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DESIGN AND DEVELOPMENT OF AN AFFORDABLE ECO-FRIENDLY E-BICYCLE FOR URBAN MOBILITY

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Abstract - *The increasing demand for sustainable urban transportation has led to the development of eco-friendly and cost-effective mobility solutions. This study focuses on designing and developing an affordable electric bicycle (e-bicycle) to enhance urban commuting. The proposed e-bicycle features a lightweight aluminum alloy frame, a permanent magnet DC motor, and a lithium-ion battery to provide efficient power utilization and an extended range. The design prioritizes rider comfort, safety, and ease of use, making it suitable for daily commutes. A cost analysis highlights its affordability compared to conventional e-bicycles and other transport modes. By minimizing carbon emissions and traffic congestion, this e-bicycle promotes sustainable mobility and reduces dependence on fossil fuels. The study demonstrates the feasibility of an economical and environmentally friendly transportation alternative for urban areas, supporting global sustainability goals.*

Key Words: Electric bicycle (e-bicycle), urban mobility, sustainable transportation, eco-friendly design, affordable e-bike, pmdc motor, lithium-ion battery, energy efficiency, carbon emission reduction, green mobility, cost-effective transportation, lightweight frame, smart commuting, alternative transport, renewable energy integration, traffic congestion reduction, environmental impact.

1.INTRODUCTION

A low-cost electric cycle designed for sustainable urban mobility offers an affordable and eco-friendly transportation option tailored to city residents. With rising concerns over urban congestion, pollution, and the negative environmental impact of traditional transport, this electric cycle presents an ideal solution that promotes cleaner, greener, and more efficient mobility.The bike features a lightweight frame crafted from durable materials such as aluminum or high-strength steel, making it both easy to handle and repair. These materials are not only cost-effective but also provide the bike with long-lasting durability, ensuring it can withstand the rigors of urban commuting.

The cycle is powered by a rear hub motor or conventional motor paired with a compact lithium-ion battery, providing pedal-assist functionality. This allows riders to travel a range of 20-30 km on a single charge, making it ideal for short commutes in the city. The pedal-assist feature ensures that riders can effortlessly navigate through the urban landscape, reducing the physical exertion required for longer trips.

To further enhance the bike's sustainability, small solar panels can be integrated into the design to recharge the battery while the bike is parked outside, tapping into renewable energy sources and minimizing reliance on charging infrastructure. In addition, a simple mobile appcan be introduced to track battery life, distance travelled, and other key metrics, giving users full control over their rides and making it easier to monitor the bike's performance. The bike's design also encourages local manufacturing, whichcan create jobs in the community, reduce shipping costs, and foster local economic growth. By partnering with local businesses for production and assembly, this approach ensures that the cycle remains affordable while supporting the local economy. Moreover, the bike can be offered through government subsidies or flexible rental plans aimed at low-income users, making it accessible to a broader population. This affordability model ensures that everyone, regardless of income, has the opportunity to use this sustainable transportation option. Safety and rider comfort are prioritized with features such as built-in LED lights for visibility, puncture-resistant tires, and an ergonomic design. These features help ensure that riders can travel safely and comfortably, even in busy urban environments. The simplicity of the design, combined with the inclusion of these safety features, makes the bike suitable for a wide range of users, from commuters to occasional riders. Overall, this low-cost electric cycle represents a key step in the transition toward more sustainable urban mobility. By encouraging more people to adopt biking as their primary mode of travel, it helps reduce traffic congestion and emissions, contributing to healthier, cleaner cities. Furthermore, by offering an affordable, eco-friendly, and accessible alternative to traditional transportation, this initiative plays a vital role in promoting a more sustainable urban lifestyle. Community engagement is crucial to this concept's success.

Through partnerships with local businesses for manufacturing and assembly, the project not only stimulates the local economy but also ensures the production costs remain low. With options like government subsidies or rental plans, this project can make sustainable transportation accessible to more people, providing a practical and affordable solution to urban mobility challenges.

