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Design, Fabrication and Testing of a Low-Cost Electric Two-Wheeler with Hub-Motor Drive and Smart Battery Management

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Abstract

Electric two-wheelers offer a direct route to reducing urban transport emissions, but their adoption in price-sensitive markets is governed by capital cost rather than by technology. This paper reports the complete design, fabrication and testing of a low-cost electric two-wheeler built to a total materials and labour budget of ₹60,000, of which the battery accounts for half. The tractive-effort requirement was established analytically for a 95 kg vehicle at a design speed of 35 km/h by summing rolling resistance, aerodynamic drag, gradient resistance and acceleration force, giving a total tractive force of 123.4 N and a required propulsive power of 1200 W; a 1 kW hub motor was selected on this basis. The powertrain calculation, allowing 80 % depth of discharge, yields a 48 V, 26.04 Ah pack of 1250 Wh, charged by a 48 V, 5 A charger. The vehicle was fabricated in four phases over approximately three months: concept development, 2D and 3D design with finite-element structural analysis, frame fabrication and component integration, and validation testing. Testing comprised power-supply verification, system functionality checks, road trials over varied terrain, overload strength testing with multiple riders, braking distance measurement, ramp gradeability and bump stability. A cost breakdown, a component-wise service-life estimate and a comparison against petrol and commercial-EV alternatives are presented. Three internal inconsistencies in the recorded design data — in the frontal-area value, in the tractive-force summation used for torque, and in the quoted range and charging time — are identified explicitly rather than resolved silently, and the measurements needed to settle them are stated.

Introduction

This work concerns the design and development of an efficient, affordable and environmentally sound electric two-wheeler for daily urban commuting. Powered by rechargeable batteries, such a vehicle offers a cleaner alternative to fuel-based transport with lower running cost and no tailpipe emission. Advances in battery and motor technology have made electric mobility increasingly practical, and the prototype reported here addresses the recurring obstacles of range, charging time and safety at a cost consistent with the Indian two-wheeler market.

1. Characteristics of Electric Two-Wheelers

The electric two-wheeler differs from its internal-combustion counterpart in several respects: it operates without fuel; an electric motor replaces the engine; smart electronics govern its operation; regenerative braking recovers a portion of the kinetic energy; charging resembles that of a consumer device; and performance is defined largely in software. The environmental consequences follow directly — reduced greenhouse-gas emission, negligible noise, cleaner energy sourcing, improved public health outcomes, reduced fuel consumption and reduced oil dependency.

Practical advantages relevant to the user include immediate torque and smooth acceleration, connected features, government subsidy support, the convenience of home charging and low running cost.

2. Objective

The objective is to design and develop an energy-efficient electric vehicle prototype using lightweight composite materials and smart electronic systems including a battery management system (BMS). The design aims to reduce reliance on fossil fuels, promote sustainable engineering practice and support the reduce–reuse–recycle principle in transport design. It further serves as a low-cost platform for innovation, student learning and practical application in green mobility, and is intended to be scalable, safe and suitable for demonstration and public awareness.

3. Literature Context

Environmental concern and technological advance have together driven interest in electric two-wheelers as a sustainable alternative to conventional vehicles. Studies document the harmful effects of emissions from internal-combustion engines — carbon monoxide, oxides of nitrogen, volatile organic compounds, carbon dioxide and particulate matter — which contribute to respiratory disease, smog formation and climate change (Gupta et al., 2021; Sharma and Singh, 2019).

The economic burden of fossil-fuel dependence is a parallel concern. Fuel prices in India are volatile, driven by global crude prices, taxation policy and seasonal demand; this instability raises transport cost and strengthens the long-term economic case for electric vehicles (Rao and Mishra, 2020). In manufacturing, compliance with stricter emission norms such as BS6 has raised costs, particularly for diesel vehicles, whose elevated oxides-of-nitrogen emissions and maintenance complexity have reduced market demand; petrol vehicles emit less but still incur frequent maintenance cost from engine complexity (Kumar et al., 2022).

Against this background, electric two-wheelers have emerged as a promising response, supported by improvements in battery technology, motor efficiency and charging infrastructure, and offering lower operating cost, minimal maintenance and zero tailpipe emission for urban use. The present work builds on these findings by developing an affordable and efficient electric two-wheeler that addresses range, performance and safety.

