International Journal of Engineering Research and Science & Technology

www.ijerst.org

ISSN : 2319-5991

Vol. 21 No. 3 (1) 2025



ijerst.editor@gmail.com

editor@ijerst.com

International Journal of Engineering Research and Science & Technology

ISSN 2319-5991 www.ijerst.com
Vol. 21, No. 3(1), 2025
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Research Paper

E-TRIKE – DESIGN AND FABRICATION

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Received: 05-6-2025 Accepted: 05-7-2025 Published: 13-7-2025

Abstract—Over the past several years, there has been an escalating interest, echoing enthusiasm, for electric vehicles. Electric vehicles (EVs) are becoming more typical in the transportation sector in recent times. As the current progression suggests, this form of transportation is more prone to oust internal combustion engine (ICE) vehicles in the coming years. The motive of this project is to design and fabricate an Electric Vehicle. An E-TRIKE is a three-wheeler propelled exclusively by an electric motor; it is a Full Electric-Battery Electric Vehicle (BEV). The design and fabrication of Trike involve designing a custom chassis on which motor, controller, battery pack and other parts can be integrated on it and fabricating a 48V, 1000Wh Battery Pack. The rider has the power to control the output power from the motor i.e., speed using throttle and controller provides power to the motor which in turn provides torque to wheels. Through this project we design and fabricate simple, and cost-effective Electric Vehicle

Keywords-E-Trike, Electric Vehicle (EVs), ICE, Battery Electric Vehicle, Motor, Controller, Throttle, Battery Pack.

I.INTRODUCTION

Transportation is the highest energy-consuming sector in 40% of all countries worldwide and causes about a quarter of energy-related CO2 emissions. The environment suffers from the increasing number of vehicles as the amount of greenhouse gas emissions reach new heights every year[2]. Filtration systems and other air detoxifying routes are being explored, but a major reduction in greenhouse gas production will make the most significant climate difference. While the transport sector faces various challenges due to environmental concerns, the use electric vehicles (EVs) provide the possible solutions towards this issue. EVs are wheeled vehicles that use an electric motor that is powered by a battery for propulsion. They must be recharged at home or at a public charging station, where three main levels of charging are used, depending mainly on the charge rate.

Environmental problems relating to air pollution and greenhouse gas (GHG) emissions from combustion of fossil fuels have prompted different countries and regions to find more sustainable modes of transportation. Electric vehicles (EVs) have emerged as highly promising technology that is expected to play a major role in energy transition towards a sustainable transport system in the next decades. In 2018, overtwo million EVs were sold worldwide, and this number is expected to rise to 56 million by 2040.

In the face of transport advancement and drive towards sustainable transportation, the presence of indigenous motorized transportation modes in developing countries remains. In fact, this has been a subject of most planners and researchers in developing countries. In India, Vietnam and Thailand, motorcycles as used as for-hire local public transport mode also known as motorcycle taxis. It is also important to note that motorcycles account for half the vehicle fleet and up to 75% in some cities in Asia such as India, Hanoi, Vietnam.

The introduction of electric bikes to the mainstream market in the previous decade has been met with enthusiasm by individuals who prefer a method of transportation that is more environmentally friendly, less expensive and more convenient than a car in certain circumstances[6]. The enthusiasm has not abated and continues to remain as new technological advances in the motorized electric bike industry keep electric bikes in the forefront for many individuals, who desire to make an environmentally friendly and cost-efficient form of transportation. One of the latest technological advances has been the creation of motorized electric tricycles. Think of your traditional tricycle that was used by those who were not skilled
enough to ride a bike. They were younger in age, did not have the capability to ride a bike and relied on the 3 wheels for additional leverage and support.

The same concept of a tricycle has been modernized to provide a form of transportation that is sturdier, helps those who may have difficulty keeping balance and allows one to perform errands as there are compartments on the front and rear of the bike to accommodate groceries and other items. It's the perfect electric road bike that could provide a bit of exercise but also help with nearby errands with the installation of front and backend compartments[2].

