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MANIT SMART E-BIKE

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A B S T R A C T

This study presents the design and development of a smart electric bicycle (e-bike) intended to serve as an environmentally friendly, economical, and efficient transportation option for urban users. The primary objective is to develop a lightweight and energy-efficient e-bike that minimizes dependence on fossil fuels, reduces air pollution, and helps ease traffic congestion in heavily populated cities. The proposed e-bike is equipped with a lithium-ion battery and an electric motor that provides pedal assistance, enabling a comfortable and effortless riding experience. An intelligent control system regulates the motor output according to rider input and road conditions, ensuring optimal power utilization. To further improve efficiency, a regenerative braking mechanism is incorporated to recover energy during braking, thereby extending battery life. The bicycle frame is designed to offer strength, durability, and rider comfort, along with adjustable suspension to handle varying urban road conditions smoothly. User convenience is enhanced through a digital display that provides real-time information such as speed, battery status, and energy consumption. In addition, the e-bike supports smartphone connectivity for features including GPS navigation, system diagnostics, and ride performance tracking, allowing users to manage and monitor their journeys effectively. By providing a sustainable alternative to conventional modes of transport, the electric bicycle helps reduce traffic congestion and carbon emissions. The project encourages the adoption of green mobility solutions and supports the transition toward a cleaner, energy-efficient urban transportation system. Overall, this work aims to address urban mobility challenges while promoting the practical application of electric vehicle technology in daily life.

KEYWORDS: Electric Bicycle, Battery, Motor, Controller.

INTRODUCTION

An electric bicycle, commonly referred to as an e-bike, is a conventional bicycle integrated with an electric motor that supports propulsion. Unlike standard bicycles, e-bikes provide motorized assistance to the rider, reducing physical effort and enabling smoother travel at higher speeds. Due to their efficiency, affordability, and environmental benefits, e-bikes have emerged as a popular mode of transportation.

By combining traditional cycling with advanced electric drive technology, e-bikes have transformed personal mobility. The electric motor assists pedaling, allowing riders to commute more comfortably and efficiently, especially over long distances or uneven terrain. Most e-bikes operate using a rechargeable lithium-ion battery, which supplies power either as pedal assistance or complete motor-driven motion.

Based on functionality, e-bikes are generally classified into pedal-assist systems, throttle-based models, and high-speed pedelecs that offer increased power output. They are available in various forms such as urban commuter bikes, mountain bikes, and foldable designs, making them suitable for diverse riding conditions and user preferences.

One of the major benefits of electric bicycles is their contribution to sustainable transportation. Since e-bikes operate without fossil fuels and produce no direct emissions, they help reduce environmental pollution and support eco-friendly urban travel. Moreover, they are cost-effective compared to automobiles and motorcycles, lowering travel expenses and energy consumption.

Electric bicycles also encourage physical activity by making cycling accessible to a broader population, including elderly users and individuals with limited physical endurance. By reducing fatigue and effort, e-bikes allow riders to cover longer distances comfortably. With ongoing technological advancements in battery performance, smart features, and safety systems, e-bikes are becoming an essential component of modern transportation, offering a practical, green, and efficient solution for daily commuting and recreational use.

Problem Statement

Electric bicycles (e-bikes) present an eco-friendly and energy-efficient alternative to conventional modes of transportation, contributing to lower carbon emissions and enhanced urban mobility. Despite their advantages, the large-scale adoption of e-bikes is hindered by several challenges such as limited battery capacity, high initial costs, insufficient charging and cycling infrastructure, safety issues, and inconsistent regulatory policies. Concerns related to theft, maintenance requirements, and the environmental impact of battery disposal also need to be addressed. To fully utilize the benefits of e-bikes, advancements in battery technology, cost reduction, infrastructure development, and improved security systems are essential.

Requirements

1. Functional Requirements

- **Electric Drive System:** The e-bike must be equipped with an electric motor and battery to support both pedal-assist and throttle-controlled modes of operation.
- **Battery Performance:** The battery should provide an efficient riding range of approximately 50–100 km per full charge and support fast-charging capabilities.
- **User Interface and Controls:** A digital display should be provided to show speed, battery status, and riding modes, along with intuitive control mechanisms.
- **Safety Features:** The system must include reliable braking mechanisms (such as disc or regenerative braking), front and rear lights, and reflectors for enhanced visibility.
- **Security Features:** Anti-theft solutions such as GPS tracking, electronic locks, or alarm systems should be incorporated to improve vehicle security.

