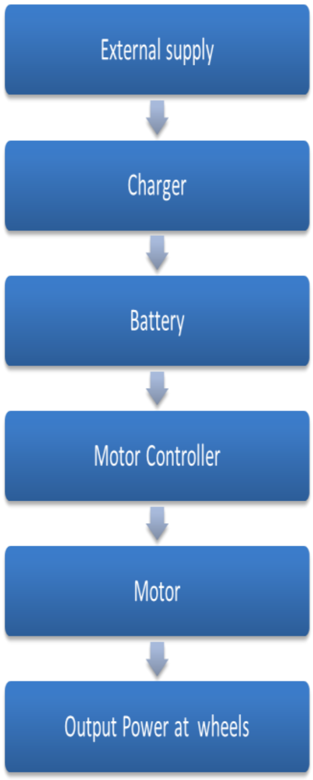

Fig8.Flowchart

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- **Calculation of motor**

For deciding the power rating of a vehicle, the vehicle dynamics like rolling resistance, acceleration force, aerodynamic drag, etc., have to be considered.

Total Tractive force

F total = **F** r + **F** a + **F** aerodynamic drag

1. Rolling resistance

Rolling Resistance is the opposing force that the vehicle has to overcome due to the rolling motion between the wheels and the surface of motion of the vehicle. The rolling resistance depends on the coefficient of rolling friction which varies depending upon the material of tires and the roughness of the surface of motion. The Rolling resistance can be calculated as

$$F_r = C_{rr} * m * g$$

2. Acceleration force

Acceleration force is the force that helps the vehicle to reach a predefined speed from rest in a specified period. The motor torque bears a direct relationship with the acceleration force. Better the torque, the lesser the time required by the vehicle to reach a given speed. The acceleration force is a function of the mass of the vehicle. Acceleration force is calculated as:

$$\mathbf{F}\ a = \mathbf{m} * \mathbf{a}$$

$$\mathbf{F}\ a = 150 * \frac{25*1000}{3600*20}$$

$$\mathbf{F}\ a = \mathbf{52.08\ N}$$

3. Aerodynamic drag

Aerodynamic drag is the resistive force offered due to the viscous force acting on the vehicle. The shape of the vehicle primarily determines it. However, our vehicle speed is too low to consider as it is 25 Kmph. The frontal area of our vehicle is also less, so the value of Aerodynamic force is negligible.

So, total force calculated as

$$F_{Total} = F_r + F_a$$

$$= 5.886 + 52.08$$

F $_{total}$ = 57.96 N

A. Power Required

The total tractive power required to move the vehicle is calculated as:

$$P = F_{total} * V$$

$$= 57.96 * \frac{25*1000}{3600}$$

P = 402.56 W

B. Torque Required

The torque required on the drive wheel will be the one that the drive motor requires to produce to obtain the desired drive characteristics. The torque is

$$T = F_{total} * \mathbf{R}$$

$$= 57.96 * 0.330$$

T = 19.12 N

- **Battery Calculations**

A. **Calculations for battery ampere-hour ratings:**

Nominal power output of motor = 350 W
Operating voltage = 36 V

Required Ampere hour rating of battery = $\frac{Power}{voltage}$

$= \frac{350}{36}$

$= 9.722 \sim 10A/hr$

B. **Kilometer Range**

We select a battery management system of 20 A according to availability and requirement.

Kilometer range = $\frac{Ampere\ rating\ of\ battery\ pack}{Required\ ampere\ hour}$

$= \frac{20}{10}$

= 2 hr.

This means the battery will supply current continuously for 2 hours
According to considerations, speed of vehicle = 25 Kmph
So, kilometer range of vehicle = 25 * 2 = 50 Km

C. **Time required for charging**

Time required for charging= $\frac{Ampere\ hour\ rating\ of\ battery}{ampere\ provided\ by\ charger}$

$= \frac{20}{4}$

= 5 hrs

- **Estimated cost per km**

KWhr of battery = Ampere hour rating of battery * operating voltage

= 20*36
= 720 Whr
= 0.72 KWhr

Per unit rate of electricity = Rs 3.46 (As per electricity bill)
Time required to charge battery =5 hrs

Total units required to charge the battery

$= \frac{no\ of\ hours\ required\ to\ full\ charge}{part\ of\ unit\ battery\ consumes\ per\ hr}$

= 6.94 units

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Total cost required to charge a battery = 6.94*3.46

= Rs 24.02

Kilometer range of vehicle = 50Km

Cost per km = 48 Paise.