1.1 Types of Trikes

1.1.1 Delta

A Delta or rear-load tricycle has cargo, passengers, and battery at the rear, all of which keep the center of gravity

(C.G.) back. It is stable at low speeds and provides consistent braking with a force of 1G. On steep climbs, though, the nose might rise. Having a long wheelbase can help with steering control and stability, especially at high speeds.

1.1.2 Tadpole

Tadpole tricycle has two front wheels with front loaded C.G, Ackerman steering. And although braking is, up to 1G force, stable, high speeds or downhill slopes can lift the rear wheel. A longer wheelbase creates a more stable turning base, but at the cost of a larger turning radius, and less downhill visibility[1].

1.1.3 Sidecar

This small tricycle for the handicapped has two inline wheels and an off-center third. It has bicycle-style steering but is less stable owing to its heavy frame. This is so important because each passenger compartment will affect the aforementioned scene and balance of the voluminous vehicle with its size and placement, greatly changing the center of gravity and, therefore, this dynamic stability condition is the biggest challenge of the design[1].

1.2 E-Trike

Electric trikes are a type of electric bike that has three wheels and is equipped with an electric motor which provides pedal support to the trike. Electric tricycle bikes can be configured in two ways. The first is where there are two wheels in the back and one wheel in the front. This is known as a delta tricycle in technical terms. The second configuration has two wheels in the front and one wheel in the back. This is known as the tadpole version.

Regardless of the preference, the benefits of electric trikes over bikes is that they have the capability to load equipment, allow the rider to sit in a more reclined or straight position, that improves comfort when riding for a long period of times and also aerodynamic efficiency with the positioning of the rider on the bike. Lightweight motorized tricycles have been a hit with senior population who love the fact that the bike has large baskets in the front and rear which allow them to perform nearby errands[8]. Now that we have explained the function and capabilities of motorized electric trikes.

1.3 Objectives of the paper

The main objectives of this paper, focused on design and fabrication of E-Trike are as follows:

1. Design a stable and lightweight chassis with proper weight distribution.
2. Build a 48V battery pack with a reliable Battery Management System (BMS).
3. Select and integrate an efficient electric motor.
4. Achieve a top speed of 40 km/h while maintaining stability and safety.
5. Fabricate and assemble the trike with durable and cost-effective materials.

II.METHODOLOGY

A battery electric trike is a type of electric motor vehicle that operates on the chemical energy stored in rechargeable battery packs. If an electric trike, say, will only use its electrical power and make a point of not having any secondary power source, and then it will, in fact, be a pure E-bike. Electric motors and motor controllers drive these vehicles through different driving systems (as in mid drive, hub drive, etc.), providing the wheel with power[7].

2.1 Design Objective:

The frame has chopper roots. It shaves off tons of weight and, importantly, is going to be very attractive for young customers who regularly use traditional I.C. engine motorbike for their daily and short commute. They are smart connected bikes with robust geometry, safe to ride, easy to carry Aside from the Eco- friendly power unit, the cost of maintenance is low compared to that of gas propelled vehicles, both are design factors as well. The material are of the highest attainable quality and desired characteristics that are needed to balance and improve the entire performance of Trike

2.2 Design Characteristics:

It needs to be sturdy enough to support the weight of the rider and any assemblies or electric Trike accessories. The components of a chassis being subjected to various loading conditions, eg compressive, tensile shear, fatigue leading to failure. Mainly as a single material is not appropriate for each sort of load[6]. They are constructed such that they can resist unintended collisions and small impacts. The chosen material should have compatibility with manufacturing and affordability. The frame should be uncomplicated, beautiful, and evenly dispersed weight. The design also needs to have provisions in terms of mounts and casing for the electronic powertrain and other accessories[7].