4. Scope

- A platform for smart-mobility experimentation.
- A basis for green-technology enterprise and local manufacture.
- An educational model for engineering and sustainability teaching.
- A demonstrator for public awareness of clean energy.

System Architecture

The vehicle operates through a coordinated set of subsystems, shown in Fig. 1.

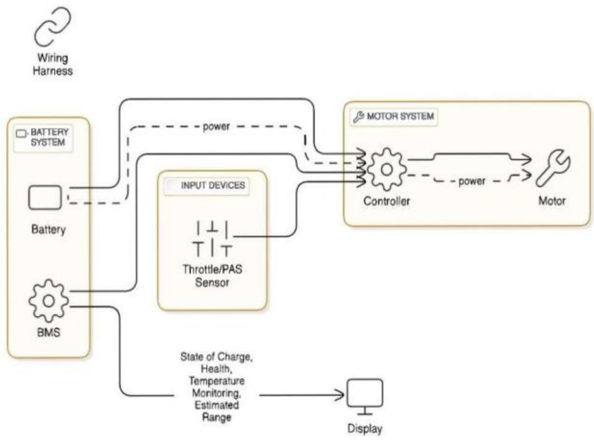

Figure 1: Block diagram of the electric two-wheeler showing the battery, BMS, controller, motor and auxiliary subsystems.

At its core is a lithium-ion battery, selected for energy density and service life, which stores the electrical energy driving the vehicle. The battery supplies a brushless DC motor that converts electrical energy to mechanical motion. Motor operation is regulated by a controller, functioning as the electronic control unit, which mediates between rider demand at the throttle and power delivery at the wheel. The battery management system monitors cell state and reports to the display, while auxiliary loads — lighting and horn — are supplied through a DC–DC converter that steps the traction voltage down to 12 V.

Development Methodology and Timeline

The development was organised into four phases, each allocated a defined duration, as given in Table 1 and illustrated in Fig. 2.

Table 1. Project Phases and Durations

Phase	Key activities	Duration
Concept development	Research and planning	1 month
Design phase	2D and 3D design, simulation	1 month
Fabrication	Assembly, wiring	1 month
Testing	Validation, safety	1 week

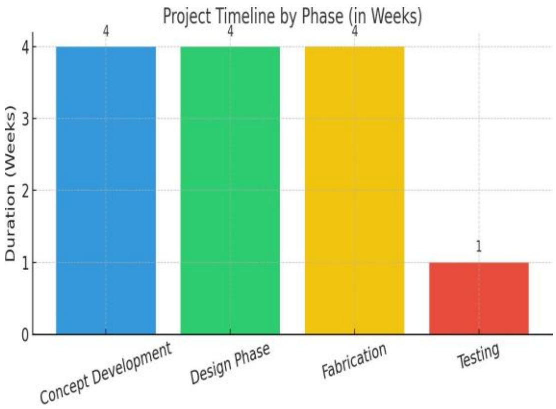

Figure 2: Project timeline by phase.

1. Concept development-This phase established the foundation through brainstorming, research and design thinking. The project scope and objectives were defined, existing electric-vehicle models were analysed, and the essential components and materials were shortlisted.
2. Design-Two-dimensional sketches and detailed three-dimensional models were produced, and structural analysis was carried out to assess stability and design integrity. Load and stress simulations informed subsequent design optimisation.
3. Fabrication-This phase covered chassis and frame fabrication, component integration and the electrical and mechanical fitting of all subsystems, including precise wiring.
4. Testing-Validation addressed performance, safety and efficiency at both component and system level. Battery testing considered energy density, charge–discharge behaviour and thermal stability; powertrain testing assessed motor and controller performance; and electrical testing verified wiring and electronic integrity.

Vehicle Design and Sizing Calculations

1. Principal Dimensions

The vehicle geometry is shown in Fig. 3 and its principal dimensions are given in Table 2.

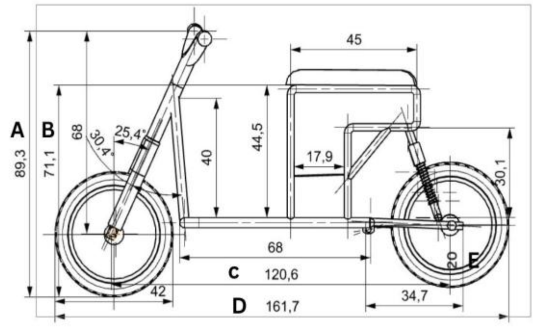

Figure 3: Principal dimensions of the vehicle.

