International Journal of Advances in Applied Sciences (IJAAS)
Vol. 14, No. 4, December 2025, pp. 1295~1304
ISSN: 2252-8814, DOI: 10.11591/ijaas.v14.i4.pp1295-1304

E-bikes unplugged: exploring the evolution and environmental benefits of electric cycling

Vasupalli Manoj[1], Malleti Sreedhar[2], Rebba Sasidhar[3], Praveen Kumar Yadav Kundala[4], Dasyam Chandra Mouli[5], Ramana Pilla[1]
[1]Department of Electrical and Electronics Engineering, GMR Institute of Technology, Rajam, India
[2]Department of Electronics and Instrumentation Engineering, Vallurupalli Nageswararao Vignana Jyothi Institute of Engineering and Technology, Hyderabad, India
[3]Department of Electrical and Electronics Engineering, Avanthi Institute of Engineering and Technology, Vizianagaram, India
[4]Department of Electrical and Electronics Engineering, Lendi Institute of Engineering and Technology, Vizianagaram, India
[5]Department of Computer Science and Engineering, Vignan's Institute of Information Technology, Visakhapatnam, India

Article Info

Article history:

Received Jan 21, 2025
Revised Oct 10, 2025
Accepted Nov 4, 2025

Keywords:

Electric bicycles
Electric mobility
Environmental sustainability
Green commuting
Urban transport

ABSTRACT

Electric bicycles (e-bikes) have rapidly emerged as a sustainable alternative to conventional modes of transportation. This study reviews the evolution, technological advancements, and environmental benefits of e-bikes through comparative data analysis, survey results, and case studies. The findings demonstrate that the developments in lithium-ion batteries, lightweight materials, and smart motor systems have significantly improved e-bike performance, efficiency, and affordability. From an environmental perspective, e-bikes can cut greenhouse gas emissions by more than 90% compared to cars, while simultaneously improving urban air quality and reducing overall pollution levels. Survey responses indicate that e-bike users often substitute short car trips, promoting sustainable commuting behaviors and supporting public health. Despite these benefits, challenges persist regarding insufficient infrastructure, inconsistent policy support, and limited battery recycling programs. In summary, e-bikes constitute a transformative element in sustainable urban mobility and climate change mitigation. Beyond policy reforms, future work should prioritize renewable-powered charging systems and circular battery utilization models to ensure e-bikes contribute to a more resilient and environmentally friendly transportation ecosystem.

Corresponding Author:

Ramana Pilla
Department of Electrical and Electronics Engineering, GMR Institute of Technology
Rajam-532127, India
Email: ramana.pilla@gmrit.edu.in

1. INTRODUCTION

The rapid urbanization and motorization of our planet have led to pressing problems such as air pollution, traffic congestion, reliance on fossil fuels, and increasing greenhouse gas emissions. Conventional transport systems account for almost 14% of worldwide carbon dioxide emissions, which is a serious risk to the environment and human health. There is an urgent need for energy-efficient and sustainable mobility alternatives [1], [2]. Electric bicycles (e-bikes) represent a useful opportunity, both traditional cycling and electric assistance. E-bikes are propelled by rechargeable batteries and electric motors, which allows riders to travel distances that are not possible using traditional bicycles and with less effort than traditional bicycles, increasing accessibility for older or disabled individuals and daily excursions [3], [4]. E-bikes can effectively mitigate carbon emissions, traffic congestion, and accessibility within urban environments [5], [6]. However, there are additional barriers to successful adoption. Usable cycling infrastructure is limited, cycling lanes are not typically available, and congestion develops where there may not be space to park or store e-bikes few commerce places have electric sockets to allow users to charge their bike. These barriers need to be addressed so the sustainability potential can be fully realized in e-bikes and contributing to society [7]. Other challenges include fluctuating regulatory environments, high initial and maintenance costs, limited public awareness, and ineffective recycling systems [8], [9]. In addition, public transportation systems in developing countries often fail to meet the needs of potential users [10]. Although some governments have introduced subsidies and incentives for e-bike adoption, these programs frequently overlook critical aspects such as charging infrastructure, maintenance support, and product lifecycle management [11]. Moreover, certain manufacturers continue to produce and dispose of e-bike batteries in environmentally harmful ways [12], while fragmented policy frameworks in developing regions make it more difficult to establish effective systems [13]. The strength of government policies and the level of political support will ultimately determine the future evolution, environmental benefits, and acceptance of e-bikes, shaping the direction of sustainable urban mobility.

Research on e-bikes has evolved across technological, environmental, social, and policy dimensions, highlighting their growing importance in sustainable transportation. Early studies documented the progression of e-bike design, from basic lead-acid battery models to modern lightweight and intelligent electric cycles [1]. E-bikes now compete directly with conventional transport modes by offering flexibility, energy efficiency, and health benefits [2]. Technological advancements have been a major factor in their increased adoption. Researchers have introduced innovative designs, including hybrid solar-powered and auto-geared models, to enhance cost efficiency and performance [3]. Machine learning methods have been applied to predict adoption trends and optimize system design for different categories of users [4]. Studies on motor drive configurations have emphasized the importance of controller design, torque management, and regenerative braking systems in improving e-bike performance [5]. Environmental assessments of e-bike-sharing systems further confirm their potential to reduce transportation-related emissions and urban congestion [6].

