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Design and Development of a Foldable E-Bike for Last-Mile Urban Mobility

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Abstract: *Urban transportation systems in India continue to face challenges related to traffic congestion, environmental degradation, and inefficiencies in last-mile connectivity. This project addresses these issues by proposing a compact, foldable electric bicycle designed specifically for daily urban commuters. Through a blend of primary user research, benchmarking, and iterative design, a final concept was developed featuring a two-step folding mechanism, a 250W BLDC hub motor, and ergonomic improvements. The bike integrates modern materials, electrical systems, and an intuitive mobile application interface. Feedback from targeted user groups validated the practicality, comfort, and appeal of the prototype. The study highlights the importance of user-centered design in creating sustainable and functional micro-mobility solutions.*

IndexTerms - Foldable e-bike, last-mile connectivity, electric mobility, urban transport, sustainable design, product ergonomics, user-centered design

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I. INTRODUCTION

With the rapid rise in urban population density and increasing vehicular congestion, Indian cities are experiencing mounting pressure on their transportation infrastructure. Existing public transit systems, while crucial, often fail to address the "last-mile" connectivity challenge—an essential factor that determines whether commuters will fully adopt public transport (Hoen et al., 2024). The last-mile gap often results in higher dependence on private vehicles, thereby worsening traffic and environmental issues. In this context, foldable electric bicycles (e-bikes) emerge as an effective micro-mobility solution that integrates the benefits of electric propulsion, portability, and ease of use.

This study focuses on designing a foldable e-bike customized for Indian cityscapes, emphasizing affordability, compactness, and user comfort. The model integrates a 250W BLDC hub motor, ergonomic seating, and a two-step folding mechanism, offering a solution that reduces travel time and supports eco-conscious commuting. Foldable e-bikes also reduce parking concerns and can be carried into public transport systems or stored in small residential spaces—key advantages in overcrowded urban areas (Polkar et al., 2023; Sharma et al., 2024).

Furthermore, the growing global emphasis on sustainability and climate action has propelled electric micro-mobility into mainstream urban planning. According to the NITI Aayog and Rocky Mountain Institute (2017), promoting electric mobility in India could lead to a 37% reduction in carbon emissions by 2030. Supporting this claim, Luo et al. (2020) demonstrate in their life-cycle analysis that electric bikes significantly outperform conventional vehicles in terms of emissions and energy efficiency.

The designed foldable e-bike also targets diverse urban segments such as students, delivery riders, and daily office-goers. It leverages user-centered design strategies, modular components, and smart mobile integration to meet evolving consumer expectations (Arvind et al., 2023). In light of rising urbanization and limited road infrastructure, such compact, personalized transportation options hold transformative potential for Indian cities. With continued innovation, foldable e-bikes can play a pivotal role in decongesting roads, reducing environmental impact, and making everyday commuting more accessible and efficient (Hu et al., 2021; Gazzola et al., 2020).

Figure 1 evolution of urban mobility(pexels,2023)(Pickart,2025)

II. LITERATURE REVIEW

Existing studies highlight the increasing relevance of foldable e-bikes in addressing the needs of modern urban transport. Polkar et al. (2023) investigated compact folding mechanisms that emphasize durability and user convenience, providing critical insights into mechanical design strategies. Tiwari et al. (2024) analyzed the ergonomic and structural challenges in developing lightweight yet strong chassis systems suitable for portable e-bikes. Similarly, Sharma et al. (2024) stressed the role of hybrid charging systems in enhancing sustainability and extending battery life, while Hoen et al. (2024) discussed how personal micro-mobility devices contribute to improved urban connectivity and reduce dependence on traditional motorized transport. Moreover, Hu et al. (2021) demonstrated that environmentally friendly design significantly influences e-bike adoption in smaller cities, particularly among women and economically constrained populations. These works collectively emphasize a multidisciplinary need to design e-bikes that are ergonomic, eco-friendly, and socially inclusive.