Table 2. Principal Vehicle Dimensions

Reference	Dimension	Value
A	Handlebar height	893 mm
B	Seat height	711 mm
C	Wheelbase	1206 mm
D	Overall length	1617 mm
E	Ground clearance	20 mm

2. Tractive Effort

The propulsive force required at the wheel is the sum of four resistances. The design case is a vehicle mass of 95 kg at a maximum speed of 35 km/h, equivalent to 9.72 m/s. The tyre aspect ratio, defined as sidewall height as a percentage of tyre width, is 90 % or 0.9.

Rolling resistance

$F_{rolling} = C_r \cdot m \cdot g$ (1)

where C_r is the coefficient of rolling resistance, m the vehicle mass in kg and g the gravitational acceleration of 9.81 m/s^2. For $C_r = 0.01$,

$F_{rolling} = 0.01 \times 95 \times 9.81 = 9.3195$ N (2)

Aerodynamic drag

$F_{drag} = 0.5 \cdot \rho \cdot v^2 \cdot C_A \cdot A_f$(3)

where C_A is the aerodynamic drag coefficient, taken as 0.75 within the 0.48 to 0.88 range typical of scooters; ρ is air density; v is vehicle velocity; and A_F is frontal area. With vehicle height 1150 mm, width 350 mm and an adjustment factor of 0.7 for rounded corners, the frontal area is

$A_f = H \times W \times Adv = 1.15 \times 0.35 \times 0.7$ (4)

The value carried forward in the design record is $A_F = 0.8408$ m^2, giving

$F_{drag} = 0.5 \times 0.75 \times 1.23 \times 9.72^2 \times 0.8408 = 36.6405$ N (5)

It should be noted that evaluating (4) directly gives 0.2818 m^2 rather than 0.8408 m^2. The recorded value is retained here because it is the figure used in the subsequent motor sizing, but the discrepancy is real and is revisited in Section VIII.

Acceleration force

$$AF = (W \times v) / t \quad (6)$$

where W is vehicle mass, v the target velocity and t the time allowed to reach it, taken as 60 s. Hence

$$AF = (95 \times 9.722) / 60 = 15.39 \text{ N} \quad (7)$$

Gradient resistance

$$F_{gradient} = m \cdot g \cdot \sin\theta \quad (8)$$

with θ the angle of inclination. Evaluating at θ = 3.82°,

$$F_{gradient} = 95 \times 9.81 \times \sin 3.82° = 62.05 \text{ N} \quad (9)$$

3. Motor Sizing

Summing the four contributions gives the total tractive force:

$$F_{total} = 9.3195 + 62.05 + 36.6405 + 15.39 = 123.4 \text{ N} \quad (10)$$

The propulsive power required follows as the product of force and velocity:

$$P = F \times v = 123.4 \times (35 \times 1000 / 3600) = 1200 \text{ W} \quad (11)$$

A 1 kW hub motor was therefore selected as sufficient for a 95 kg vehicle at 35 km/h. The wheel radius, from a wheel size of 450.088 mm, is 0.225 m; the corresponding wheel torque is the product of tractive force and radius.

The design record additionally contains a torque calculation in which the summation is taken as 9.3195 + 36.6405 + 241.206 + 15.39 = 302.556 N, yielding 68.075 N·m at the wheel. The third term in that sum, 241.206 N, does not correspond to the gradient resistance of (9), and the two summations are therefore mutually inconsistent. Equation (10) is the version consistent with the motor actually selected, and is adopted here; the discrepancy is addressed in Section VIII.

4. Powertrain and Battery Sizing

From the motor rating of 1000 W at 48 V, the energy drawn in one hour of continuous operation at rated power is 1000 W·h. Allowing a usable depth of discharge of 80 %, with 20 % retained as reserve, the required pack energy is

$$1000 \text{ W·h} / 0.8 = 1250 \text{ W·h} \quad (12)$$

At the 48 V pack voltage this corresponds to a capacity of

$$1250 \text{ W·h} / 48 \text{ V} = 26.04 \text{ A·h} \quad (13)$$

The pack specification is therefore 48 V, 26.04 A·h, giving a rated energy of 1250 W·h.