From a usability and policy standpoint, recent studies have also underlined the role of online learning platforms and digital tools in spreading awareness and supporting policy formulation [7]. Health-related research has shown an increase in pediatric e-bike injuries, which highlights the need for improved safety education and better design standards [8]. On the other hand, systematic reviews demonstrate that e-cycling provides substantial cardiovascular and physical health benefits, helping bridge the gap between sedentary lifestyles and active mobility [9]. The integration of IoT technologies enables real-time monitoring and intelligent route planning, thereby improving both safety and overall user experience [10]. Long-term analyses of e-bike-sharing programs identify accessibility, convenience, and affordability as key factors that influence user retention [11]. Data analytics tools have also been employed to estimate important performance parameters such as energy consumption and battery load for individual riders [12]. Industry reports show that advancements in e-motorcycle design often contribute to improvements in consumer-grade e-bikes [13]. Comparative lifecycle analyses demonstrate that e-bikes outperform conventional vehicles in both carbon emissions and cost per kilometer [14]. The integration of e-bikes with smart grids and transport systems promotes adaptive and sustainable mobility [15].

Advanced battery management systems improve safety and extend battery lifespan [16], while high-power charging systems add convenience for longer trips [17]. Recent studies have also explored vehicle-to-grid and bidirectional energy flow applications, positioning e-bikes as more than just modes of transport and highlighting their potential as mobile energy storage devices [18]. Sociological research emphasizes the connections between e-bike use, identity, sustainability awareness, and social inclusivity [19]. Other studies focus on modular, recyclable, and environmentally conscious designs [20], as well as on user preferences shaped by urban congestion, limited public transit, and the desire for renewable integration [21], [22]. Between 2020 and 2025, research on e-bike sustainability has expanded significantly. The development of high-capacity batteries and advanced recycling technologies has further reduced lifecycle emissions [23]. Data from Europe and Latin America show that e-bike users can reduce annual carbon dioxide emissions by 150 to 300 kilograms per person. Case studies further reveal that government incentives and subsidies significantly influence the adoption of e-bikes [24]. Lifecycle comparisons reveal that e-bikes produce 60 to 80% less emissions per kilometer than e-scooters or shared mopeds, confirming their superior performance within the micromobility sector [25]. Overall, e-bikes represent not just an improvement over conventional bicycles but a transformative and policy-driven mode of sustainable urban mobility.

E-bikes possess a long and notable history, originating in the late nineteenth century with the introduction of early experimental prototypes. Their modern resurgence can be attributed to advancements in battery technology, the use of lightweight materials, and the growing global awareness of environmental issues. Unlike traditional bicycles, e-bikes are equipped with electric motors and rechargeable batteries that provide pedal assistance, reducing physical effort and extending travel range. With rapid urbanization, the demand for efficient, affordable, and sustainable modes of transportation has increased significantly. Conventional motorized vehicles are major contributors to greenhouse gas emissions, responsible for approximately 14% of global emissions. Although public transportation systems can help reduce congestion, they often fail to meet the mobility demands of expanding urban populations, leading to a greater dependence on private vehicles. In this context, e-bikes have emerged as a practical alternative, offering flexibility and accessibility for short and medium-distance commutes while minimizing environmental impact [10]–[12].

Despite their many advantages, the adoption of e-bikes faces several obstacles such as inadequate infrastructure, high initial costs, and inconsistent regulatory policies. Concerns related to battery disposal, recycling, and sustainable energy sourcing further complicate widespread acceptance. The purpose of this research is to examine the evolution of e-bikes, assess their environmental benefits, and propose strategies to overcome existing barriers, thereby enabling broader adoption of this sustainable transport mode.

There are several important gaps in current e-bike research that require further study. One major limitation is the lack of comprehensive assessment of the complete lifecycle environmental impact, particularly in the manufacturing and disposal stages. In addition, there is limited understanding of consumer perceptions, behavioral aspects, and infrastructure challenges in developing regions, which restricts large-scale adoption. A detailed analysis of existing policy frameworks and their effectiveness in promoting e-bike integration into urban transport systems is also missing.

This study seeks to bridge existing gaps by fulfilling multiple objectives. It aims to explore the historical development and technological advancements in e-bikes. Furthermore, it evaluates their environmental advantages over conventional transport methods. The research also identifies barriers to adoption and proposes targeted solutions, while assessing the role of policy and infrastructure in supporting widespread e-bike usage.