III. MARKET ANALYSIS

The Indian urban commuting landscape is characterized by challenges of traffic congestion, last-mile connectivity, affordability, and growing environmental concerns. Existing market solutions highlight a clear trade-off between portability, pricing, comfort, and user experience. The Brompton Electric, globally acknowledged for its ultra-compact folding mechanism and engineering excellence, remains prohibitively expensive for average Indian users, thereby limiting mass adoption. Conversely, shared e-bike services like Yulu focus on affordability and wide availability but often compromise on ergonomics, aesthetics, and long-term comfort, making them less appealing for frequent personal use.

Furthermore, sustainability remains a growing concern. Lifecycle assessments and studies on battery performance (Sharma et al., 2024; Hu et al., 2021) point out the urgent need to optimize materials, charging cycles, and energy efficiency. Mohammad Zabiulla et al. (2024) identified affordability, battery durability, and environmental impact as the top purchase drivers among Indian users. Additionally, the integration of mobile applications and IoT-enabled systems is emerging as a significant trend in the personal mobility sector, offering enhanced control, security, and real-time diagnostics (Tiwari et al., 2024).Therefore, the market presents a significant opportunity for a well-designed foldable e-bike that balances cost, compactness, comfort, and smart functionality—tailored to the needs of Indian urban commuters, particularly low- to middle-income users seeking sustainable and flexible transport options.

Table 1 product comparison

S.No	Brand/Model	Image	Key Components
1 1	UBOARD X7		The UBOARD X7 is a budget-friendly, foldable electric scooter with 25 km/h speed, 20 km range, ABS braking, and LED lights—ideal for safe, short urban commutes and easy transport.
2 2	Tygatec G281		The Tygatec G281 is an off-road hoverboard with 8.5-inch all-terrain tires, 300W battery, stable ride, and ₹15,000 price—ideal for rough terrain and outdoor exploration.
3 3	Yulu		Yulu offers shared, license-free electric bikes with app-based unlocking, low-speed commute, delivery-focused DeX model, affordable rental plans, AI-powered fleet, battery swapping via Yuma, eco-friendly rides, and gig worker support.
4 4	Honda Motocompacto		The Honda Motocompacto is a $995 ultra-compact electric scooter with 490W motor, 24 km/h speed, 19 km range, and a unique foldable design—perfect for city commutes and campus travel.
5 5	Gocycle GX		The Gocycle GX is a sleek, foldable e-bike with a fast 10-second fold, front hub motor, integrated battery, and PitstopWheel®—ideal for stylish urban commuting in cities like Bengaluru.
6 6	Doodle V3		The Doodle V3 is a ₹52,999 foldable e-bike with fat tires, 250W motor, 60+ km range (PAS), 7-speed Shimano gears, and quick-charging removable battery—ideal for versatile, terrain-ready urban commuting.

figure 2 (a) UBOARD X7,(b) Tygatec G281,(c)Yulu, (d) HondaMotocompacto,(e) Gocycle GX,(f) Doodle V3

IV. METHODOLOGY

A structured and multi-phase design methodology was adopted to guide the development of the foldable electric bicycle. The process began with **ethnographic research** and a comprehensive **user questionnaire survey**, engaging 113 participants from diverse urban backgrounds to identify real-world pain points in last-mile travel. To extract qualitative insights, **10 in-person interviews** were also conducted across varied age groups and occupational segments, including students, working professionals, and delivery personnel (Creswell, 2014). This mixed-method approach helped gather data on mobility patterns, ergonomic needs, and preferred product features.

Benchmarking was performed against leading micro-mobility products like **Brompton Electric**, **Doodle V3**, and **Yulu**, focusing on folding mechanisms, weight distribution, and motor integration. These comparisons provided valuable functional insights into the strengths and shortcomings of existing solutions (Polkar et al., 2023; Gazzola et al., 2020). Based on initial research, six design concepts were generated and evaluated using **Quality Function Deployment (QFD)** to align customer needs with technical capabilities (Akao, 1990), and further filtered through the **Pugh Matrix** to determine the most viable concept. **Concept 6** emerged as the optimal design, balancing usability, aesthetics, and feasibility.