2.3 Design of E-Trike

It uses a sturdy backbone frame chassis to provide strength and stability while supporting the trike's key components — motor, battery, and tires. It absorbs impacts, keeps wheels on the ground, and can support as much as 150 kg. Built for surviving small impacts and collisions; low on weight and cost. The frame has to be sized to accommodate the rider, accessories, and mounts for the actual powertrain while ensuring weight distribution is proportionate. The backbone design is the bike’s spine — simple, torsionally rigid, and easy to manufacture. Designed for low to medium power propulsion, provides flex and durability whilst not overly using the material and therefore lightweight, which makes it ultimately suited for e-trikes[8].

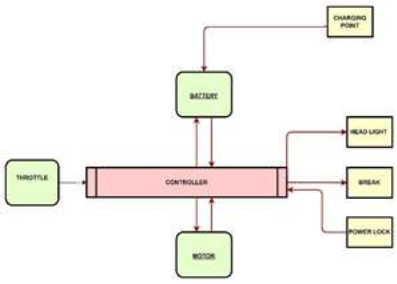


Fig.2.1: Block Diagram of E-Trike

The e-trike will come with a powertrain featuring a 48V lithium-ion battery, DC-DC converter, motor, and controller. The battery provides power to all electronics, while the rear-wheel motor is controlled through throttle and brakes. Voltage converters to operate low-voltage accessories safely.

The brushless DC (BLDC) motor comprises a permanent magnet rotor, a three-phase stator winding, and electronic commutation, eliminating the need for brushes[5]. Figure 1 shows a rotor with Hall sensors used to detect its position. BLDC motors are preferred due to their long life, low maintenance, high efficiency, noiseless, and the best torque to size ratio. The permanent magnets are rotated instead of electromagnets, and an electronic controller is employed in place of the traditional brush-commutator system to distribute power more4596 efficiently. This is why BLDC motors are a preferred choice in applications where space, weight, and performance are important[9].

A motor controller is a device that regulates and controls an electric motor's operation, including start/stop, direction of rotation, speed control, and overload and fault protection. For example, in an electric motorbike system, it rules parts such as the brushless direct current (DC) motor and battery. The block diagram of E-Trike is shown in Fig.2.1 This includes under-voltage and over-current protection, power regulation, and motor control. This device handles signals for current sensing, speed regulation, and capacity management to guarantee optimal performance.

This system provides fine control over the E-Trike motor power (the moment, users can vary the speed according to their needs). It's a direct connection (wired) to the E-Trike controller circuitry so it communicates very well. This arrangement enables greater efficiency, responsiveness, and overall performance, providing smooth and reliable operation for speed control[1]. When interfacing with the controller, optimizes the power and protection to play a point, thereby effectively ensuring the safety and efficiency of E-Trike's work.

The e-Trike brake lever substitutes for standard levers, either disabling power to the controller or activating regenerative braking when pressed. Compatible with mechanical and hydraulic brakes as well as providing greater safety and efficiency. It can also be retrofitted in existing brake levers, turning those into e-brakes to give us more control. It helps seamlessly improve performance features including braking and energy recovery characteristics for the e-Trike system[9].

III. DESIGN AND FABRICATION

3.1 E-Trike Chassis:

The e-Trike has a tubular frame of hollow welded pipes, again with larger-diameter tubing used in high-load areas such as the front steering pipe and rear vertical supports. The chassis is the vehicle's understructure that supports key elements like the suspension, wheels, and seats. It ensures strength, stability, freedom and integration of motors and innovations. Picking a wheelbase at the right length improves handling, and the design of the airflow helps in cooling the batteries and motors[1]. Not only does this frame help users to easily remove the battery, but it also protects the battery from damage during impacts.

Table 3.1 E-Trike Dimensions

DIMENSION	VALUE	UNITS
Length	5	ft
Width	3	ft
Height	2.3	ft


Fig.3.1: E-Trike Chassis

3.2 E-Trike Suspension:

Its suspension system works to cushion bumps and vibrations for a more comfortable ride. It absorbs kinetic energy, mitigates shocks, and improves grip on the road surface, braking and safety in general.