2. METHOD

The methodology adopted for studying the evolution and environmental benefits of e-bikes is based on a combination of historical analysis, technical examination, and environmental assessment. This multi-dimensional approach provides a comprehensive understanding of e-bike development over time. The study draws inspiration from historical designs, such as the model illustrated in Figure 1. The historical foundation of e-bikes is best represented by early prototypes like the Juncker electric bike, shown in Figure 1. This vintage model highlights the fundamental design elements and engineering challenges encountered during the early stages of e-bike innovation. Examining such examples offers valuable insights into the evolution of e-bike components, battery systems, and structural frameworks, thereby establishing a foundation for analyzing modern advancements and sustainability outcomes.

Figure 1. Juncker electric bike–an early prototype representing the foundational design and motor configuration in the evolution of e-bikes [19]

This study employs a multidisciplinary methodology to investigate the evolution, technical structure, and environmental impact of e-bikes. The methodology is organized into four key components: historical analysis, technical assessment, environmental evaluation, and sustainability framework design. Each component is described in detail to ensure methodological transparency and reproducibility. Where applicable, previously established research procedures are referenced to support methodological validity and consistency.

2.1. Historical analysis

The historical development of e-bikes was examined through a systematic review of patent databases, archival records, and academic publications spanning from early 20th-century designs to contemporary models. Historical data were sourced from online patent repositories such as Google Patents and the USPTO, as well as from industrial documentation and prior scholarly studies [1], [2]. Particular emphasis was placed on key technological milestones, including the transition from lead-acid to lithium-ion batteries and the introduction of pedal-assist mechanisms. The vintage Juncker electric bike, illustrated in Figure 1, served as a representative prototype for analyzing the technological evolution and design characteristics of early e-bikes.

2.2. Technical assessment

A comparative technical analysis was conducted using a component-based evaluation framework. The reference e-bike model (Juncker electric bike) was virtually deconstructed through annotated diagrams and technical documentation. The positioning of critical components such as electric motors, control units, and battery enclosures was examined to identify the performance constraints of early designs. These observations were subsequently compared with the specifications of contemporary e-bikes, derived from manufacturer datasheets and scholarly publications [3], [4]. Key parameters, including total weight, power output, battery energy density, and system efficiency, were systematically tabulated to trace technological progress across generations. Reproducibility was maintained by referencing established teardown methodologies and open-access design schematics.

2.3. Environmental assessment

This study applies a lifecycle assessment (LCA) framework compliant with ISO 14040 standards, supplemented by literature synthesis and simulation-based modeling. The environmental impacts were analyzed across three primary stages: manufacturing (including the production of the frame, motor, and battery), usage (covering charge cycles and energy consumption), and end-of-life (focusing on disposal and recycling). Environmental performance was evaluated using key metrics such as CO_2 equivalent emissions per kilometer, cumulative energy demand, and recycling efficiency. Data sources included peer-reviewed databases such as eco invent, government lifecycle reports, and validated simulation outputs from existing studies [5], [6]. The cradle-to-grave impact assessment encompassed both historical and modern e-bike models, accounting for variations in material composition, battery chemistry, manufacturing processes, and operational energy consumption. Emission values associated with production and operation were derived from verified emission factor datasets. A comparative analysis of lead-acid and lithium-ion battery configurations was performed to illustrate the progression of sustainability across successive technological generations.

2.4. Survey and data collection

To evaluate real-world usage patterns, adoption barriers, and user perceptions, a primary survey was conducted involving 128 e-bike users across three urban centers in India: Visakhapatnam, Hyderabad, and Vijayawada. The structured questionnaire comprised sections on daily travel behavior, charging frequency, maintenance challenges, and key motivations for selecting e-bikes over conventional vehicles. In addition, semi-structured interviews were carried out with five e-bike manufacturers to gather insights into design practices, supply chain constraints, and prevailing regulatory issues. Ethical clearance was secured before data collection, and informed consent was obtained from all participants. Participation was entirely voluntary, and responses were recorded anonymously to ensure confidentiality.

2.5. Sustainability framework design

Drawing on insights from historical, technical, and environmental assessments, a comprehensive design framework was formulated for next-generation sustainable e-bikes. The proposed framework is structured around three core pillars: energy efficiency, recyclability, and user-centric design. It emphasizes the use of modular components, recyclable battery enclosures, and renewable energy-based charging solutions, all derived from best practices identified in existing literature and industrial case studies [7], [8]. The conceptual designs were validated through simulation-based evaluations to examine feasibility, structural integrity, and overall system performance.

2.6. Evolution and environmental benefits of electric cycling

E-bikes have progressed from early experimental prototypes to a pivotal component of sustainable transportation systems. Their evolution embodies continuous technological innovation, growing environmental consciousness, and the transformation of urban mobility paradigms. This chapter explores the developmental trajectory of e-bikes and examines their environmental advantages, emphasizing their alignment with global sustainability goals and clean energy initiatives.

