

# Electric Bicycle

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**Abstract:** *Increasing urban populations and expanding city infrastructure are placing considerable pressure on existing transportation networks. Conventional vehicles powered by internal combustion engines contribute significantly to air pollution, energy consumption, and greenhouse gas emissions. As environmental concerns and traffic congestion continue to rise, the development of cleaner and more efficient mobility solutions has become increasingly important. Electric bicycles provide a practical approach to addressing these challenges by combining human-powered cycling with electrically assisted propulsion.*

*This study focuses on the design, construction, and testing of an electric bicycle created by modifying a standard pedal bicycle with an electric propulsion system. The developed system incorporates a 24 V, 250 W DC gear motor, a rechargeable lithium-ion battery pack, a pulse width modulation (PWM) motor controller, and a handlebar-mounted throttle control unit. The primary objective of the project is to develop an economical and energy-efficient transportation alternative while preserving the original mechanical functionality of the bicycle.*

*The modified bicycle operates under three distinct modes: manual pedaling mode, electric propulsion mode, and combined hybrid mode. Experimental evaluation shows that the system can achieve a top speed of approximately 25–30 km/h and can travel close to 40 km on a single battery charge under typical operating conditions. Mechanical power generated by the electric motor is transmitted to the rear wheel through a chain-sprocket drive mechanism, allowing effective torque transfer without affecting the existing pedal drivetrain.*

*Additional protective elements such as a current-limiting fuse, manual power cutoff switch, and PWM-based motor regulation enhance operational safety and system reliability. The modular configuration of the conversion components enables installation on different bicycle frames with minimal modification. The results indicate that electric bicycle conversion systems can provide an affordable and environmentally responsible transportation option capable of reducing fuel consumption and lowering urban carbon emissions.*

**Keywords:** Electric bicycle, sustainable mobility, E-bike conversion, DC gear motor, lithium-ion battery, urban transportation

## I. INTRODUCTION

Mobility is a fundamental requirement of modern society because it supports economic activity, education, and daily commuting. In recent decades, rapid urban growth has led to a dramatic increase in the number of motor vehicles operating in cities worldwide. Although these vehicles provide convenient transportation, their widespread use has resulted in several negative consequences, including traffic congestion, increased fuel demand, and environmental pollution.



Vehicles powered by internal combustion engines release various harmful pollutants, including carbon dioxide (CO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), and particulate matter. These emissions contribute to climate change and deteriorating air quality in densely populated urban regions. As a result, researchers and engineers are actively exploring transportation technologies that reduce environmental impact while maintaining mobility efficiency.

Among the various alternatives under investigation, electrically assisted transportation systems have gained considerable attention. Electric bicycles represent one of the simplest and most accessible forms of electric mobility. An electric bicycle integrates a compact electric motor, rechargeable battery, and electronic control components into the structure of a conventional bicycle. The motor provides supplementary propulsion that assists the rider during pedaling or propels the bicycle through a throttle mechanism.

Compared with conventional motorized vehicles, electric bicycles consume far less energy during operation and do not produce direct exhaust emissions. In addition, their compact size allows them to navigate congested streets more easily while requiring minimal parking space. These characteristics make electric bicycles particularly suitable for short-distance travel within urban environments.

The present research investigates the development of an electric bicycle through a conversion-based approach, where an existing bicycle is modified by installing electric propulsion components. This approach offers several advantages compared with purchasing a new factory-built electric bicycle. Conversion systems are typically more affordable, allow customization of component selection, and encourage the reuse of existing bicycles.

The objectives of this study are summarized as follows:

- To design an electric bicycle conversion system using commonly available mechanical and electrical components
- To integrate an electric drive system while maintaining the original pedaling capability of the bicycle
- To evaluate system performance in terms of speed, energy consumption, and travel distance
- To demonstrate the practicality of electric bicycle technology for sustainable urban transportation

## **II. LITERATURE REVIEW**

Interest in electric bicycles has grown substantially as cities seek cleaner transportation alternatives. Numerous studies have explored the adoption, performance characteristics, and environmental implications of electric bicycle technology. Cherry and Cervero (2007) examined travel behavior among electric bicycle users in China, where E-bikes have become widely adopted for daily commuting. Their study showed that electric bicycles offer a practical alternative to motorcycles and automobiles for short-distance travel, largely due to their relatively low operating cost and convenient operation.

Fishman and Cherry (2016) reviewed research conducted over approximately ten years on the role of electric bicycles in urban transportation systems. Their analysis suggested that E-bikes can replace a significant proportion of short car trips, which may contribute to reduced traffic congestion and lower greenhouse gas emissions.