5. Charging Circuit

For a target charging time of five hours, the charger must deliver the pack energy over that interval. Taking 1200 W·h as the energy to be replaced, the required charger power is 1200 W·h / 5 h = 240 W, and at 48 V the corresponding current is 5 A. A 48 V, 5 A charger was accordingly specified for the 48 V, 26 A·h pack. The intermediate arithmetic recorded in the source at this step contains a transcription error; the specification stated above is the one consistent with both the pack energy and the five-hour target.

6. Simulation and Structural Analysis

The powertrain was modelled in MATLAB/Simulink (Fig. 4) to verify the control and power-flow arrangement before fabrication. The chassis was analysed by finite-element methods (Fig. 5) to establish that the frame could carry the operational loads.

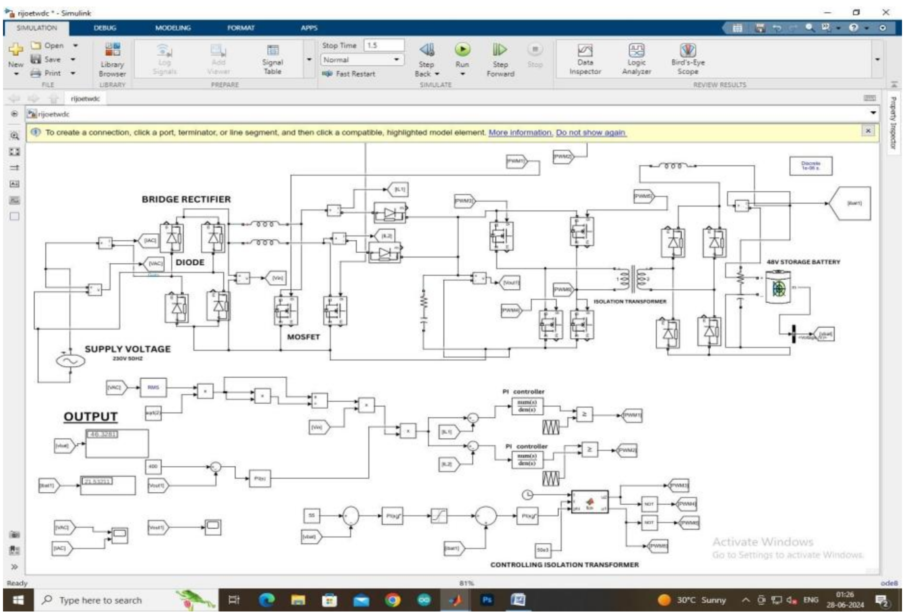

Figure 4: MATLAB/Simulink model of the powertrain.

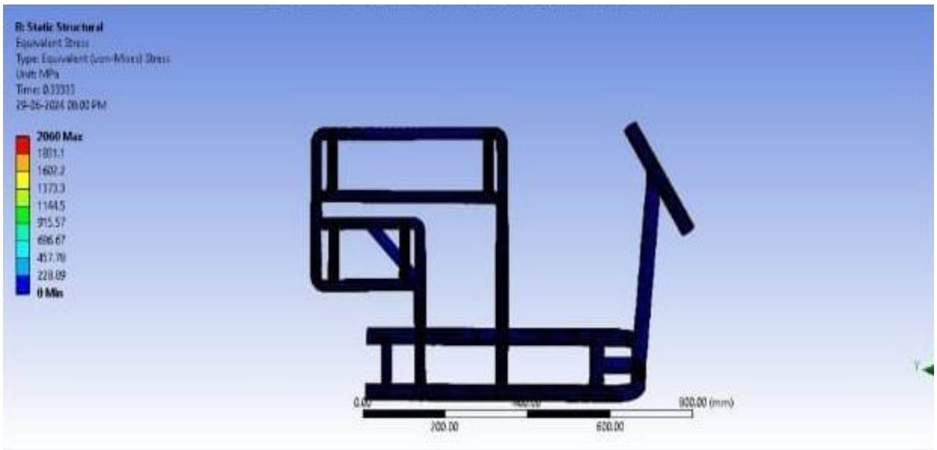

Figure 5: Finite-element analysis of the chassis.