Front Suspension: The e-Trike employs a telescopic suspension, a damping device held by a triple tree for offset. It has a hydraulic shock absorber with a coil spring inside, where the front wheel can move around freely when riding for a smoother ride. The fork tubes slide up and down in the fork bodies, keeping fork oil from leaking out and allowing for proper suspension. It connects the front axle to the underside of the forks, so the wheels can rotate smoothly[5].


Fig.3.2: E-Trike Suspension

3.3 E-Trike Brakes:

Brakes create frictional resistance to slow or stop a vehicle, playing a crucial role in safety by preventing or reducing injury during accidents.

Rear Disc Braking System: As an example, the e-Trike brakes are disc brakes, where pads press against a spinning disc, creating friction and heat, which dissipates. As opposed to drum brakes, disc brakes consist of a thin rotating disc that is gripped by the pads, and as you might guess, force is transferred hydraulically. The caliper grabs the disc to arrest its spin, providing reliable braking. The inboard pad is closer to the center of the vehicle, whereas the outboard pad is farther away. They provide better braking performance, heat dissipation, and dependability[4].



Fig.3.3:E-trike Brake

3.4 E-Trike Alloy Wheels:

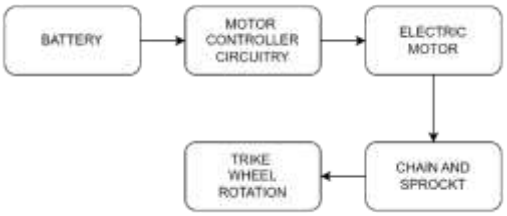
The rim is the outer lip of a wheel between which the tire is mounted, having a U-shaped cross-section to support the tire bead. E-Trike Wheels: Historically, motorcycles sported wire-spoked wheels equipped with inner tubes; however, cast alloy wheels hit the mass market in the 1970s[1]. The last invented, alloy wheels are produced and manufactured out of aluminium or magnesium and they are lighter than steel wheels which increase speed and handling. They also welcome tubeless tires, enhancing inflation retention, minimizing maintenance, and providing improved rigidity. Such benefits being greater runout tolerance, less hub size, weight savings and side-load handling, making them a premium choice for high-speed performance and durability[3].



Fig.3.4: E-Trike Wheels

3.5 E-Trike Transmission:

Transmission System: The transmission system is a crucial component that transfers the power generated by the motor to the vehicle's wheels, allowing the vehicle to start and control its speed while also converting torque when necessary. In E-Trikes, chain drive from the BLDC motor shaft sprocket to the rear wheel sprocket is used. One motor sprocket shackles with the rear wheel sprocket, purposely lowering the high motor speed to a decisive wheel speed & callously augmenting torque. Gear train is responsible for smooth functioning and it allows the engine revolution to convert it into wheel drive, adaptability for multiple speed and



running conditions. Difference gears are commonly used in motor vehicles, bicycles, and stationary devices where optimal conditions require that the components turn at various speeds and torques.

Fig.3.5: E-Trike Transmission

3.6 E-Trike Chain Drive:

A Chain is an array of links held together with each other using steel pins. This type of arrangement makes a chain more long-lived, long lasting and the better approach to transmit rotary motion from one gear to another. The primary benefit of the chain drive over the ordinary gear is that, It can transmit rotary movement using two gears and a chain over a distance, on the contrary, in the traditional many gears must be arranged in one mesh in order to transmit motion.

3.7 E-Trike Controller:

The electronically controlled E-Trike motor controller easily manages speed, position, and torque for more efficiency. It does this through pulse width modulation (PWM), as it quickly switches the current flow to the motor's coils to maximize power delivered. Mosfet based controllers improve motor drive and power control whilst managing current and voltage changes with greater efficiency. They also control the flow of current through motor coils, allowing for very precise speed and direction control, which is vital for enabling smooth and energy-efficient operation of E-Trikes[4].