Technological progress in battery development has played a key role in improving electric bicycle performance. Earlier designs often relied on lead-acid batteries, which were heavy and offered limited energy storage capacity. In contrast, lithium-ion battery technology provides greater energy density, lower weight, and longer cycle life, making it more suitable for compact electric mobility systems.

Advancements in motor control techniques have also contributed to improved performance. Pulse width modulation (PWM) controllers are commonly used in electric drive systems because they allow efficient regulation of motor speed and power output. By adjusting the duty cycle of the electrical signal supplied to the motor, PWM control enables smooth acceleration and better energy efficiency.

Researchers have also investigated electric bicycle conversion kits, which allow existing bicycles to be upgraded with electric propulsion components. These kits typically consist of an electric motor, battery pack, motor controller, and user control interface. Conversion systems provide a practical pathway for expanding electric mobility without requiring users to purchase entirely new vehicles.



Overall, previous studies indicate that electric bicycles can contribute significantly to sustainable transportation by offering an efficient, low-emission alternative for short urban trips.

### **III. SYSTEM DESIGN AND METHODOLOGY**

The development of the electric bicycle conversion system involved three major stages:

- Conceptual system design
- Hardware component integration
- Performance testing and evaluation

The design process focused on creating a system that is efficient, reliable, and compatible with a conventional bicycle frame.

#### **3.1 System Architecture**

The electric bicycle system consists of several interconnected subsystems:

- Electric propulsion system
- Energy storage system
- Motor control system
- Mechanical transmission system
- User control interface

The electric propulsion system generates the mechanical power required to assist the bicycle. The energy storage system supplies electrical energy to the motor, while the controller regulates power delivery based on rider input.

#### **3.2 Hardware Components**

##### **DC Gear Motor**

The propulsion unit used in the system is a 24 V, 250 W DC gear motor. The motor includes an internal gear reduction mechanism that increases torque output while maintaining moderate rotational speed. This configuration is suitable for bicycle applications where high torque is required for acceleration and climbing slopes.

The motor is mounted near the rear wheel to minimize transmission losses and maintain mechanical stability.

##### **3.3 Lithium-Ion Battery Pack**

The electric motor is powered by a rechargeable lithium-ion battery pack rated at 24 V. Lithium-ion batteries were selected because of several advantages:

- High energy density
- Lightweight structure
- Long charge–discharge cycle life
- Low self-discharge rate
- Fast charging capability

These characteristics make lithium-ion batteries well suited for compact electric transportation systems.

##### **Motor Controller**

A PWM-based motor controller is used to regulate the electrical power delivered to the motor. PWM controllers operate by rapidly switching the power supply on and off at a controlled frequency. By adjusting the duty cycle of the switching signal, the controller can control motor speed and torque efficiently.

This method reduces power loss and improves overall system efficiency.



**Throttle Control**

A handlebar-mounted throttle allows the rider to control motor speed. When the rider rotates the throttle grip, a voltage signal is transmitted to the motor controller, which adjusts the motor power accordingly. This interface provides smooth and intuitive control over the electric propulsion system.

**Drivetrain Mechanism**

The mechanical power generated by the motor is transmitted to the rear wheel through a chain and sprocket mechanism. This configuration provides efficient torque transfer and allows the bicycle to retain its original pedal drivetrain.

**4. Safety and Protection Features**

Safety considerations are essential in the design of electric mobility systems. Several protective features were incorporated into the electric bicycle conversion system:

- Electrical Fuse: protects the electrical circuit from excessive current
  - Manual Cutoff Switch: enables immediate disconnection of power in emergency situations
  - Motor Controller Protection: prevents damage caused by voltage fluctuations or overheating
- These safety mechanisms help ensure reliable operation and protect both the rider and electronic components.

**5. System Operation**

The developed electric bicycle can operate in three different modes depending on the rider’s requirements.

**Electric Mode**

In electric mode, the rider activates the throttle to power the motor. The motor controller regulates the electrical power supplied from the battery to the motor, which drives the rear wheel through the chain transmission.

**Manual Mode**

In manual mode, the bicycle operates exactly like a traditional pedal bicycle. The electric motor remains inactive, allowing the rider to cycle without using battery power.

**Hybrid Mode**

Hybrid mode combines both pedaling and electric assistance. In this configuration, the rider pedals while the motor provides additional propulsion. This mode improves energy efficiency and reduces rider fatigue.

**6. Performance Evaluation**

Performance testing was conducted to assess the efficiency and practicality of the developed electric bicycle system.

Performance Parameters

Parameter	Value
Motor Power	250 W
Battery Voltage	24 V
Maximum Speed	25–30 km/h
Travel Range	Up to 40 km
Charging Time	3–4 hours

The testing results indicate that the system provides sufficient torque for normal urban riding conditions. The electric motor assists the rider during acceleration and when traveling on moderate slopes.