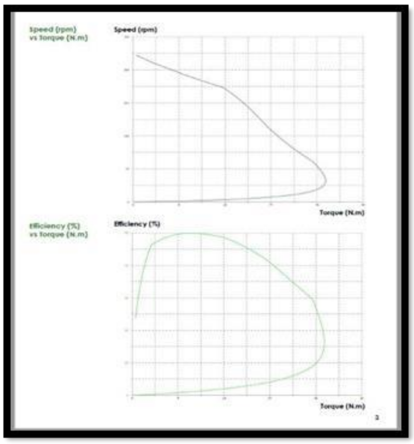

Fig9. Speed vs torque and efficiency vs torque

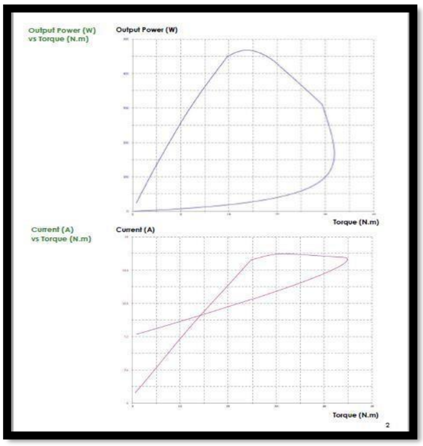

Fig10. Power vs torque and current vs torque

Battery Type	Lithium ion	Lead Acid	Ni-Cd
Energy Density(Wh/Kg)	120	35	40-60
Power Density(W/m3)	1800	180	150
Cycle Life	3500	4500	2000
Characteristics	• Recyclable • Long life Optimum performance at high temperature	• Low cost Availability in production volume	Costly for vehicular application Cd content is harmful for environment

Fig11. Cells Comparison

Size	Thickness	Mass/Metre	Second Moment of Area	Torsional Constants Inertia	Torsional Constants Modulus
B	T	M/m	I	J	C
mm x mm	mm	kg/m	cm^4	cm^4	cm^3
20	2	1.05	0.692	1.21	1.06
20	2.5	1.25	0.766	1.39	1.19
25	2	1.36	1.48	2.53	1.8
25	2.5	1.64	1.69	2.97	2.07
25	3	1.89	1.84	3.33	2.27

Fig12. Selection of tubes (Square tubes)

Outside Dia	Thickness	Mass /Metre	Second Moment Of Area	Torsional Constants	
D	t	M	I	J	C
mm	mm	kg/m	cm^4	cm^4	cm^3
21,3	2	0,952	0,571	1,14	1,07
21,3	2,5	1,16	0,664	1,33	1,25
21,3	3	1,35	0,741	1,48	1,39
26,9	3,2	1,87	1,7	3,41	2,54
33,7	2	1,56	2,51	5,02	2,98

Fig13. Selection of tubes (Round tubes)

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Reasons to choose round tubes for chassis:

- The round tube has a higher resistance to flex and torsional twisting than square for a given weight.
- Cylindrical tubing requires less material while offering the same amount of space on the inside. This makes the tubing lighter and cheaper.
- Round tubes have less surface area; friction is also reduced, increasing flow and efficiency. Circular tubes are easier to bend, thread, seal, and insulate, making them ideal for various applications.
- Without corners, they do not have weak points, giving them consistent strength all around.

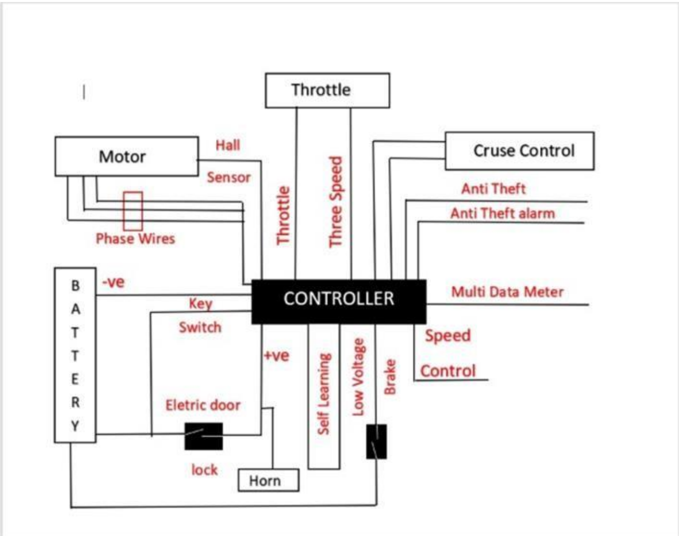

Fig14. Wiring Diagram

X. PROPOSED EXPERIMENTAL SETUP

Fig15. Fixtures for chassis manufacturing

Fig16. Manufactured chassis

XI. CONCLUSION

By the implementation of many pilot projects and EV-related events, public expectation on E.V.s is high. However, there is no clear indication for full-fledged diffusion. This is because of the high prices of E.V.s, limited models, lack of charging infrastructure, and lack of trust in the market regarding the life span of E.V.s and safety. The progress that the electric vehicle industry has seen in recent years is highly welcomed and highly necessary in light of the increasing global greenhouse gas levels. As demonstrated within the economic, social, and environmental analysis sections of this webpage, the benefits of electric vehicles far surpass the costs. The biggest obstacle to the widespread adoption of electric-powered transportation is cost-related, as gasoline and the vehicles that run on it are readily available, convenient, and less costly.

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