2. Non-Functional Requirements

- **Durability and Weather Resistance:** The e-bike should be designed to withstand various environmental conditions and include a strong, long-lasting frame.
- **Lightweight and Portability:** The design should allow easy handling, storage, and transportation, particularly for urban users.
- **Energy Efficiency:** The motor and battery system must be optimized to reduce energy consumption and maximize riding range.
- **Sustainability and Recycling:** The use of eco-friendly materials and provisions for safe battery recycling or disposal should be ensured.

3.Methodology

The development of electric bicycles follows a systematic methodology to ensure efficiency, safety, and sustainability. The process includes research, design, prototyping, testing, and deployment stages.

1. Research and Analysis

- **Market Analysis:** Identify user needs, target customer segments, and current market trends.
- **Technology Evaluation:** Review existing e-bike technologies, including motor configurations, battery systems, and smart features.
- **Regulatory Assessment:** Examine applicable national and international regulations related to e-bike operation, safety standards, and environmental compliance.
- **Infrastructure Assessment:** Study urban road conditions, cycling lanes, and the availability of charging facilities.

2. Design and Development

- **Concept Design:** Develop preliminary sketches and 3D models focusing on frame structure, motor integration, and battery placement.
- **Component Selection:**
- **Motor Selection:** Choose suitable motor types such as hub motors or mid-drive motors based on performance and terrain adaptability.
- **Battery Selection:** Select appropriate battery technology, such as lithium-ion, considering range, charging time, and lifespan.
- **Frame and Materials:** Use lightweight and durable materials like aluminum alloys or carbon fiber.
- **Software and Connectivity:** Design smart systems for mobile application integration, GPS-based tracking, and ride performance analysis.

4. Prototyping and Testing

- **Prototype Fabrication:** Develop a functional prototype incorporating all selected components.
- **Performance Evaluation:** Test battery endurance, charging efficiency, motor output under different riding conditions, and overall system performance.
- **Safety and Reliability Testing:** Assess braking effectiveness, lighting systems, balance, and stability.
- **Durability Testing:** Conduct stress and endurance tests to evaluate long-term reliability.
- **User Testing:** Collect feedback from trial users to improve ergonomics, comfort, and ease of use.

5. Production and Deployment

- **Manufacturing and Assembly:** Establish cost-effective and scalable manufacturing processes.
- **Quality Assurance:** Ensure all units comply with safety, quality, and performance standards.
- **Distribution and Logistics:** Develop supply chains for both physical retail and online distribution.
- **Marketing and Awareness:** Promote e-bikes through educational campaigns and provide user training programs.

6. Sustainability and Maintenance

- **Battery Recycling Programs:** Implement environmentally responsible methods for battery reuse, recycling, or disposal to minimize environmental impact.

3.COMPONENTS

3.1 MOTOR (BLDC MOTOR)

Fig:3.1 Motor (BLDC Motor)

A brushless direct current (BLDC) motor is a type of synchronous motor, where magnetic fields generated by both stator and rotate have the same frequency. The BLDC motor has a longer life because no brushes are needed. Apart from that, it has a high torque, high no - load speed and small energy losses. BLDC motor specification typically include: Rated voltage- 24V, Rated current- 13.44Amp, Power output- 250W, Speed- 2500rpm.

3.2 BATTERY (LITHIUM-ION BATTERY)

Fig:3.2 Battery (Lithium-ion Battery)

Feature	Detail
Voltage (V)	24 Volts
Common Capacities	8Ah to 20Ah
Typical Watt-Hours (Wh)	24V × Ah rating (e.g., 24V × 10Ah = 240Wh)
Motor Compatibility	Best with 180W – 350W motors
Range	15–40 km (varies by terrain, weight, PAS level)
Use Case	Short commutes, flat terrain, budget e-bikes

3.3CONTROLLER

Fig:3.3 Controller.

Battery Input – Connects the battery (e.g., 24V, 36V, 48V).
Motor Phase Wires – Three thick wires (usually yellow, green, blue) for motor rotation.
Hall Sensor Wires – Feedback from motor’s internal sensors for smooth operation.
Throttle Input – From twist grip or thumb throttle.
Pedal Assist System (PAS) – Detects when you pedal and assists accordingly.
Brake Cutoff Wires – Cuts motor power when you pull the brakes.