Energy consumption remains relatively low, allowing the bicycle to travel significant distances using a single battery charge.



### **7. Advantages of the Proposed System**

The electric bicycle conversion system offers several advantages:

- Environmentally friendly transportation solution
- Reduced reliance on fossil fuels
- Lower operating and maintenance costs
- Quiet operation with minimal noise pollution
- Suitable for short-distance commuting
- Flexible installation on different bicycle frames

### **8. Applications**

Electric bicycles can be utilized in a wide range of practical situations due to their energy efficiency, compact design, and low operational cost. As cities continue to grow and transportation challenges increase, E-bikes provide a flexible and sustainable mobility option for both personal and commercial use. Some important applications of electric bicycles are discussed below.

#### **8.1 Urban Commuting**

One of the most common uses of electric bicycles is daily commuting in urban environments. Many city residents travel short to medium distances between their homes, workplaces, or public transportation stations. Electric bicycles allow riders to cover these distances quickly while avoiding traffic congestion. The electric motor assistance reduces physical effort, making commuting more comfortable, especially in cities with uneven terrain or long travel distances.

#### **8.2 Courier and Delivery Services**

Electric bicycles are increasingly used by courier companies and food delivery services. Their ability to move quickly through congested traffic makes them ideal for last-mile delivery operations. Compared with motorcycles or vans, E-bikes consume significantly less energy and require minimal maintenance. This makes them a cost-effective option for businesses that rely on frequent deliveries within urban areas.

#### **8.3 Campus Transportation**

Large university campuses, research institutions, and educational complexes often require efficient transportation systems for students and staff. Electric bicycles provide a convenient solution for moving between buildings, laboratories, libraries, and residential facilities within a campus environment. They reduce travel time while maintaining an environmentally friendly transportation approach.

#### **8.4 Industrial Facility Mobility**

In large industrial plants, warehouses, and manufacturing facilities, employees often need to travel long distances between different work areas. Electric bicycles can be used as internal transportation vehicles for supervisors, technicians, and maintenance personnel. Their quiet operation and compact size allow them to move safely within industrial environments without producing noise or harmful emissions.

#### **8.5 Eco-Friendly Tourism**

Electric bicycles are increasingly used in tourism and sightseeing activities. Many cities and tourist destinations provide E-bike rental services that allow visitors to explore attractions in an environmentally responsible way. Tourists can cover more distance compared with walking while still enjoying outdoor travel without contributing to air pollution.



### **8.6 Senior and Assisted Mobility**

Electric bicycles can be particularly beneficial for elderly individuals or people with limited physical strength. The motor assistance reduces the effort required to pedal, allowing users to maintain an active lifestyle while still receiving mobility support. This makes electric bicycles an inclusive transportation option for a wider range of age groups.

## **IX. FUTURE SCOPE**

Although the developed electric bicycle conversion system demonstrates satisfactory performance for short-distance transportation, several technological improvements can be implemented in future developments to further enhance system efficiency, safety, and user convenience. Continuous advancements in electric vehicle technology, battery systems, and smart electronics provide many opportunities for improving the design and functionality of electric bicycles.

### **9.1 Integration of Regenerative Braking Systems**

Future versions of the system could incorporate regenerative braking technology. In this method, the motor operates as a generator during braking and converts kinetic energy into electrical energy. The recovered energy can then be stored in the battery, improving overall system efficiency and extending the travel range.

### **9.2 Advanced Battery Management System (BMS)**

A sophisticated battery management system can be integrated to monitor battery voltage, temperature, and charging cycles. The BMS helps protect the battery from overcharging, deep discharge, and overheating, which improves battery life and ensures safer operation.

### **9.3 Solar-Assisted Charging**

The use of small solar panels mounted on parking stations or directly on the bicycle could support solar-assisted battery charging. This approach would allow partial charging through renewable energy sources, reducing dependence on grid electricity and further promoting sustainable transportation.

## **X. CONCLUSION**

This research presented the design and development of an electric bicycle conversion system intended for sustainable urban transportation. By integrating a 24 V, 250 W DC gear motor, lithium-ion battery pack, and PWM motor controller into a conventional bicycle, a practical and energy-efficient mobility solution was created.

Experimental results demonstrate that the converted bicycle can reach speeds of 25–30 km/h and travel up to 40 km per charge, making it suitable for daily commuting and short-distance travel. The system maintains the original pedaling capability while providing electric assistance when required.

Electric bicycle conversion systems represent a cost-effective and environmentally responsible approach to urban mobility. With continued improvements in battery technology and electric drive systems, electric bicycles are expected to play an increasingly important role in sustainable transportation.

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