Table 3.1 E-Trike Controller Specifications

SPECIFICATION	VALUE
Rated current(A)	30
Operating Voltage(V)	48
Ambient Temperature	-20-48
Dimensions in mm (LxWxH)	175x83x44
Weight(gm)	555



Fig.3.7: E-Trike Controller

3.8 E-Trike Motor:

A Brushless DC (BLDC) motor is a type of electronically commutated motor (ECM) that does not have Fig.3.8: E-Trike Motor brush components. The controller manages speed and torque by sending current through the coils in pulses. Permanent magnets rotate around a fixed armature instead of brushed motors, making them mechanically wear-free and more reliable. Hence, BLDC motors are most suited for the E-Trike application as Electronic commutation allows flexibility[7].

Table 3.2 E-Trike Motor specification

SPECIFICATION	VALUE
Rated operating voltage	48v
Rated power	750w
No load current	4.0A
Rated torque	102 kg-cm
Rated current	13.4A



Fig.3.8: E-Trike Motor

3.9 E-Trike Battery Pack:

A battery cell is the basic building block of an electric vehicle's energy storage system. A lithium battery is primarily made up of four important elements: cathode, anode, electrolyte, separator, and terminals. The battery is ranked by its literature and chemistry. It plays a key role in determining the performance of the electric vehicle as a whole. A battery module is a structure that includes several battery cells connected in series and/or in parallel and is located inside mechanical shell. More specifically, the increasingly compact arrangement or stacking of the battery cells inside a module is an important consideration for integrating the pack, which also requires the integrated battery management system, thermal management system, and sensors[11].

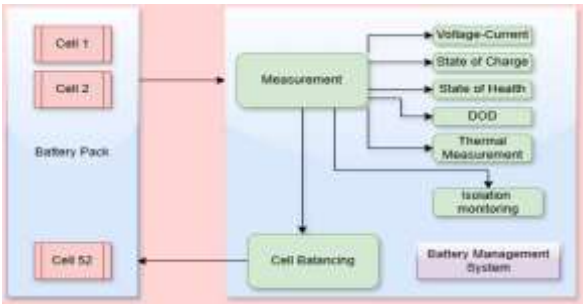


Fig.3.9: Block Diagram of Battery Pack

3.9.1 Series Parallel Configuration:

The series-parallel (S-P) arrangement will give you the needed voltage and capacity with a 48V EV battery pack. A 13S (13 cells in series) configuration provides a nominal 48V (3.7V × 13) with a max charge voltage of 54.6V and a minimum safe voltage of 39V. Parallel groups (P) increase capacity, with 13S4P (52 cells) for medium range, 13S6P (78 cells) for long distance and the 13S8P (104 cells) configuration for maximum endurance. Battery Management System (BMS), thermal management, and weight balance is vital from safety as well as efficiency perspective in EV applications.

3.9.2 Cell Parameters:

To select the battery cells for our pack, we will conduct an analysis of various battery cell models available in the market. After careful consideration, we have opted for DMEGC 18650 26E Li-ion battery model for our battery design as show in DMEGC 18650 26E.
Specifications of the cell model are as follows:
Nominal capacity: 2.6Ah at a 0.5C rate
Minimum capacity: 2.5Ah at a 0.5C rate
Nominal voltage: 3.7V
Charge end voltage: 4.2±0.05V
Standard charge current: 0.5C
Discharge Cut-off Voltage: 2.75±0.005V
Maximum Continuous Charging Current: 2C
Internal Resistance: <25m ohms
Cycle life: +0.5C/-1C
: +0.5C/-10C
: +0.5C/-13C
Operating Temperature: Charge: 0 to 50°C
: Discharge: -20 to 60°C
Weight: <47 g
Cell Dimension: Height- 64.95mm±0.20mm
: Diameter-18.25mm±0.20mm

