

Design and Fabrication of an Electric Passenger Vehicle

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ABSTRACT

The rapid depletion of fossil fuels and the increasing environmental impact of conventional automobiles have accelerated the transition toward electric mobility. This paper presents the design, fabrication, and experimental evaluation of a low-speed smart electric passenger vehicle developed for short-distance transportation. The vehicle was designed using CAD modeling to ensure structural integrity, ergonomic comfort, and proper load distribution. A mild steel tubular chassis, DC motor propulsion system, rechargeable battery pack, and electronic motor controller were integrated to develop a functional prototype. Performance tests including speed measurement, braking distance, turning radius, and energy consumption were conducted. The developed vehicle achieved reliable operation with zero tailpipe emissions, low noise, and reduced operating cost. The study demonstrates the feasibility of indigenous development of electric vehicles at diploma level and provides a platform for further research in sustainable mobility.

Keywords:- Electric Vehicle, Smart Transportation, DC Motor, Battery Management, Sustainable Mobility, Low-Speed EV

1. INTRODUCTION

Transportation plays a vital role in the economic and social development of any nation by enabling the movement of people, goods, and services. However, the same sector has also become one of the largest contributors to environmental degradation and energy consumption. Conventional internal combustion engine (ICE) vehicles rely heavily on fossil fuels and emit significant quantities of carbon dioxide (CO₂), nitrogen oxides (NO_x), unburnt hydrocarbons, and particulate matter. These emissions not only deteriorate urban air quality but also contribute to global warming, climate change, and various health disorders. According to recent international energy assessments, the road transport sector alone is responsible for nearly 18–20% of global carbon emissions, and this share is expected to increase with the growing demand for personal mobility. In addition to pollution, dependence on imported petroleum fuels increases economic burden and energy insecurity for developing countries.

Electric vehicles (EVs) are therefore emerging as a promising and sustainable alternative to conventional automobiles. EVs operate using electrical energy stored in batteries and produce zero tailpipe emissions, leading to cleaner and quieter transportation. They offer higher energy conversion efficiency compared to ICE vehicles, reduced maintenance requirements due to fewer moving parts, and lower operating cost over the vehicle lifetime. Rapid advancements in battery technology, motor controllers, and charging infrastructure have further strengthened the feasibility of electric mobility for short- and medium-distance applications. Governments across the world, including India, are actively promoting EV adoption through policies and incentives to achieve carbon-neutral transportation systems.

At the same time, educational institutions have an important responsibility to prepare skilled manpower for this emerging industry. Development of practical EV platforms within academic environments enables students to understand modern automotive technologies such as electric drives, battery management, power electronics, and vehicle integration. Hands-on projects help bridge the gap between theoretical learning and real-world engineering practice. In this context, the present project aims to design and fabricate a smart electric passenger vehicle that can be safely used for transportation within campuses, hospitals, industrial premises, and other restricted areas. The emphasis of the work is on developing a simple, affordable, and reliable vehicle using locally available components while ensuring passenger safety, ease of maintenance, and acceptable performance characteristics. The project also intends to create a demonstrative model that can be further upgraded with advanced features such as regenerative braking, lithium-ion batteries, and smart monitoring systems.

Objectives

1. To design a low-cost electric passenger vehicle using CAD tools.
2. To fabricate a safe and lightweight chassis and body.
3. To integrate electrical propulsion and control system.
4. To evaluate vehicle performance through experimental testing.
5. To analyse feasibility for real-world short-distance mobility.

2. LITERATURE REVIEW

Low-speed electric passenger vehicles (LS-EVs) are increasingly explored for campus mobility and short-range transport because they reduce local emissions, noise, and operational cost while allowing simpler powertrains and safer speed limits. A campus-focused low-speed EV design study shows how early-stage packaging decisions (wheelbase, battery placement, ground clearance) strongly influence stability and manufacturability, and it also summarizes common EV motor options and charging considerations for institutional use [1].