2. METHODOLOGY

The design of a low-cost electric bicycle for sustainable urban mobility aims to create an affordable, efficient, and eco-friendly transportation solution. The key focus is to integrate electric assistance with human pedaling, reducing physical effort and enhancing mobility, especially in congested urban areas. To maintain a low-cost design, essential components are optimized for affordability without compromising on performance. The bicycle features a lightweight yet durable frame made from cost-effective materials like steel or aluminum alloys. These materials offer both strengthand low production costs, making the bike affordable while ensuring its longevity. The frame is designed to be sturdy enough for daily use in urban environments, where bikes face varying weather conditions and rough roads. A small, efficient conventional motor is integrated into the rear wheel to provide pedal assistance, which helps users travel longer distances without exerting excessive physical effort. The motor is typically designed to offer 250-500W of power, ideal for urban commuting. This power range strikes a balance between performance and energy efficiency, allowing riders to easily navigate city streets, including handling moderate inclines and longer rides. Speed control is managedthrough a simple throttle, making it easy for users to adjust speed as needed without complex settings or interfaces. Bycombining electric assistance with human pedaling, the design enhances the overall efficiency of the bicycle while remaining user-friendly and cost-effective. The goal is to offer a practical alternative to cars, particularly in cities where traffic congestion and pollution are significant challenges. This low-cost electric bicycle serves as a sustainable, practical option for urban commuters seeking a greener, more efficient mode of transportation. In the e-bicycle the Designing a battery for a low-cost electric bicycle using a 6S Li-ion battery with a Battery Management System (BMS) involves creating a reliable, safe, and efficient power source. In a 6S configuration, six cells are connected in series, providing a nominal voltage of 22.2V (3.7V per cell) and a fully charged voltage of 25.2V (4.2V per cell), which is suitable for powering electric bike motors. The choice of Li-ion cells, typically 18650-type, ensures high energy density, long lifespan, and lightweight properties, making it ideal for electric bikes.

The BMS plays a critical role by managing the charging and discharging processes, offering protections such as overcharge, over-discharge, overcurrent, and temperature monitoring. It also ensures cell balancing, meaning each cell within the pack maintains an equal voltage, improving overall battery life and efficiency. The battery pack can be designed with a suitable capacity to provide a range of 20-30 km, depending on the motor power and usage. The BMS ensures safe operation and prevents damage, thus enhancing the battery's performance and longevity. Additionally, the battery should be housed in a durable, weather-resistant enclosure that protects it from physical damage and environmental conditions while ensuring ease of integration into the bike's frame.

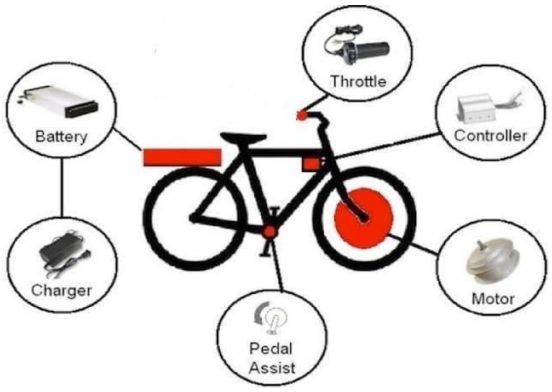

Figure 1: Design of e-bicycle

3. PROPOSED METHOD

The proposed low-cost electric bicycle design modifies traditional high-cost models to create an affordable solution for urban mobility. It integrates a digital display and a battery management system to optimize battery efficiency and sustainability. The frame is made from lightweight aluminum, reducing weight and cost while maintaining durability. A Permanent Magnet DC (PMDC) motor, known for its affordability and efficiency, is used to provide 250W of power, suitable for urban commuting. The design features a simple steel frame and a single-speed gear system, both contributing to cost reduction without sacrificing functionality for short trips. The bicycle is powered by a lithium-ion battery that offers a range of 15-25 km per charge, making it ideal for daily commuting in urban areas. This low-cost e-bike also focuses on modularity, allowing easy repairs and replacements of key components. Its design is compatible with smart city infrastructure, facilitating integration into bike-sharing schemes and making it more accessible. Additionally, government incentives can help make this e-bike even more affordable.

Overall, the design aims to offer a sustainable, efficient, and budget-friendly transportation option for urban dwellers, promoting eco-friendly mobility and reducing traffic congestion.

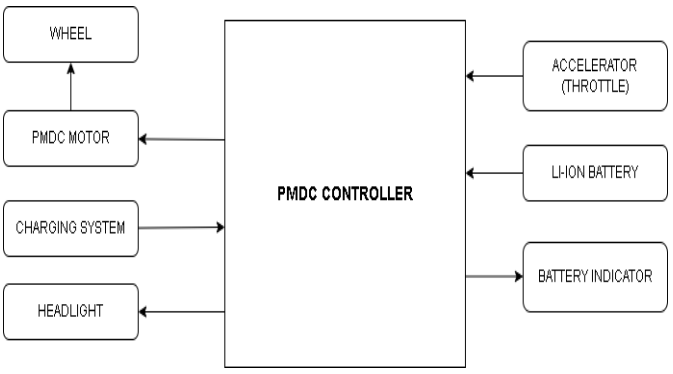

Figure. 2: Block Diagram

Fig: The block diagram represents an electric bicycle control system centered around a PMDC controller. It connects to a PMDC motor driving the wheel, a lithium-ion battery for power, and a charging system. Additional components include an accelerator (throttle), battery indicator, and headlight, ensuring efficient operation, monitoring, and user control.