Chassis analysis proceeds from a detailed three-dimensional CAD model, which forms the basis for subsequent simulation. Finite-element analysis is then applied to determine the response to operational loads, comprising static analysis of stress and deformation under normal conditions and dynamic analysis of behaviour under vibration and transient forces. Modal analysis establishes natural frequencies and mode shapes so that resonance can be avoided. Material properties — high-strength steel or aluminium alloy, chosen for their strength-to-weight balance — are incorporated into the model, from which stress distribution, strain and potential failure points are computed, identifying regions requiring reinforcement or redesign. Analytical results are validated by physical static load, impact and vibration testing, and the design is then optimised iteratively to reduce weight, improve stiffness or redistribute load without compromising strength.

Component Selection

1. Hub Motor

A hub motor is an electric motor built directly into the wheel hub, delivering torque at the wheel and eliminating the transmission. Conventional brushless or brushed motors require mounting arrangements, gear ratios and periodic maintenance, and are less space-efficient. The hub motor operates on electromagnetic induction: a stator and rotor are contained within the hub, and current through the stator windings establishes a field that interacts with the rotor to drive the wheel. This direct-drive arrangement removes the gear train, giving quieter and more efficient operation.

Figure 6: Hub motor integrated into the wheel.

Table 3. Hub Motor Specification

Parameter	Value
Rated power	1000 W
Operating voltage	48 V / 60 V
Current range	10 A/h
Speed	25–35 km/h
Torque output	approximately 30–40 N·m
Motor diameter	12 inch rim diameter

2. Controller

The controller governs the flow of power from battery to motor, managing speed, direction, braking and efficiency to give responsive and smooth operation.

Figure 7: Motor controller unit.

Table 4. Controller Specification

Parameter	Value
Power rating	250 W
Voltage	48 V / 60 V (connect at 60 V, disconnect at 48 V)
Current	35 ± 1 A
Phase angle	120°
Control type	Sine-wave controller

Figure 9: Instrument display.

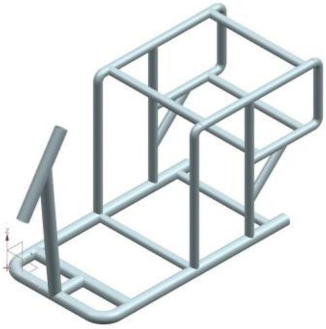

Figure 10: Vehicle frame.

3. Battery

The battery pack stores the electrical energy and supplies the motor, and determines both range and performance. Lithium-ion cells were selected for their high energy density, which stores more energy in less space and mass — an advantage in a compact vehicle — together with longer service life, faster charging and lower maintenance than lead-acid alternatives.

Figure 8: Battery pack.

Table 5. Battery Specification

Parameter	Value
Battery type	Lithium-ion
Rated voltage	48 V / 60 V
Capacity	20–30 A·h (design dependent)
Discharge current	15–30 A
Charging current	5–10 A
Charging time	3–4 hours

4. Display, Frame and Auxiliary Systems

The display provides the rider with real-time information including battery level, gear mode selection with reverse, and trip distance and odometer readings (Fig. 9). The frame (Fig. 10) forms the structural skeleton, supporting and protecting all components while maintaining balance.

A DC–DC converter (Fig. 11) steps the traction-pack voltage down to 12 V for lights, horn and other accessories. The throttle (Fig. 12) controls power flow from battery to motor and is built in weather-resistant plastic with a rubber grip, terminating in a three- or five-pin waterproof connector. The wiring harness (Fig. 13) connects and powers every component, and is made from multi-strand pure copper with waterproof multi-pin connectors.

Figure 11: DC–DC converter stepping traction voltage down to 12 V for auxiliary loads.

Figure 12: Throttle assembly.

Figure 13: Wiring harness.

Lighting-Lighting uses energy-efficient LEDs. Headlights serve five functions: they illuminate the road so the rider can identify obstacles, potholes and signage, which is essential at night or in low light; they make the vehicle conspicuous to other road users, reducing collision risk in dense traffic where two-wheelers are easily overlooked; they satisfy the legal requirement for functioning headlights, which applies in India as in many jurisdictions; they support the Automatic Headlight On provision, mandatory on all new two-wheelers sold in India since 1 April 2017, which keeps headlights illuminated at all times and improves daytime conspicuity; and where the automatic provision is absent, manually activated headlights remain essential to night-riding safety.
Horn-The horn is an electronic sounder powered from the auxiliary rail, rated at 12 V DC with a sound level of at least 105 dB (Fig. 14). Audible warning is of particular importance for electric vehicles, whose low noise emission reduces the incidental audible cues by which pedestrians detect an approaching vehicle; manufacturers have accordingly developed dedicated acoustic alert systems for urban environments.