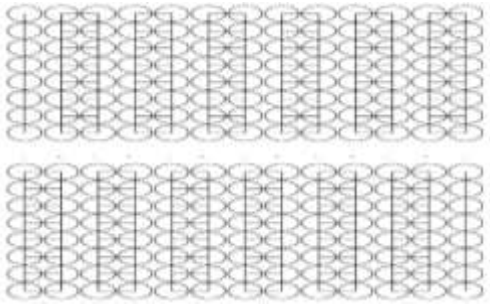
The DMEGC 26E is a lithium-ion battery cell with Nickel Manganese Cobalt Oxide (NMC) chemistry, providing a 2600mAh capacity and 3.7V nominal voltage. It features a 4.2V maximum charge and a 2.5V–3. You are meant for EVs and energy storage systems that require 0V discharge cut-off and a 5A continuous discharge current.

This means a configuration of 13S (13 cells in series) for a 48V battery pack. Parallel groups (P) govern capacity, with 13S4P (52 cells), 13S6P (78 cells) or 13S8P (104 cells) for different power/range requirements. Safety and efficiency helped in making sure of thermal management, BMS integration, and weight balance.

3.9.3 Battery Pack Calculations:

To determine the battery pack specifications using the DMEGC 18650 26E battery cells, we will utilize the provided information about the battery cell and conduct the necessary computations. We will assume that the battery pack is composed of multiple strings connected in parallel[11].

Battery Cell Specifications:
Nominal Capacity: 2.6Ah at 0.5C rate
Nominal voltage: 3.7V
Battery Pack Requirements:
Battery pack voltage: 48V
The range that battery should cover: 40 km
Calculations:
Average Energy Consumption per km: 23Wh/km
1.Total Wh Required:
Total Wh required=23 Wh/km*40km=920Wh
Lets us consider a 1Wh battery pack
2.Battery Capacity:
To get the battery capacity=Total Wh/Battery pack voltage
Battery Pack Capacity=1000Wh/48V=20.8Ah
Battery Pack Capacity=20.8Ah
3.Number of Cells Connected in Series:
Cells in Series=Battery pack Voltage/Cell Nominal Voltage
Cells in Series=48V/3.7V=13
4.Number of Cells Connected in Parallel:



Cells in Parallel=Total Battery pack Capacity/Nominal Cell Capacity
Cells in Parallel=20.8/2.6=8
5.Total Number of Cells in the Battery Pack:
Total Cells in the Pack=S*P=13*8=104 cells
The required battery is 48V, which is provide a range of 40 Km. The battery capacity should be 20.8Ah. Which should be configured as 13 cells in series and 8 cells in parallel (13S8P), resulting in a total of 104 cells in the battery pack.
6.Summary of Results:
Number of Cells in Series: 13
Number of Cells in Parallel: 8
Total Number of Cells in the Battery Pack: 104 cells

Fig.4.2: Interconnections of Cells in Battery Pack

IV. RESULTS & DISCUSSION

The final assembly of the E-Trike completes the vehicle as the following are added: motor, controller, tires, steering handle, brakes, battery pack, and suspension. Performance was tested over an 40 km course with rider weights ranging between 30 and 150 kg. The trike performed well on Indian road conditions, righteously justifying its design.



Fig.4.1: E-Trike

Table 4.1 E-Trike specifications

SPECIFICATION	DETAILS
Wheelbase	**1320mm**
Length	**5ft**
Width	**3ft**
Height	**2.3ft**
Ground clearance	**150mm**
Vehicle weight	**33kg**
suspension	**Front-Telescopic**
Brakes	**Rear Disc**
Motor	**750W**
Controller	**48v,30A**

Lithium-ion battery technology has become the cornerstone of modern energy storage solutions due to its high energy density, long cycle life, and efficiency. This study focuses on the design and fabrication of a 48V 20.8Ah battery pack using DMEGC 18650 26E cells in a 13S8P configuration[. The primary objective is to build a reliable and efficient power source that integrates a 48V 13S 40A Battery Management System (BMS) for optimal performance, safety, and longevity.