1) Powertrain and motor selection for small EVs

Motor selection is a key factor that drives efficiency, speed capability, and cost. Reviews comparing traction motors (DC, BLDC, PMSM, IM, SRM) report that permanent-magnet machines (BLDC/PMSM) typically offer higher power density and efficiency, while brushed DC drives remain attractive in low-cost prototypes due to simpler control and availability [5]. For student/prototype vehicles, practical go-kart EV studies highlight drivetrain sizing using vehicle dynamics, motor selection, and CAD/FEA-assisted design workflows that reduce trial-and-error in fabrication [3].

2) Motor control and controller strategies (DC motor focus)

For low-cost EV prototypes using DC motors, PWM-based controllers remain common due to simplicity. A PWM DC motor controller design using a microcontroller (PIC-based) demonstrates how duty-cycle control can regulate speed effectively and maintain stable motor operation under varying load [4]. At a broader level, traction motor control reviews (FOC, DTC, MPC and advanced methods) emphasize that control strategy selection directly impacts EV efficiency and drivability; these insights help guide upgrades from basic control toward higher- efficiency control as projects mature [6]. Power electronics trends such as multiphase traction inverters are surveyed in a state-of-the-art review, showing benefits like improved fault tolerance and reduced dc-bus capacitor stress—useful when planning future “smart EV” upgrades [7].

3) Battery technology: lead-acid vs lithium-ion and design implications

Battery choice dominates vehicle mass, range, lifecycle cost, and safety. Comparative economic analysis work reports that while lead-acid has lower upfront cost, lithium-ion generally offers higher energy density and longer life, shifting total cost of ownership in many applications [8]. A feasibility-oriented comparison (lead-acid vs Li-ion) under charging constraints also highlights performance limitations of lead-acid (cycle life/efficiency) and supports Li-ion when long-term performance is prioritized [9]. These findings are practically reflected in student EV/go-kart electrical system studies, where accumulator sizing and safety (fusing, wiring, thermal concerns) are treated as core design requirements, not afterthoughts [10].

4) Battery Management Systems (BMS) and SOC estimation

SOC estimation is central to range prediction, battery protection, and “smart” features. A comprehensive discussion of SOC estimation methods (model-based and data-driven) shows tradeoffs among accuracy, computational complexity, and robustness for real-time EV use [11]. Recent SOC research increasingly applies data-driven

methods and ensembles to improve estimation accuracy and reduce onboard complexity, indicating a clear direction for smarter, low-cost BMS implementations [12]. Optimization + EKF-based methods also remain active, showing how adaptive parameter identification can improve SOC robustness under varying operating conditions [13].

5) Regenerative braking and energy recovery

Regenerative braking (RB) is widely reported as a practical way to extend range, but its effectiveness depends on braking intensity, SOC limits, and stability constraints. A broad review of RB systems (design and control strategies) summarizes how recovery potential varies with vehicle dynamics and energy storage limits [14]. Safety-critical allocation of brake torque between friction and regenerative braking is addressed in control-strategy literature, showing structured methods to balance stability and energy recovery [15]. Regulatory/curve-based distribution studies (ECE considerations and “I-curve” logic) demonstrate that energy recovery strategies must respect braking stability; simulations show measurable improvements in recovered energy and range under driving cycles [16]. Fuzzy-logic RB strategies are repeatedly validated in the literature as robust for nonlinear braking behavior and varying SOC/speed conditions, making them attractive for practical implementation [17], [18]. Parameter-based recovery studies also quantify how charging current limits affect maximum recovery

efficiency, reinforcing the need to coordinate RB control with battery acceptance constraints [19].

6) Chassis/frame design, materials, and structural analysis for small EVs

For prototype EVs, chassis decisions influence mass, safety, vibration, and manufacturability. Space-frame and tubular chassis studies emphasize static strength, torsional rigidity, and packaging of battery/motor masses as essential for stable handling [20]. Material and geometry optimization work on ultra-light chassis structures shows systematic approaches (constraints, testing, and iteration) to reduce mass while maintaining mechanical integrity—useful when upgrading from mild steel to lighter materials [21]. Tubular space-frame investigations including impact-absorber concepts further show how chassis structural choices can improve safety and energy efficiency through mass reduction [22].