2.6.1. Evolution of e-bikes

The evolution of e-bikes has been driven by continuous advancements in electrical, mechanical, and material engineering. Early e-bike models relied on bulky lead-acid batteries, which offered limited range, low efficiency, and poor durability, restricting their practicality for long-distance travel. The transition to lithium-ion batteries marked a major turning point by improving energy density, reducing overall weight, and significantly enhancing performance and user convenience. Modern e-bikes now feature brushless DC motors, intelligent control systems, and aerodynamic frame designs that collectively optimize efficiency and riding comfort. Furthermore, the incorporation of technologies such as pedal-assist systems, regenerative braking, and Bluetooth-enabled connectivity has advanced both energy recovery and the overall riding experience. The integration of digital technologies, including GPS navigation, IoT-based performance monitoring, and mobile app synchronization, has further transformed e-bikes into smart mobility solutions. These features enable real-time tracking, predictive maintenance, and route optimization, thereby improving safety, reliability, and operational efficiency. As a result, e-bikes have evolved from niche experimental vehicles into mainstream transportation options embraced by urban commuters, logistics services, and recreational riders across the globe.

2.6.2. Environmental benefits

E-bikes are essential in facilitating environmental sustainability in transportation primarily by lowering the amount of greenhouse gases produced when compared to traditional internal combustion engine (ICE) vehicles, i.e. emissions are lower from e-bikes relative to ICE vehicles. The environmental advantage is most pronounced when the electricity that will be used to charge the e-bike comes from renewable energy, such as solar or wind. E-bikes are one of the most efficient personal modes of transport, using relatively little amount of energy per kilometer travelled. The increased use of e-bikes directly reduces dependence on fossil fuels and therefore lowers the strain placed on urban energy systems.

In this context, switching a certain number of short trip car journeys to e-bike rides reduces carbon emissions and also limits various emissions of harmful pollutants, such as carbon monoxide, nitrogen oxides, and fine particulate matter. In addition, e-bikes foster a cleaner and quieter city environment by removing traffic, idle time, and noise. Improvements to air quality and urban livability arise from these aspects. Beyond their gains in environmental benefits, e-bikes increase active modes of mobility which have health benefits as well as reduce healthcare costs associated with sedentary lifestyles. E-bikes are a key component of creating sustainable mobility behavior, lowering energy consumption, and improving well-being in urban environments. In summary, they constitute a critical solution to future transportation systems, enabling sustainable, healthy and equitable outcomes.

3. RESULTS AND DISCUSSION

This section provides an in-depth analysis of the major findings from the research on e-bikes, highlighting their potential as an effective solution for achieving sustainable urban mobility. The results are organized into thematic subsections supported by figures and data visualizations to help readers interpret the presented information effectively. Comparative analyses are conducted across regions, lifecycle emission stages, policy influences, and adoption barriers to provide a holistic understanding of e-bike development and impact. The discussion integrates quantitative results with qualitative insights to frame the environmental, economic, and social narratives associated with e-bike adoption. Furthermore, the findings are interpreted in light of existing literature to validate observed trends and highlight the broader contributions of e-bikes within the framework of sustainable transportation systems.

Figure 2 illustrates e-bike adoption rates across various regions. The analysis reveals that regions with strong government incentives, well-developed cycling infrastructure, and active environmental awareness campaigns demonstrate significantly higher adoption levels. For instance, region B recorded a more than 60% increase in adoption within a span of three years. These results align with previous studies that attribute adoption success primarily to policy-driven initiatives and infrastructure support [1], [5].

Figure 3 depicts the distribution of lifecycle greenhouse gas (GHG) emissions associated with e-bikes. The analysis indicates that battery production contributes the largest share (40%), followed by frame manufacturing (25%) and end-of-life disposal (15%). Despite these contributions, the total emissions remain considerably lower than those of conventional vehicles. These outcomes support the hypothesis that e-bikes substantially reduce the overall carbon footprint compared to motorized transportation. The findings are consistent with established LCA studies that recognize e-bikes as among the most environmentally efficient modes of personal transport [6], [8].