The selected design was modeled using **Computer-Aided Design (CAD)** software, ensuring dimensional accuracy and ergonomic compliance using **Indian anthropometric data** (Desai et al., 2022). Materials such as **Mild Steel (MS) square tubes** were chosen for the chassis, and **sunboard** was used for enclosure fabrication due to its lightweight and low-cost properties (Callister & Rethwisch, 2020). Design for Manufacturability (DFM) principles were applied throughout the process to minimize production complexity and ensure cost-effectiveness (Kumar, 2012).

A companion **mobile user interface (UI)** was also developed to provide real-time updates on speed, battery level, and travel distance, enhancing user interaction. The app followed standard UX principles tailored to urban commuters (Interaction Design Foundation, 2023). Iterative **prototyping and validation** cycles were conducted to assess foldability, ride comfort, and safety under simulated urban use cases. Each phase was grounded in user feedback and usability testing, ensuring that both digital and physical systems aligned with user expectations and market needs.

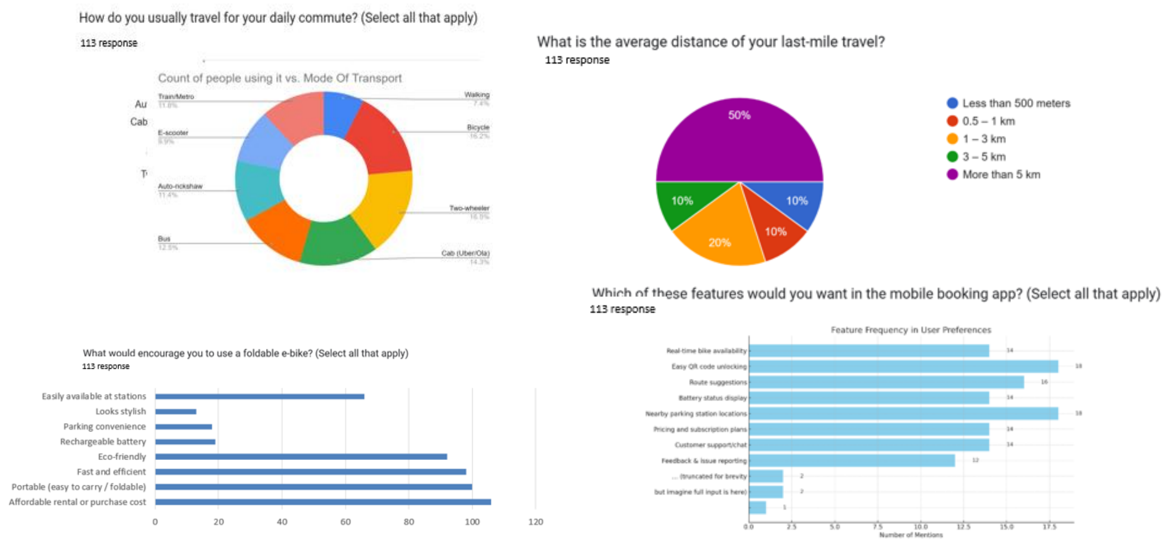

Figure 3 methodology

V. PRODUCT DESIGN AND DEVELOPMENT

5.1 Concept Finalization

Concept 6 was selected based on superior performance in folding efficiency, aesthetics, and ergonomic compatibility. It demonstrated practical folding action through a two-step mechanism and compact footprint for easy storage in urban environments. The design also incorporated user preferences from the research phase. Aesthetically, the concept balances modern geometry with smooth curvature, ensuring both visual appeal and structural integrity. The frame geometry was designed using Fusion 360, and the form supports proper posture and balance. Additionally, its modular components offer easier maintenance and potential for future upgrades. The final concept was also evaluated based on material usage, ease of manufacture, and part count, aligning with DFMA principles (Tiwari et al., 2024).