3. DESIGN METHODOLOGY

3.1 Conceptual Design

The conceptual design stage formed the foundation for the development of the smart electric passenger vehicle. At this stage, the overall purpose of the vehicle, expected operating conditions, and user requirements were carefully analyzed to establish the basic design framework. The vehicle was intended for short-distance transportation in controlled environments such as educational campuses, hospitals, industrial premises, and tourist locations. Therefore, priority was given to low operating speed, high safety, simple construction, and ease of driving. The seating layout was planned for two passengers to maintain compact size and reduce overall weight. A maximum design speed of 40 km/h was selected considering safety regulations for low-speed electric vehicles and to ensure stable operation without the need for complex suspension and braking systems.

The targeted driving range of 25–30 km was chosen based on typical daily travel requirements inside campuses and institutions. Payload capacity of 180 kg was considered sufficient to accommodate two adult passengers along with minor luggage. During conceptualization, special attention was given to vehicle stability by maintaining a low center of gravity through proper placement of the battery pack and motor near the chassis base. Weight distribution between front and rear axles was also considered to achieve better steering response and braking efficiency. The structure was designed to be simple and modular so that maintenance and replacement of components could be performed easily by students and technicians. Safety aspects such as proper seating support, protective body frame, reliable braking, and electrical insulation were treated as essential requirements from the beginning of the design process.

Table 1. Specification table

Parameter	Specification
Passenger capacity	2 persons
Maximum speed	40 km/h
Driving range	25–30 km per charge
Payload capacity	180 kg
Vehicle type	Low-speed electric passenger vehicle
Operating environment	Campus / industrial premises
Design priorities	Stability, safety, easy maintenance
Propulsion	DC electric motor
Energy source	Rechargeable battery pack
Chassis material	Mild steel tubular frame
Braking system	Mechanical drum/disc brake
Steering	Manual steering mechanism

3.2 CAD Modeling

Solid modeling of the vehicle was carried out using CAD software to convert the conceptual idea into a precise and manufacturable design. The digital model helped in visualizing the complete vehicle structure, positioning of major components, and assessment of ergonomics before actual fabrication. Based on stability requirements and available components, key dimensional parameters were finalized as a wheelbase of 1350 mm and a track width of 920 mm to ensure proper balance and maneuverability. A ground clearance of 160 mm was selected to allow safe operation on uneven campus roads and small speed breakers. The chassis structure was designed using mild steel square tubes of size 25 × 25 × 2 mm, considering adequate strength, ease of welding, availability, and low cost. The CAD model also assisted in minimizing material wastage and reducing fabrication errors during workshop execution.

Solid modeling was performed using CAD software. The following were finalized:

Wheelbase: 1350 mm, Track width: 920 mm, Ground clearance: 160 mm, Chassis material: Mild steel square tube (25×25×2 mm)

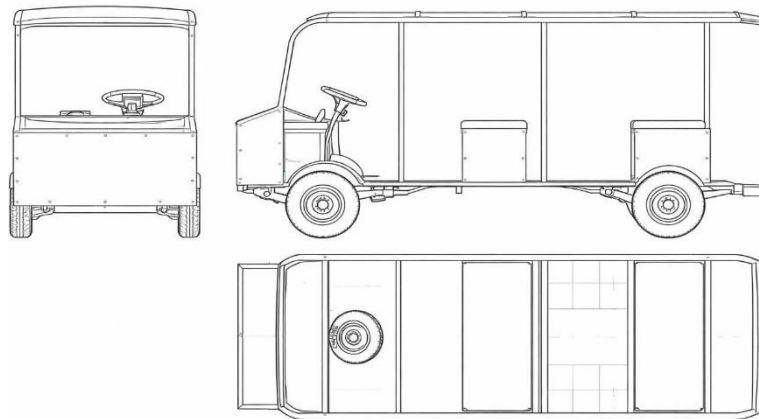


Figure 1. - CAD Representation of Chassis Structure (Line diagram)



Figure 2. - CAD Representation of Chassis Structure



Figure 3. - CAD Representation of Chassis Structure in 3D view

Finite element checks were performed for static loading to ensure factor of safety > 2.