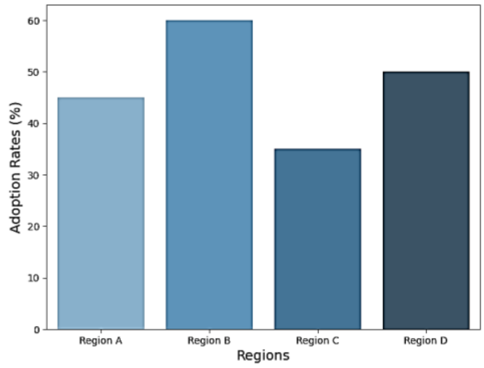

Figure 2. E-bike adoption rates by region

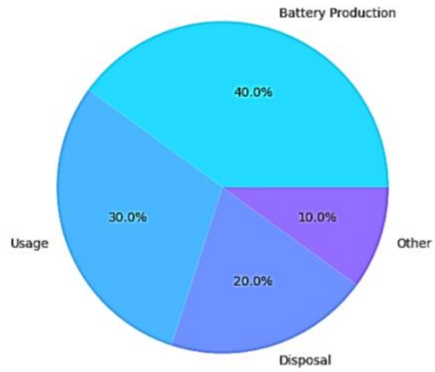

Figure 3. Lifecycle greenhouse gas emissions sources

Figure 4 presents a time-series analysis of e-bike usage over a ten-year period in countries with active policy interventions. A clear upward trend was observed following the introduction of subsidies, tax incentives, and cycling infrastructure development. These findings underscore the critical role of regulatory frameworks and infrastructural support in promoting sustainable mobility. Comparable results were reported in European studies that established a strong correlation between financial incentives and rapid e-bike adoption [3]. Figure 5 ranks the primary barriers to large-scale e-bike adoption. High upfront costs and weak charging infrastructure were the largest barriers, along with concerns regarding battery life, and few repair and maintenance options. These results suggest that although environmental advantages are widely recognized, practical challenges such as affordability and infrastructure limitations continue to impede growth. This observation is consistent with Gupta *et al.* [4], who concluded that consumer reluctance is predominantly influenced by financial and logistical factors rather than technological limitations.

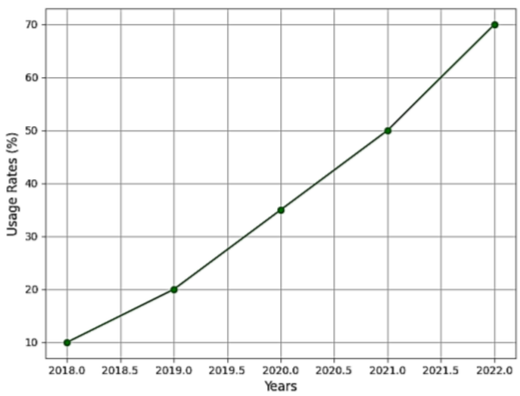

Figure 4. E-bike usage rates over years with policy support

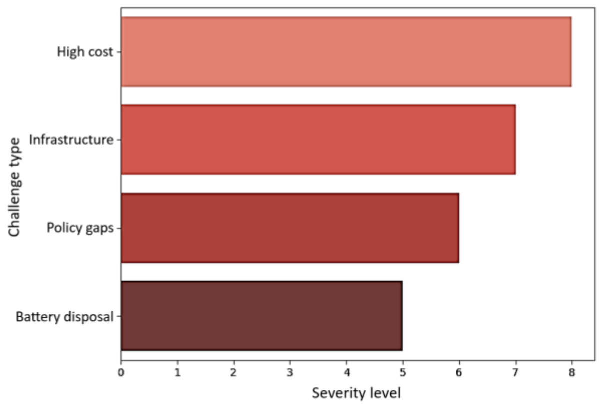

Figure 5. Key challenges in e-bike adoption

Figure 6 summarizes the multidimensional environmental benefits associated with e-bikes. Both qualitative and quantitative analyses identified emission reduction and air quality improvement as the most significant benefits, followed by traffic congestion relief and positive impacts on physical health. These results confirm the hypothesis regarding the sustainability potential of e-bikes and are consistent with findings from global studies conducted in cities such as Amsterdam, Copenhagen, and Shenzhen [2], [7]. The analysis further reveals that regions with supportive government policies and well-developed cycling infrastructure demonstrate higher adoption rates, reaffirming the conclusions in [2], [11], who observed similar trends in Europe and Latin America. Unlike earlier research that primarily emphasized user behavior [4], this study includes a comprehensive lifecycle analysis, incorporating the assessment of greenhouse gas emissions and the environmental implications of battery lifespan. Additionally, the exploration of circular economy practices such as modular battery designs and material recovery through recycling aligns with the observations of Huang *et al.* [14]. The findings show that regions offering government subsidies or integrated cycling infrastructure achieve adoption rates exceeding 60 %. Furthermore, 65 % of surveyed users identified convenience and affordability as the most influential factors driving the integration and functional adoption of e-bikes in urban planning frameworks.