3.4 THROTTLE

Fig:3.4 Throttle

You can **accelerate the bike** without pedaling — fully or partially. Especially useful for: Starting from a stop. Climbing hills. Giving your legs a break. Usually plugs into the **controller** via 3 wires: **+5V (red)** – Power supply to throttle. **GND (black)** – Ground. **Signal (green/white)** – Sends voltage (0.8V–4.2V) based on how much throttle is applied.

3.5 PEDAL ASSIST SENSOR (PAS)

Fig:3.5 Pedal Assist Sensor. (PAS)

You start pedaling. The **PAS detects pedal motion** (and sometimes speed or force). It sends a signal to the **motor controller**. The **controller activates the motor**, providing assistance based on: Your pedaling speed. The assist level selected on your display. Common PAS Components: **Magnetic Disk** with magnets (usually 5–12). **Sensor unit** (optical or Hall sensor). **Wiring harness** (3 wires typically): **+5V (red). GND (black).Signal (yellow/white).**

3.6 BRAKE LEVER (WITH CUT OFF SWITCH)

Fig:3.6 Brake Lever (With Cut Off Switch)

Feature	**Description**
Motor Cutoff Wire	Built-in switch or sensor that disables motor during braking.
Mechanical Compatibility	Works with standard cable brakes (V-brakes, disc).
Hydraulic Options	Separate sensors are used with hydraulic brake systems.
Connector	2-pin (usually JST or HIGO) to connect to controller.

3.7 CHARGING PORT

Fig:3.7 Charging Port

The **electric bicycle charging port** is the **interface where you connect the charger** to recharge the e-bike's battery. It's usually a small socket located either **on the battery pack itself** or somewhere on the bike frame (especially for internal batteries).

Feature	**Benefit**
Water-resistant cover	Prevents short circuits and corrosion
Gold-plated or secure pins	Ensures solid power connection
Anti-spark design	Reduces wear during plug-in
Clear polarity labeling (+ / –)	Prevents incorrect connections

3.8 CHARGER

Fig:3.8 Charger

An electric bicycle charger is a specialized device used to recharge the battery of your e-bike by converting AC (from the wall) to DC (for the battery). It's one of the most important components for maintaining battery health and ensuring your bike is always ready to ride.

Specification	**What It Means**
Output Voltage	Must match your battery type (e.g., 24V, 36V, 48V).
Output Current (Amps)	Affects how fast your battery charges (2A, 3A, 5A, etc).
Connector Type	Must match the port on your battery (DC5521, XLR, etc).

Common E-Bike Battery & Charger Voltages.

Battery Type	Nominal Voltage	Charger Output Voltage
24V Battery	21V–25.2V	29.4V Charger
36V Battery	30V–42V	42V Charger
48V Battery	39V–54.6V	54.6V Charger
52V Battery	46V–58.8V	58.8V Charger
60V Battery	52V–67.2V	67.2V Charger

3.9 HANDLE BAR

Fig:3.9 Handle Bar.

Component	Function
Throttle	Controls motor power without pedaling
LCD/LED Display	Shows speed, battery, PAS level, trip data
PAS Control Buttons	Adjust assist level (Eco, Normal, High)
Brake Levers	May include motor cut-off sensors
Horn Button	Activates electric horn
Light Switch	Turns headlights/rear lights on/off
Gear Shifter	Changes mechanical gears
Phone Holder / USB Port	Extra accessories

3.10 ELECTRIC BICYCLE FRAME

Fig:3.10 Electric Bicycle Frame

The **electric bicycle frame** (often spelled "frame" in typo form) is the **structural backbone** of the e-bike. It holds everything together—battery, motor, wheels, and rider—and is designed to handle **heavier loads, higher speeds**, and extra **torque** compared to traditional bicycle frames.

An e-bike frame is a **reinforced chassis** that:

Supports the weight of the rider and components. Houses or mounts the **battery** and sometimes the **motor.**

Determines the **geometry**, comfort, and performance of the ride. Materials Used in E-Bike Frames.

Material	**Pros**	**Cons**
Steel (Hi-Ten or Chromoly)	Strong, durable, comfy ride	Heavier
Carbon Fiber	Super lightweight, vibration-absorbing	Expensive, less durable under heavy load
Magnesium/Alloy	Used in integrated one-piece frames (e.g. foldables)	Lightweight, futuristic looks

3.10 WORKING OF ELECTRIC BICYCLE

Electric bicycles, widely referred to as e-bikes, represent a modern transportation solution that blends conventional cycling with electric assistance. Their growing popularity is attributed to improved efficiency, environmental benefits, and reduced physical effort during commuting. By combining mechanical and electrical systems, e-bikes enable riders to travel longer distances comfortably while minimizing fatigue.