3.3 System Architecture

The system architecture of the electric vehicle is designed by integrating mechanical, electrical, and control subsystems to achieve efficient and safe operation. The vehicle is powered by a DC motor coupled to the rear axle through a chain drive mechanism, which transmits torque to the wheels and enables smooth motion. Electrical

energy is supplied from a rechargeable battery pack that serves as the primary power source for propulsion and auxiliary loads. A motor controller regulates the speed and direction of the DC motor based on input signals from the throttle unit, ensuring precise acceleration control. The throttle and braking system allows the driver to control vehicle speed and provide effective stopping capability when required. The steering mechanism ensures proper maneuverability and directional stability of the vehicle. In addition, lighting and safety circuits such as

headlamps, indicators, horn, and protective fuses are incorporated to enhance visibility, user safety, and compliance with basic automotive standards. All these components are interconnected to function as a coordinated and reliable electric mobility system.

The vehicle consists of:

- DC motor with chain drive
- Battery pack
- Motor controller
- Throttle and braking system
- Steering mechanism
- Lighting and safety circuits

4. COMPONENT SELECTION AND SPECIFICATIONS

The major components of the vehicle were selected based on performance, cost, and availability. A 48V, 750W permanent magnet DC motor is used as the prime mover to provide adequate torque for urban driving conditions. Power is supplied by a battery pack consisting of four 12V, 26Ah lead-acid batteries connected in series to obtain 48V output. A 48V, 30A PWM motor controller is employed to regulate motor speed and ensure efficient power delivery. The transmission system uses a chain and sprocket arrangement for reliable torque transfer to the rear wheel. Braking is achieved through a rear drum brake system which offers simple and effective stopping performance. The vehicle is fitted with 3.00–10 pneumatic tyres to provide good road grip and ride comfort. The chassis is fabricated from mild steel tubular sections, giving sufficient strength while keeping the structure economical and easy to manufacture.

Table 2. - Specifications of components

Component	Specification
Motor	48V, 750W DC PM motor
Battery	4 × 12V, 26Ah lead acid
Controller	48V, 30A PWM
Transmission	Chain and sprocket
Brake	Drum brake rear
Tyres	3.00–10 pneumatic
Chassis	Mild steel tubular

Selection was based on availability, cost, and ease of replacement.

5. FABRICATION PROCESS

The fabrication of the vehicle was carried out in a systematic sequence to ensure structural accuracy and functional reliability. Chassis fabrication was performed first by cutting mild steel tubular members to the required dimensions, followed by jig welding to maintain proper alignment; dimensional inspection was conducted to verify wheelbase, track width, and overall geometry. In the mounting stage, brackets for the rear axle, motor base, and steering column were fixed to the chassis at predetermined locations to provide rigid support for all major components. The mechanical assembly involved installation of wheels, bearings, brake system, and transmission elements such as chain and sprocket, ensuring smooth rotation and correct tensioning. During electrical integration, the battery tray, wiring harness, motor controller, and lighting circuits were installed and properly routed to avoid short circuits and mechanical damage. The body work phase included fitting of seating arrangement, roof frame, and protective panels to improve ergonomics and user safety. Finally, comprehensive safety checks such as insulation testing, earthing continuity, and fuse protection verification were carried out to confirm that the vehicle met essential electrical and mechanical safety requirements before testing.

1. **Chassis Fabrication:** Cutting, jig welding, dimensional inspection.
2. **Mounting:** Axle brackets, motor base, steering column.
3. **Mechanical Assembly:** Wheels, bearings, brakes.
4. **Electrical Integration:** Battery tray, wiring harness, controller.
5. **Body Work:** Seating, roof frame, protective panels.
6. **Safety Checks:** Insulation, earthing, fuse protection.