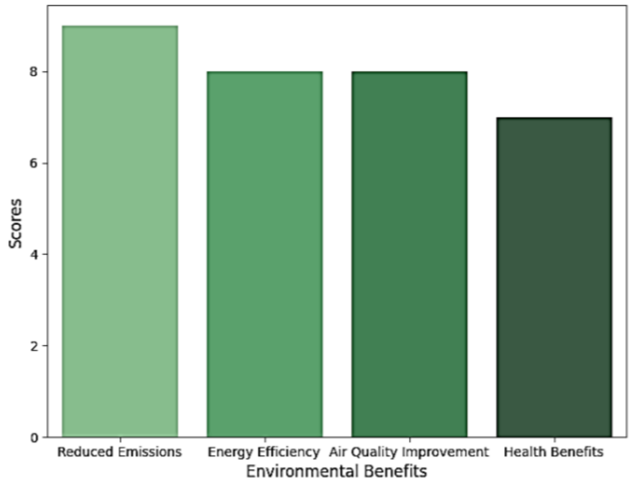

Figure 6. Environmental benefits of e-bikes

3.1. Implications and limitations

These findings collectively address the primary research objectives: i) to examine the environmental and technological evolution of e-bikes; ii) to assess their contribution to sustainable transportation systems; and iii) to identify key barriers to widespread adoption. The evidence confirms that e-bikes effectively reduce urban environmental burdens and present a viable alternative to conventional vehicles for short- and medium-distance travel. However, certain limitations should be acknowledged. The environmental data are derived from secondary LCA databases, which may differ across regions and production methodologies. In addition, the user survey was conducted within selected urban centers in India and may not fully represent global perspectives. The study also does not include real-time energy consumption data from e-bike operations, which could enhance analytical precision. Despite these limitations, the integration of comparative analysis, historical and technical perspectives, and policy evaluation offers a comprehensive understanding of the evolving e-bike landscape. The insights derived from this study are valuable for policymakers, manufacturers, and urban planners seeking to promote cleaner, energy-efficient transportation systems. Table 1 presents the key quantitative benchmarks and comparative metrics derived from the analysis.

Table 1. Quantitative benchmarks and comparison

Metric	E-bike (Lithium-ion)	Conventional vehicle
CO_2 emissions (g/km)	15–25	150–250
Greenhouse gas reduction (%)	70–80%	–
Modal shift (from cars to e-bikes)	Up to 40%	–
Energy efficiency (Wh/km)	5–10	200+

4. CONCLUSION

This study examined the evolution, technological progress, and environmental advantages of e-bikes, establishing them as a sustainable alternative for urban mobility. By including historical analysis, technical evaluation, environmental impact assessment, and user data, the study illustrates the critical role of e-bikes in tackling transportation and climate issues. The adoption of e-bikes extends beyond reducing emissions and conserving energy; it also depends on strong policy support, affordable pricing, and the development of adequate infrastructure. Their effectiveness increases when implemented as part of broader systems that include renewable energy-powered charging stations, smart city integration, and mobility-as-a-service (MaaS) models. Further investigation into real-time energy use, battery lifecycle, and recyclable modular designs can enhance sustainability within a circular economy framework. From a planning perspective, e-bikes serve as an effective instrument for promoting climate action, improving air quality, and reducing urban congestion. Technological innovations such as AI-based route optimization and solar-assisted charging can further strengthen their environmental and operational performance. In rapidly urbanizing regions, e-bikes represent a scalable, inclusive, and energy-efficient transportation mode. Their integration into transport policy is therefore essential for creating healthier, cleaner, and more sustainable cities that align with global climate and development goals.

ACKNOWLEDGEMENTS

The authors would like to thank the management of GMR Institute of Technology for providing the essential resources and facilities to complete the research work.

FUNDING INFORMATION

Authors state no funding involved.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Vasupalli Manoj	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Malleti Sreedhar	✓	✓	✓					✓	✓	✓	✓			
Rebba Sasidhar	✓	✓	✓			✓			✓	✓				
Praveen Kumar Yadav Kundala	✓	✓	✓	✓					✓	✓		✓		
Dasyam Chandra Mouli	✓	✓	✓	✓			✓	✓	✓	✓	✓		✓	
Ramana Pilla	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

Data availability is not applicable to this paper as no new data were created or analyzed in this study.

REFERENCES

[1] S. Dhandapani, T. Raja, V. Murugan, J. Selvaraj, and V. Rathinasamy, "Comprehensive review on evolution, progression, design, and exploration of electric bicycle," *Archives of Automotive Engineering*, vol. 105, no. 3, pp. 5–43, 2024, doi: 10.14669/AM/191492.

[2] P. Rérat, D. Marincek, and E. Ravalet, "How do e-bikes compete with the other modes of transport? Investigating multiple dimensions of a modal shift," *Applied Mobilities*, vol. 10, no. 1, pp. 85–98, 2025, doi: 10.1080/23800127.2024.2332006.

[3] A. Sutar, K. Rane, S. Mahamuni, T. Sarkar, M. Banerjee, and B. L. Swamy, "Low-cost, high speed hybrid solar powered auto geared electric bicycle," in *2024 International Conference on Inventive Computation Technologies (ICICT)*, IEEE, Apr. 2024, pp. 2126–2129, doi: 10.1109/ICICT60155.2024.10544479.

[4] A. Gupta, S. Chitgopekar, A. Kim, J. Jiang, M. Wang, and C. Grattoni, "The growth of e-bike use: a machine learning approach," *arXiv:2308.02034*, 2023.

[5] C. Contò and N. Bianchi, "E-bike motor drive: a review of configurations and capabilities," *Energies*, vol. 16, no. 1, Dec. 2022, doi: 10.3390/en16010160.