Figure 4 concepts generated

Pugh Matrix – Foldable E-Bike Concept Evaluation

Criteria	Existing (Base)	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5	Concept 6
Portability	0	+	0	+	–	+	++
Aesthetics	0	+	–	0	+	+	++
Ease of Folding	0	0	–	+	0	+	++
Comfort & Ergonomics	0	+	–	0	–	0	++
Stability	0	–	0	0	+	0	+
Battery Integration	0	0	–	+	0	+	++
Visual Innovation	0	+	–	0	+	+	++
Mechanism Simplicity	0	0	–	0	–	+	+
Material Efficiency	0	0	0	0	0	+	+
Urban Usability	0	+	–	0	0	+	++

Summary Table

Concept	+ Score	– Score	Net Score
Concept 1	4	1	+3
Concept 2	1	4	–3
Concept 3	2	0	+2
Concept 4	3	2	+1
Concept 5	6	0	+6
Concept 6 ✅	**9**	**0**	**+9**

figure 5 pugh matric chart

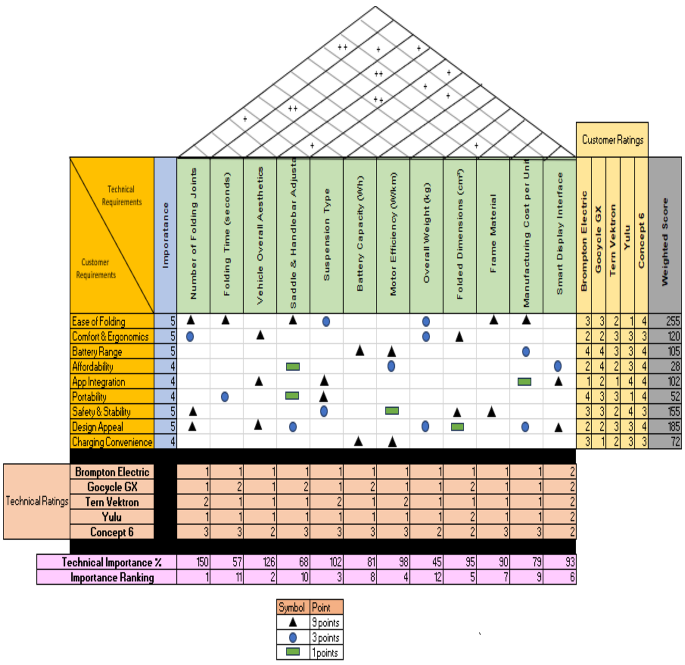

figure 6 QFD Chart

5.2 Technical Features

Key specifications include a 250W BLDC hub motor for reliable propulsion, electrical braking for safety, and a dual-fold mechanism (Polkar et al., 2023). A mobile app interface displays speed, distance, and battery level. Lightweight materials were chosen to ensure portability without compromising durability. The bike's frame features a telescopic seat post for varied user heights and quick-release systems on the handlebar and wheels for faster assembly. Battery placement is along the central downtube to balance the center of gravity, while the wiring is integrated into the frame to maintain aesthetics. The two-step fold combines a central hinge with a collapsible front section, allowing the bike to reduce to 60% of its full length.

Figure 7 prototyping process

5.3 Materials and Mechanism

MS square tubes were used for the frame due to their strength-to-weight ratio. Sunboard formed the enclosure for aesthetics and weight reduction. The folding mechanism includes a central hinge and front fold supported by locking latches, with a telescopic seat and quick-release parts for ease of adjustment. The electrical components are connected via concealed channels. The mechanism was tested for repetitive folding cycles and strength under urban use-case conditions. The design ensures that folding is intuitive, quick, and secure, enhancing everyday usability.