6. WORKING PRINCIPLE

When throttle is applied, the controller modulates current to the DC motor using PWM technique. Electrical energy from the battery is converted into mechanical rotation:

Torque is transmitted to rear wheels via chain drive. Speed control is electronic; braking is mechanical.

minimal resistance. The loaded speed was then measured with the design payload to understand the effect of weight on acceleration and running characteristics. For safety evaluation, the braking distance was recorded by applying the mechanical brake from a specified speed to analyze stopping capability and system reliability. The turning radius was measured to evaluate maneuverability in narrow pathways and campus roads. In addition, energy consumption in Wh/km was calculated using battery discharge data to estimate vehicle efficiency and expected driving range per charge. These parameters collectively provided a comprehensive assessment of the vehicle's operational suitability for short-distance transportation applications.

7.2 Sample Results

students, staff, and visitors between departments, hostels, and libraries. In hospitals and medical complexes, the vehicle can be used for patient movement, delivery of medicines, and internal transport without creating noise or emissions. The vehicle is also appropriate for airports, railway stations, and bus terminals to assist passengers with luggage movement and last-mile connectivity. In industrial premises and warehouses, it can serve for light material handling, inspection rounds, and movement of workers across large factory areas. Additionally, the vehicle has good potential in **eco**-tourism zones, parks, and heritage sites, where pollution-free and silent transportation is essential to protect the environment and enhance visitor experience. These diverse applications demonstrate the social and commercial relevance of the developed electric vehicle platform.

10. CONCLUSION

The present work successfully demonstrated the design, fabrication, and performance evaluation of a smart electric passenger vehicle intended for short-distance transportation applications. The project began with conceptual planning and CAD modeling, which enabled proper visualization of dimensions, weight distribution, and component placement before fabrication. A mild steel tubular chassis was developed, and an electric propulsion system consisting of a DC motor, battery pack, and motor controller was integrated to create a functional prototype. The systematic approach adopted in the project ensured that the vehicle was economical, simple in construction, and safe for practical use.

Experimental testing confirmed that the vehicle meets the basic requirements of a low-speed electric transport system. The prototype achieved satisfactory speed, maneuverability, braking performance, and energy efficiency under both no-load and loaded conditions. The measured energy consumption indicated that the vehicle can operate economically with an estimated range suitable for campus and institutional mobility. The low noise level and zero tailpipe emissions highlight its environmental benefits over conventional ICE vehicles. These outcomes validate that an effective electric vehicle can be developed at diploma level using locally available components and workshop facilities.

The project has also provided valuable hands-on learning in the areas of electric drives, battery systems, mechanical fabrication, and vehicle integration. It has helped to bridge the gap between theoretical knowledge and real engineering practice. Although the developed model fulfills the intended objectives, certain limitations such as battery weight, charging time, and absence of advanced control features were observed. Addressing these aspects can further enhance vehicle performance and user comfort.

Overall, the study proves the feasibility and relevance of low-cost electric vehicles for sustainable transportation in campuses, hospitals, industries, and eco-sensitive zones. The developed prototype can serve as a foundation for future research on improved battery technology, regenerative braking, smart monitoring, and lightweight materials, contributing to the growth of indigenous electric mobility solutions.

11. FUTURE SCOPE

The performance of the developed electric passenger vehicle can be further enhanced through several improvements. Replacing the existing lead-acid battery with a lithium-ion battery pack can reduce vehicle weight and increase driving range. The integration of a regenerative braking system can recover energy during deceleration and improve overall efficiency. Addition of solar panel assisted charging will make the vehicle more sustainable for daytime use. The vehicle can also be upgraded with IoT-based monitoring, digital speed display, and GPS tracking for smart operation. Use of lightweight composite body materials and improved suspension can further enhance comfort and performance in future versions.

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