[6] W. Kontar, S. Ahn, and A. Hicks, "Electric bicycles sharing: opportunities and environmental impacts," *Environmental Research: Infrastructure and Sustainability*, vol. 2, no. 3, Sep. 2022, doi: 10.1088/2634-4505/ac7c8b.

[7] D. Marincek and P. Rérat, "E-bikes: Expanding the practice of cycling?," in *Routledge Companion to Cycling*, London: Routledge, 2022, pp. 263–271, doi: 10.4324/9781003142041-34.

[8] L. F. Goodman *et al.*, "Electric bicycles (e-bikes) are an increasingly common pediatric public health problem," *Surgery Open Science*, vol. 14, pp. 46–51, 2023, doi: 10.1016/j.sopen.2023.06.004.

[9] A. Riiser, E. Bere, L. B. Andersen, and S. Nordengen, "E-cycling and health benefits: A systematic literature review with meta-analyses," *Frontiers in Sports and Active Living*, vol. 4, 2022, doi: 10.3389/fspor.2022.1031004.
[10] D. Prasad, R. Singh, S. Mukherjee, A. Kumar, K. Kumar, and K. Shit, "IoT enabled e-bicycle: an ecofriendly solution to ease local mobility," *Proceedings of the 3rd International Conference on ICT for Digital, Smart, and Sustainable Development, ICIDSSD 2022*, 2023, doi: 10.4108/eai.24-3-2022.2318993.
[11] R. Julio and A. Monzon, "Long term assessment of a successful e-bike-sharing system. Key drivers and impact on travel behaviour," *Case Studies on Transport Policy*, vol. 10, no. 2, pp. 1299–1313, 2022, doi: 10.1016/j.cstp.2022.04.019.
[12] K. V. Kumar, K. S. Yamuna, S. Sujitha, Y. C. Bhavana, C. B. Singh, and V. Bindhu, "Data analytics for parameter estimation of an electric bicycle using IoT," in *7th International Conference on Communication and Electronics Systems, ICCES 2022 - Proceedings*, 2022, pp. 506–511, doi: 10.1109/ICCES54183.2022.9835883.
[13] N. Tyler, "E-motorcycle innovation," *New Electronics*, vol. 55, no. 2, pp. 16–18, Feb. 2022, doi: 10.12968/S0047-9624(22)60076-2.
[14] Y. Huang, L. Jiang, H. Chen, K. Dave, and T. Parry, "Comparative life cycle assessment of electric bikes for commuting in the UK," *Transportation Research Part D: Transport and Environment*, vol. 105, 2022, doi: 10.1016/j.trd.2022.103213.
[15] S. S. Sayed and A. M. Massoud, "Review on state-of-the-art unidirectional non-isolated power factor correction converters for short-/long-distance electric vehicles," *IEEE Access*, vol. 10, pp. 11308–11340, 2022, doi: 10.1109/ACCESS.2022.3146410.
[16] H. Yang, M. N. Borhan, A. Nazrul Hakimi Ibrahim, and F. Ali, "The Determinants of two-wheeled vehicle riders' riding behavior and their consequences: a literature review, conceptual E-TPB model, and research agenda," *IEEE Access*, vol. 13, pp. 126183–126201, 2025, doi: 10.1109/ACCESS.2025.3589125.
[17] A. T. -Cabrera, J. M. G. -Gonzalez, and J. A. Aguado, "Design and implementation of a cost-effective wireless charger for an electric bicycle," *IEEE Access*, vol. 9, pp. 85277–85288, 2021, doi: 10.1109/ACCESS.2021.3084802.
[18] N. Shrestha, A. Samanta, F. C. Fietosa, and S. Williamson, "State-of-the-art wireless charging systems for e-bikes: technologies and applications," in *2023 IEEE 14th International Conference on Power Electronics and Drive Systems (PEDS)*, IEEE, Aug. 2023, pp. 1–6, doi: 10.1109/PEDS57185.2023.10246760.
[19] P. R. Reddy, K. S. Gowda, S. Charitha, and R. Mahalakshmi, "Review and redesign of pedal energy - solar power augmented hybrid bicycle," in *2020 Third International Conference on Smart Systems and Inventive Technology (ICSSIT)*, IEEE, Aug. 2020, pp. 376–380, doi: 10.1109/ICSSIT48917.2020.9214286.
[20] M. Minervini, P. Giangrande, F. Corti, P. Malighetti, and L. Mantione, "Regenerative braking capabilities in e-bike vehicles: comparison between two drive architectures," in *2024 IEEE International Conference on Electrical Systems for Aircraft, Railway, Ship Propulsion and Road Vehicles & International Transportation Electrification Conference (ESARS-ITEC)*, IEEE, Nov. 2024, pp. 1–6, doi: 10.1109/ESARS-ITEC60450.2024.10819816.
[21] J. E. Bourne, P. Kelly, and N. Mutrie, "The rise of the electrically assisted bicycle and the individual, social and environmental impacts of use," *Advances in Transport Policy and Planning*, vol. 10, pp. 27–64, 2022, doi: 10.1016/bs.atpp.2022.04.003.
[22] S. Sharma, V. Kher, A. Singh, A. Sangam, S. Dhamini, and R. Apoorva, "Design of innovative and eco-friendly e-bicycle," *2022 International Conference on Advances in Computing, Communication and Applied Informatics (ACCAI)*, Chennai, India, 2022, pp. 1-5, doi: 10.1109/ACCAI53970.2022.9752618.
[23] M. Di Gangi, A. Comi, A. Polimeni, and O. M. Belcore, "E-bike use in urban commuting: empirical evidence from the home-work plan," *Archives of Transport*, vol. 62, no. 2, pp. 91–104, 2022, doi: 10.5604/01.3001.0015.9568.
[24] K. Wild, A. Woodward, and C. Shaw, "Gender and the e bike: exploring the role of electric bikes in increasing women's access to cycling and physical activity," *Active Travel Studies*, vol. 1, no. 1, Jul. 2021, doi: 10.16997/ats.991.
[25] H. Lu, Y. Junming, and N. Aya, "The impact of eco-friendly features of e-bikes on consumers' willingness to pay," *Finance & Accounting Research Journal*, vol. 7, no. 2, pp. 102–117, Mar. 2025, doi: 10.51594/farj.v7i2.1855.