Figure 14: Horn assembly.

5. Battery Management System

The battery management system monitors, manages and protects each cell to secure service life, efficiency and safety. Its functions are as follows.

- Real-time battery state: indicates whether the pack is fully charged, charging or approaching depletion.
- Dynamic current monitoring: tracks instantaneous current flow and energy consumption.
- Application connectivity: a mobile application displays live pack voltage, temperature, charge cycles and power output in graphical form.
- Remote management over Bluetooth, making the BMS an integral smart feature of the vehicle.

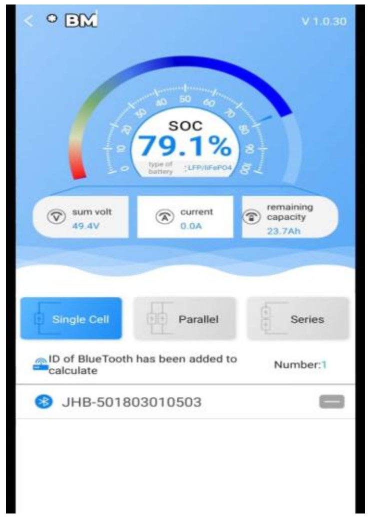

Figure 15: Battery management system application displaying state of charge.

Table 6. Battery Management System Specification

Parameter	Value
Monitored parameters	State of charge, battery temperature
Connectivity	Bluetooth enabled
Mobile application	Balance 100

Fabrication

Fabrication translated the design into a physical vehicle through a defined sequence of operations.

1. Design Realisation

Work began with a holistic view of the vehicle architecture, in which every component was identified before dimensions were fixed. Hand sketches were followed by two-dimensional layouts (Fig. 16), part-wise design with structural analysis (Fig. 17), and a complete three-dimensional model (Fig. 18) that established the final form.

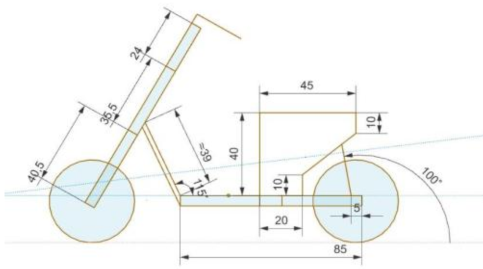

Figure 16: Two-dimensional design layout.

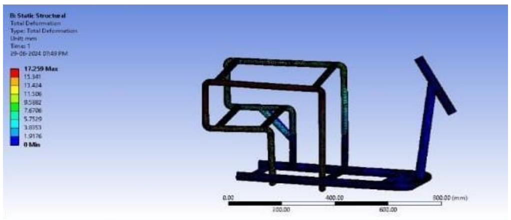

Figure 17: Structural analysis of the frame.

Figure 18: Three-dimensional model of the completed vehicle.

2. Frame Fabrication

Frame construction proceeded through precision bending and cutting of galvanised iron tube, framing and welding of the base structure (Fig. 19), assembly of the swing arm, fork and handlebar, integration of the side and centre stands, and mounting of the wheels to produce the rolling skeleton shown in Fig. 20.

Figure 19: Welded frame during fabrication.

Figure 20: Rolling chassis with wheels and running gear mounted.

3. Battery Assembly and Component Integration

The battery pack was constructed in-house from individual cells (Fig. 21), providing direct experience of pack building. The motor was then installed, the battery mounted with attention to location and restraint, and the remaining components assembled, tightened and locked in sequence (Fig. 22).

Figure 21: Battery pack assembly from individual cells.

Figure 22: Assembled components and wiring on the chassis.

4. Bodywork

The outer covering was produced by first creating a pattern in cardboard, then applying resin and laying fibre over it, cutting and shaping the hardened shell, and finishing with resin putty and graining before painting (Fig. 23).

Figure 23: Completed bodywork before final finishing.

Testing and Results

1. Component and System Checks

Testing began with verification of the power supply to every component. Each wire and connection was re-checked for stable current flow and secure termination (Fig. 24). With assembly complete, a full system functionality test exercised throttle response, motor speed, display accuracy, brake lights and switchgear.