The importance of a well-structured battery pack lies in its ability to deliver stable power output while ensuring safety and durability table 5.1 shows E-Trike's Battery Pack Specifications. This project involves careful selection of cells, configuration strategy, integration of a BMS, and performance testing. The designed battery pack is suitable for applications such as electric bicycles (e-bikes), solar energy storage, and backup power systems[11].

The battery pack follows a 13S8P configuration, meaning 13 cells are connected in series to achieve a nominal voltage of 48V (3.7V × 13), while 8 cells are connected in parallel to provide a total capacity of 20.8Ah (2.6Ah × 8). This setup balances voltage requirements with adequate current supply and capacity.

Table 4.2 E-Trike's Battery Pack Specifications

SPECIFICATION	DETAILS
Cell Nominal Voltage	3.7V
Cell Nominal Capacity	2.6Ah
Cell Dimensions	18(D),65(H) in mm
Battery Pack Voltage	48V
Battery Pack Capacity	20.8Ah
Number of Cells in Series	13
Number of Cells in Parallel	8
Cell Configuration	13S8P
Max Charge Current	10A
Max Discharge Current	15A
Range	40-45 Km
Weight	8 kg
Battery Pack Dimensions	27,17,7(L,W,T)in cm
Charge Time	3hrs at 6A

V. CONCLUSION

The electric trike, successfully designed and developed, offers a solution to pollution. Our oil dependence poses environmental, security, and economic challenges. Oil vulnerability leads to price fluctuations and gas shocks, complicating foreign policy. Oil and petroleum products are major contributors to global warming pollution, surpassing coal. Transportation, heavily reliant on oil, accounts for over two-thirds of petroleum demand and is a significant source of



Fig.4.2: E-Trike's Battery Pack



Fig.4.3: E-Trike parts

air pollutants. Motor vehicles emit pollutants like carbon dioxide, exacerbating global climate change. The transportation
sector is responsible for approximately 30% of all greenhouse gas emissions. Electric vehicles offer a solution, reducing pollution and providing an eco-friendly mode of transportation. The successful fabrication of a 48V 20.8Ah lithium-ion battery pack using a 13S8P configuration with DMEGC 18650 26E cells demonstrates the feasibility of building high-performance energy storage systems. The integration of a 48V 13S 40A BMS ensures safety, reliability, and longevity. With proper thermal management and regular maintenance, this battery pack can serve as a sustainable and efficient power source for E-Trike. The entire vehicle design is optimized to achieve a projected range of 40-45 km, which serves as a fundamental assumption for the battery pack calculation.

VI.FUTURE SCOPE

Electric tricycles (e-trikes) are positioned to play a crucial role in the future of sustainable urban transportation and logistics. Here's a detailed look at their potential impact. E-trikes offer a practical solution for short-distance travel within cities, especially where road congestion is high. Their compact design allows them to navigate narrow streets, making them ideal for crowded urban environments. As more cities aim to reduce car dependency, e-trikes provide an affordable, convenient alternative. E-trikes produce zero direct emissions, which is essential in reducing urban air pollution and combating climate change. With governments worldwide setting stricter emission standards, e-trikes align with these regulatory shifts and help cities move closer to zero-emission transportation goals. Operating costs for e-trikes are significantly lower compared to traditional fuel-powered vehicles, which is beneficial for individuals and businesses. E-trikes offer savings on fuel and maintenance, making them an economically attractive choice over time. Advances in lithium-ion and solid-state batteries are enhancing the range

and lifespan of e-trikes. Improved battery efficiency allows e-trikes to cover longer distances on a single charge, addressing a key limitation of early electric vehicles.

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