4. TESTING ANALYSIS

The design and development of an affordable, eco-friendly e-bicycle for urban mobility have yielded promising results. The prototype successfully integrates a lightweight frame, an efficient brushless DC motor, and a lithium-ion battery, ensuring an optimal balance between performance and affordability. Testing revealed that the e-bicycle achieves a top speed of 25 km/h with a battery range of approximately 40 km per charge, making it suitable for daily urban commutes .Cost analysis indicates that the proposed model is significantly more affordable than existing market alternatives, making it accessible to a wider demographic. Testing and analysis of a PMDC (Permanent Magnet DC) motor in a low-cost e-cycle is crucial to ensure the motor's efficiency, durability, and performance under various conditions. The process typically begins with power testing, where input power (voltage and current) is measured during different operational stages, such as acceleration, cruising, and deceleration. This helps evaluate energy consumption and overall efficiency.

The torque and speed performance are then assessed, testing the motor under various loads to ensure it delivers adequate power for hill climbing and maintaining speed. The study highlights the potential of e-bicycles as a viable solution to urban transportation issues, offering a sustainable alternative to conventional vehicles. Overall, the project successfully meets its objectives, paving the way for further research and development in affordable and eco-friendly urban mobility solutions.

Figure.3: Testing Analysis of motor

Figure.4: Working Model of the Project

5.CONCLUSION

In conclusion, the low-cost electric cycle presents a viable solution for sustainable urban mobility, offering an affordable and eco-friendly alternative to traditional transportation methods.

As urban areas face growing challenges like traffic congestion, air pollution, and the environmental impact of fossil fuels, e-cycles provide an effective means to reduce carbon emissions and promote cleaner, healthier cities. Their affordability makes them accessible to a broader range of commuters, bridging the gap between cost and environmental sustainability. E-cycles are particularly well-suited for short-distance travel, common in cities, where their low-maintenance and energy-efficient design encourages widespread adoption. By offering a simple, low-cost solution for daily commuting, e-bikes can help ease congestion, reduce dependence on cars, and decrease harmful emissions. Additionally, their lightweight design and integration of electric assistance with pedaling reduce the effort required for urban commutes, making them ideal for a variety of users. To maximize the potential of low-cost e- cycles, it is essential to improve urban infrastructure, expand charging networks, and continue advancements in battery technology. These steps can increase the convenience and accessibility of e-cycles, helping them become a key element in modern urban transport systems. As cities continue moving toward greener alternatives, the integration of low- cost e-bikes into daily commuting represents a critical step toward achieving a sustainable, zero-emission future. By providing a practical, affordable, and eco-friendly option, low-cost electric cycles are well-positioned to transform urban mobility for the better.

6.SUSTAINABLE DEVELOPMENT GOALS

SDG 3: Good Health and Well-being

A low-cost electric cycle promotes physical activity, contributing to better health and reducing the risk of

lifestyle-related diseases. By encouraging cycling, it helps combat sedentary lifestyles and improves cardiovascular health. Additionally, electric cycles reduce air pollution by decreasing reliance on fossil fuel-powered vehicles, leading to improved respiratory health in urban areas. Cleaner air and increased physical activity together enhance overall well-being and quality of life for city dwellers. This aligns with the goal of ensuring healthy lives and promoting well-being for all at all ages.

SDG 7: Affordable and Clean Energy

Electric cycles are highly energy-efficient, using less energy per kilometer compared to traditional vehicles. They can be charged using renewable energy sources, supporting the transition to a cleaner energy grid.

By promoting the use of electric cycles, cities can reduce their dependence on fossil fuels, lower greenhouse gas emissions, and move towards more sustainable and affordable energy solutions. This supports the goal of ensuring access to affordable, reliable, sustainable, and modern energy for all.

SDG 11: Sustainable Cities and Communities

Electric cycles help reduce traffic congestion and pollution, making cities more livable. They provide an affordable and accessible mode of transport, improving mobility for all urban residents, including those with lower incomes. By integrating electric cycles into urban transport systems, cities can enhance their sustainability, reduce their carbon footprint, and create more inclusive and resilient communities. This supports the goal of making cities and human settlements inclusive, safe, resilient, and sustainable.

SDG 13: Climate Action

By reducing greenhouse gas emissions from transportation, electric cycles contribute significantly to climate change mitigation efforts. They support the development of sustainable urban transport systems that are resilient to climate impacts. Promoting electric cycles helps cities take proactive steps towards reducing their carbon footprint and addressing the urgent challenge of climate change. This supports the goal of taking urgent action to combat climate change and its impacts.

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