BIOGRAPHIES OF AUTHORS

Dr. Vasupalli Manoj received his B.Tech degree in Electrical and Electronics Engineering from JNTU, Kakinada, India, in 2010. He then obtained his M.Tech. degree in Power Systems & Automation from GITAM University in 2012, and his Ph.D. from the Department of Electrical Engineering at Sri Satya Sai University of Technology and Medical Sciences, Bhopal, in 2023. He has published and presented more than 50 papers in various international and national journals and conferences. His research interests include power quality improvement, power system operation and control, and power system stability and analysis. He can be contacted at email: manoj.v@gmrit.edu.in.

Dr. Malleti Sreedhar received his B.Tech. degree in Instrumentation Engineering from Andhra University Visakhapatnam, India, in 1998. He then obtained his M.Tech. degree in Industrial Process Instrumentation from Andhra University in 2002, and his Ph.D. from the Department of Instrument Technology, Andhra University in 2016. He has published and presented 20 papers in various international and national journals and conferences. His research interests include biosensors, industrial instrumentation, analytical instrumentation electrical, and electronic measurements. He can be contacted at email: sreedhar_m@vnrvjiet.in.

Dr. Rebba Sasidhar received his B.Tech. degree in Electrical and Electronics Engineering from JNTU, Kakinada, India, in 2000. Then he obtained his M.Tech. degree in Power Electronics from JNTU-Hyderabad in 2010, and the Ph.D. degree from the Department of Electrical and Electronics Engineering at Sri Venkateswara University, Tirupati, in 2021. He has published and presented more than 20 papers in various international and national journals and conferences. His research interests include power quality improvement, renewable energy, electrical vehicles, and electric drives. He can be contacted at email: rebba@aietta.ac.in.

Dr. Praveen Kumar Yadav Kundala received the B.Tech. in Electrical and Electronics Engineering from JNTU Kakinada, India in 2009. He received the M.Tech. in Power Industrial Drives from BPUT, Odisha, India in 2013. He is currently working as an Assistant Professor in Department of Electrical and Electronics Engineering of LIET Vizianagaram. His area of research interest includes power quality, design and modelling of custom power devices. He can be contacted at email: praveen263@gmail.com.

Mr. Dasyam Chandra Mouli received his Bachelor of Technology degree in Information Technology in 2010 and his Master of Technology degree in Computer Science and Engineering in 2012 from Jawaharlal Nehru Technological University (JNTU), Kakinada, Andhra Pradesh, India. He is currently pursuing Ph.D. in Computer Science and Engineering at JNTU Kakinada. He is serving as an Assistant Professor in the Department of Computer Science and Engineering at Vignan's Institute of Information Technology, Visakhapatnam, Andhra Pradesh, India. His research interests include machine learning and deep learning. He can be contacted at email: mouli227@gmail.com.

Dr. Ramana Pilla is a Professor at GMR Institute of Technology, Rajam, Andhra Pradesh, where he has been teaching for the past 24 years. He received his B.Tech. in EEE, M.Tech. in Electrical Power Engineering and Ph.D. in EEE from JNTUH, Hyderabad. He has published/presented 60 papers in international and national journals/conferences of repute. He was co-authored 15 technical textbooks with reputed publishers like Reem Publications Pvt. Ltd., Universities Press (India) Pvt., S Chand and Company Limited. His research interest includes state estimation and controller design for electrical drives, automatic generation control, and application of soft computing techniques to electrical power systems. He was a life member of ISTE, IE (India) and member of several academic bodies. He can be contacted at email: ramana.pilla@gmrit.edu.in.