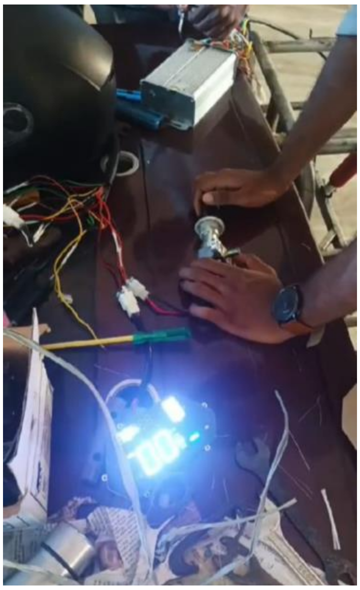

Figure 24: Component-level electrical testing.

2. Road Testing

Road trials were conducted over varied terrain to assess real-world behaviour (Fig. 25). Battery endurance was evaluated under load and over extended distance, and speed and acceleration were assessed on level road, together with range per full charge. The results informed subsequent refinement of performance and battery utilisation.

Figure 25: Road testing of the completed vehicle.

3. Strength, Braking and Stability

Structural durability was assessed by riding the vehicle with multiple occupants to simulate overload. Safety testing comprised braking trials measuring stopping distance under both normal and emergency application; a ramp test establishing gradeability on inclined surfaces; a bump test assessing shock absorption and stability on uneven road; and evaluation across varying rider weights.

4. Outcome

All mechanical, electrical and digital systems were brought into alignment and the vehicle completed its first full test ride, confirming that the design functions as an integrated whole. The tests listed above were performed and their qualitative outcomes recorded; numerical results for stopping distance, gradeability, measured range and achieved top speed were not tabulated in the project record, and are therefore not reported here.

Cost and Service-Life Analysis

1. Cost Breakdown

The vehicle was built to a total budget of ₹60,000. The distribution across components and labour is given in Table 7 and illustrated in Fig. 26. The battery dominates at half the total outlay, which is characteristic of low-cost electric vehicle construction and identifies pack cost as the principal lever on affordability.

Table 7. Vehicle Cost Breakdown

Component	**Cost (₹)**	**Description**
Battery	30,000	50 % of total cost
Motor and components	10,000	BLDC motor, controller and throttles
Miscellaneous	7,000	Wiring, lights, switches, charger, fuses
Frame	5,000	Lightweight alloy
Welding	4,000	Labour and tools
Manual work	4,000	Skilled assembly, testing and alignment
Total	60,000	

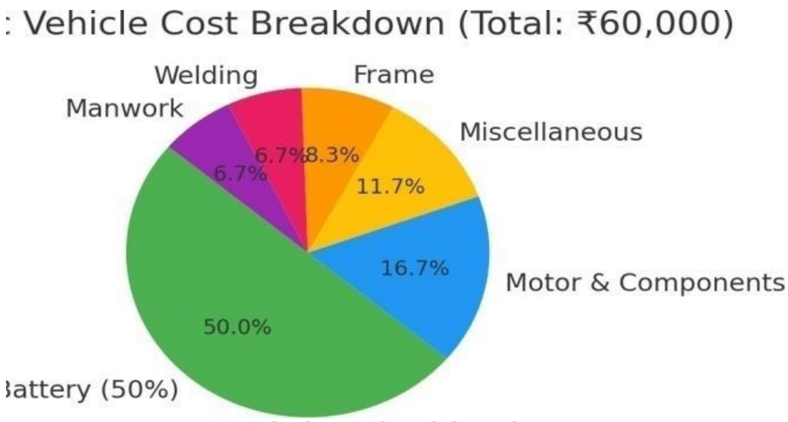

Figure 26: Vehicle cost breakdown by component.

2. Service Life

Estimated service life by component is given in Table 8.

Table 8. Component-Wise Service-Life Estimate

Component	Service life	Remarks
Battery	3–5 years	Replaceable; lithium-ion rated above 1000 cycles
Motor and controller	8–10 years	BLDC; high reliability, low maintenance
Frame and chassis	10+ years	Rust-protected high-strength metal frame

A lifecycle profile was estimated as full efficiency in years 0 to 1, slight battery wear in years 2 to 3, and battery replacement in years 4 to 5.

3. Comparison with Alternatives

Table 9 compares the prototype against a petrol two-wheeler and a commercial electric equivalent. The figures are estimates prepared during the project rather than measured outcomes, and should be read as such.