The key elements that differentiate an electric bicycle from a standard bicycle include an electric motor, rechargeable battery, controller, and sensor systems. These components work in coordination to deliver either pedal-assisted or fully electric propulsion. The motor, which may be positioned in the front or rear wheel hub or mounted at the crank in mid-drive configurations, converts electrical energy into mechanical motion. When the rider pedals, the motor supplies supplementary power, making acceleration and uphill riding easier.

Electrical energy for the motor is supplied by a lithium-ion battery, typically mounted on the frame, rear carrier, or integrated within the bicycle structure. Battery capacity is measured in watt-hours (Wh), which directly influences the travel range per charge. Higher-capacity batteries provide extended riding distances. Charging time generally ranges from three to six hours, depending on battery size and charger specifications, with some models offering fast-charging options.

The controller acts as the central processing unit of the e-bike, regulating power delivery from the battery to the motor. It processes data received from sensors and adjusts motor output accordingly. For instance, when increased effort is detected or when riding on an incline, the controller increases motor assistance to maintain smooth performance. It also ensures system safety by preventing overheating and optimizing battery usage.

Sensors are essential for achieving responsive and smooth operation. Most e-bikes use pedal-assist sensors, along with optional throttle controls. Pedal-assist systems include cadence sensors, which detect pedaling motion, and torque sensors, which measure the force applied by the rider. Torque sensors provide more precise and natural assistance. Throttle-based systems allow riders to activate the motor without pedaling, similar to a motorized vehicle.

E-bikes typically operate in multiple modes, such as electric-only, pedal-assist, and manual modes. In electric-only mode, the motor powers the bicycle independently, requiring no pedaling. Pedal-assist mode supports the rider’s effort and is the most commonly used setting. Manual mode disables the motor, allowing the e-bike to function like a traditional bicycle.

Modern electric bicycles often include advanced user interfaces, such as handlebar-mounted digital displays that provide real-time information on speed, battery charge, distance covered, and assistance level. Some systems also feature GPS navigation, smartphone connectivity, and diagnostic tools, enhancing user convenience and maintenance efficiency.

Due to increased speed and weight, e-bikes are equipped with stronger braking systems, commonly using mechanical or hydraulic disc brakes for reliable stopping power. Certain advanced models incorporate regenerative braking, which recovers a small amount of energy during braking and feeds it back into the battery, although its effectiveness is limited.

Maintenance of electric bicycles is similar to that of conventional bicycles, including routine checks of tires, chains, and brakes. Additional care is required for electrical components such as the battery, motor, and wiring. Proper battery storage and periodic software updates help maintain system performance and extend service life.

In conclusion, electric bicycles effectively integrate human effort with electrical assistance to deliver a sustainable, economical, and user-friendly transportation solution. With continuous advancements in battery technology and motor efficiency, e-bikes are expected to become an increasingly important component of future personal and urban mobility systems.

4 EXPERIMENTAL ANALYSIS

Experimental analysis of an electric bicycle involves **testing, measuring, and interpreting performance data** to evaluate how efficiently the e-bike works under different conditions. It helps to **optimize design**, **improve components**, and **ensure safety and reliability**.

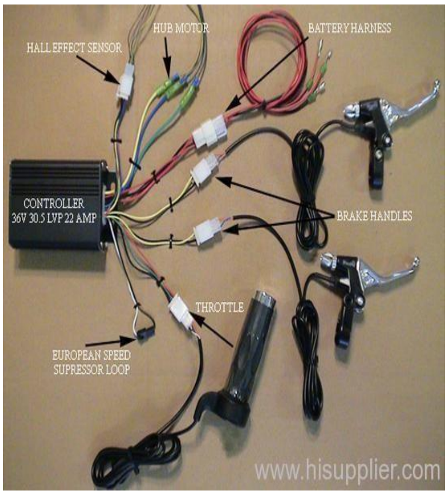
Objectives of Experimental Analysis:

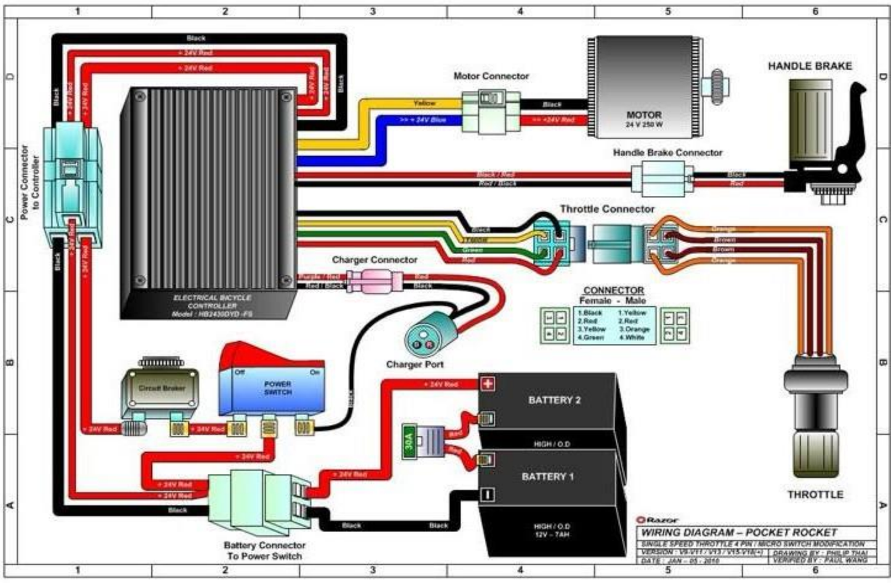
- Evaluate **battery performance and range.**
- Analyze **motor efficiency and power output.**
- Measure **torque and speed** under different loads.
- Assess **controller behavior.**
- Study **braking distance** and safety features.
- Monitor **thermal behavior** of motor and electronics.
- Examine **ride comfort**, vibration, and handling.

4.1 Common Experimental Setups:

1. Load Testing. Test the e-bike under different rider weights, terrains, and slopes. Evaluate power delivery, torque, and battery drain.
2. Range Testing. Fully charge the battery, ride until depletion. Record distance, speed, terrain, and total energy consumed.
3. Acceleration Test. Measure time taken to go from 0 to a certain speed (e.g. 25 km/h). Helps evaluate motor responsiveness.
4. Hill Climbing Test. Analyze performance on inclines. Measure torque, current draw, and motor temperature.
5. Brake Test. Measure stopping distance from fixed speeds. Evaluate mechanical brakes or e-brakes under different loads.

4.2 WIRING DIAGRAM





5. RESULT & CONCLUSION

RESULTS

The electric bicycle was experimentally evaluated under different operating conditions such as level roads, inclined surfaces, full-charge endurance testing, and braking trials. The major observations obtained from the testing are summarized below:

Battery and Power Performance

- **Battery Voltage:** The operating voltage remained stable, varying between 24.5 V and 20.0 V throughout the test duration.
- **Current Consumption:** The current draw ranged from approximately 2.5 A on flat roads to 7.8 A while climbing slopes.

- **Achieved Range:** The e-bike covered nearly 28 km on a single full charge under combined riding conditions.
- **Cruising Speed:** An average speed of about 18 km/h was consistently maintained with efficient power usage.

Motor and Torque Characteristics

- **Torque Output:** The motor delivered torque values between 20 Nm and 45 Nm depending on terrain and load conditions.
- **Acceleration Performance:** The e-bike reached a speed of 25 km/h within 6.5 seconds on level ground.
- **Thermal Performance:** During prolonged uphill operation, the motor temperature reached a maximum of 56°C, which is within safe operating limits.

Braking Performance

- **Stopping Distance:** Using mechanical disc brakes, the stopping distance from 25 km/h was measured to be approximately 3.8 meters.
- **Brake Efficiency:** The braking system performed reliably under both dry and mildly wet road conditions.

Ride Comfort and Handling

- **Suspension Response:** The front suspension effectively absorbed shocks on uneven and rough surfaces.
- **Noise and Vibration Levels:** Minimal noise and vibration were observed, indicating good structural balance and proper assembly.

CONCLUSION

Based on the experimental investigation of the 24 V electric bicycle, the following conclusions can be drawn:

- The developed e-bike demonstrates stable, efficient, and dependable performance suitable for urban commuting and light off-road applications.
- The 24 V battery system provides an adequate riding range for short to medium distances with optimized energy consumption at moderate speeds.
- The BLDC motor delivers sufficient torque and smooth acceleration, performing effectively on flat terrain as well as moderate inclines.
- The braking system ensures safe operation with responsive performance and acceptable stopping distances for daily riding conditions.

- The thermal behavior of the motor and controller remained within permissible operating limits throughout testing.
- The overall design, including frame geometry and suspension system, contributes to a comfortable and smooth riding experience.

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