figure 8 folding mechanism

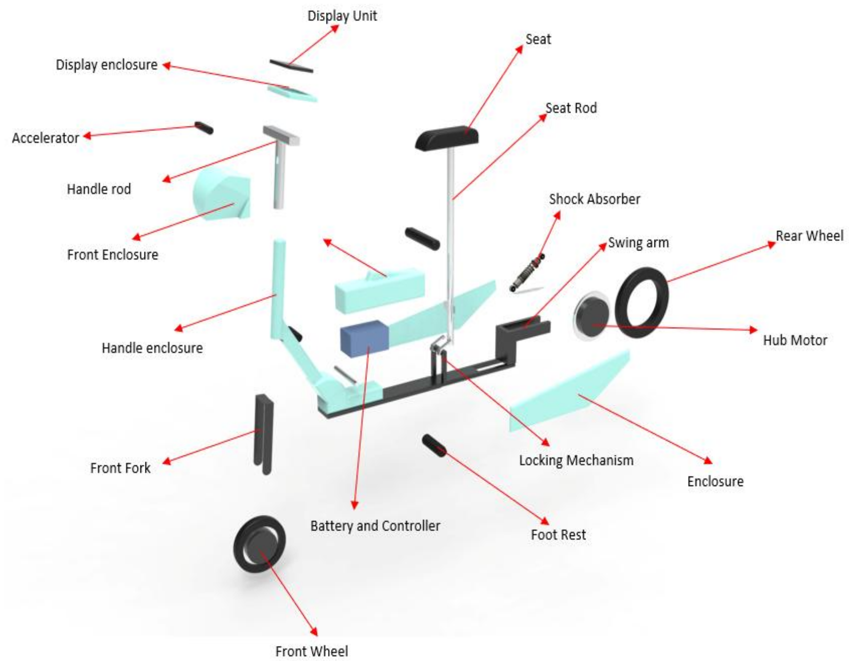

figure 9 vehicle assembly

figure 10 task analysis

VI. Validation and Testing

Seven users (aged 20–26) tested the prototype, including students and working professionals. Feedback emphasized the product's portability, ease of use, and stylish design. Ergonomic seating and smooth electric assistance were well-received. Minor critiques included the need for better seat cushioning and pedal clearance. These insights affirmed the concept's alignment with commuter needs and guided future improvements. The testing phase also explored mobile app feedback, and users found the interface intuitive and data displays accurate. Riders could easily fold and unfold the bike within 15 seconds, which supports quick transitions during commutes. The structure was tested for basic load stability, and the motor responded effectively on flat terrains. Adjustability in seat and handlebar height was appreciated by users of different body types. Reflectors and braking feedback were noted as helpful safety features. The bike was compared to existing rental options like Yulu, with users expressing preference for the comfort and ownership value (Mohammad Zabiulla et al., 2024) of the foldable design. Observations were recorded in a structured evaluation sheet. Final analysis confirmed that the design met ergonomic, aesthetic, and functional expectations.

figure 11 user validation

figure 12 final prototype

VII. Conclusion

The project successfully delivers a foldable e-bike concept tailored to address the last-mile mobility needs of urban Indian commuters. The final prototype combined ergonomic design, functional folding mechanisms, and integrated electrical systems, all guided by user research and market benchmarking. Its dual-fold structure and lightweight frame offer a practical solution for everyday transport. The study reinforces the value of incorporating direct user feedback into the design process and highlights the growing role of micro-mobility in sustainable (Hoen et al., 2024) urban transit. Future improvements may include IoT integration and enhanced smart features to further align with emerging urban infrastructure. The successful development of this prototype also demonstrates that locally sourced materials and accessible fabrication techniques can produce a cost-effective and scalable solution. Integration of smart app features such as ride history, distance alerts, and real-time navigation could further enrich the user experience. The design and research approach used in this project serve as a framework for future innovations (Sharma et al., 2024) in the micro-mobility sector, offering potential pathways toward more inclusive and adaptable urban transport (Polkar et al., 2023)ation systems.

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