Table 9. Comparison with Petrol and Commercial Electric Alternatives

Parameter	This vehicle	Petrol two-wheeler	Commercial EV
Total service life	approximately 10 years	approximately 7 years	approximately 10 years
Battery life	3–5 years	Not applicable	4–6 years
Maintenance cost over 10 years	₹5,000–₹10,000	₹30,000+	₹15,000–₹20,000
Replacement frequency	Low	High	Medium
Environmental impact	Very low	Very high	Low

Limitations and Data Inconsistencies

Three inconsistencies in the recorded design data are identified here rather than resolved silently, since each affects a quantity a reader might otherwise rely on.

1) Frontal area. Equation (4) evaluates to 0.2818 m^2, whereas the value carried forward is 0.8408 m^2 — a factor of approximately three. Since drag is directly proportional to frontal area, the drag term of (5) would fall from 36.64 N to approximately 12.3 N if the computed value were used, reducing total tractive force from 123.4 N to approximately 99 N and required power from 1200 W to approximately 963 W. The 1 kW motor selection remains adequate under either value, so the conclusion is unaffected, but the intermediate figure should be re-derived before the calculation is reused.

2) Tractive-force summation. The torque calculation sums to 302.556 N using a third term of 241.206 N, which does not match the gradient resistance of 62.05 N established in (9). The resulting wheel torque of 68.075 N·m is therefore not consistent with the 123.4 N total adopted in (10), which would instead give approximately 27.8 N·m. The latter is consistent with the 30–40 N·m rating of the selected hub motor in Table III; the former exceeds it.

3) Range and charging time. The project summary states a range of 60 km per charge and a charging time of 5 hours, while the feature comparison of Table X records a present range of 30–50 km and the battery specification of Table V gives a charging time of 3–4 hours. These figures cannot all be correct simultaneously, and no measured range or charge-duration record exists to adjudicate between them.

Further limitations apply to the evaluation as a whole. Road, braking, gradeability and stability tests were performed but their numerical outcomes were not recorded, so no measured performance figure is reported. The cost and service-life analyses are estimates prepared during the project rather than observed outcomes. The controller power rating of 250 W in Table IV is inconsistent with the 1000 W motor it drives, which suggests a specification transcription error. Resolving all of these requires an instrumented test programme: a measured range trial to depletion under a defined duty cycle, a timed charge from a defined state of charge, and logged speed, current and voltage during braking and gradeability runs.

Conclusion

A low-cost electric two-wheeler has been designed, fabricated and tested. The tractive-effort analysis established a total resistance of 123.4 N and a required propulsive power of 1200 W for a 95 kg vehicle at 35 km/h, on which basis a 1 kW hub motor was selected, with a 48 V, 26.04 A·h lithium-ion pack of 1250 W·h charged by a 48 V, 5 A charger. The vehicle was built over approximately three months through concept development, design with finite-element structural analysis, fabrication and testing, at a total cost of ₹60,000 of which the battery accounts for half.

The project demonstrates a compact and lightweight design suited to urban routes, smart control integration with real-time monitoring, an effective battery management system, and zero-emission operation. It establishes that a functional electric two-wheeler can be produced at this cost by a student team, and it identifies pack cost as the dominant constraint on affordability.

Three internal inconsistencies in the design data — in frontal area, in the tractive-force summation used for torque, and in the quoted range and charging time — have been stated explicitly, together with their consequences and the measurements required to settle them. The performance claims that the recorded testing supports are qualitative; the numerical characterisation remains to be done.

Future Scope

Table 10 sets out the intended development path from the present configuration.

Table 10. Present Configuration and Intended Upgrades

Feature	Current	Future upgrade
Frame material	Mild steel	Carbon fibre / aluminium
Range	30–50 km	100+ km
Charging time	3–4 hours	Under 1 hour (fast charging)
User interface	Manual controls	Touch and voice assist

Smart technology

IoT-based remote monitoring, GPS and route optimisation, mobile application synchronisation for rider interaction, and AI-based energy management.

Energy efficiency

Integration of solar panels on body surfaces, regenerative braking, and adoption of higher-efficiency lithium-ion or solid-state cells.

Applications

Deployment as a hyperlocal delivery vehicle and as a campus or corporate commuter platform.

The vehicle is intended not as a finished model but as a modular foundation for smart-city and green-mobility work, adaptable and affordable enough to serve as a starting point for further development.

Acknowledgment

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