

A Comprehensive Study & Database Development for the Design of Electric Three-Wheeler Chassis and Its Subsystems

Mr. Sachin N. Londhe¹, Dr. R. S. Pawar²,

¹*P.G. Scholar, Padmabhooshan Vasantdada Patil Institute of Technology Bavdhan -411021*

²*Principial (Guide), Padmabhooshan Vasantdada Patil Institute of Technology Bavdhan -411021*

Abstract- The growing demand for sustainable and energy-efficient transportation has increased the importance of electric three-wheelers, particularly in urban and semi-urban mobility sectors. This study presents a comprehensive analysis of the electric three-wheeler chassis and its associated subsystems, with a primary focus on systematic data collection and database development rather than physical design or fabrication. The research examines existing chassis configurations, structural characteristics, and subsystem arrangements, including suspension systems, braking mechanisms, powertrain layout, and battery integration. Through this analytical approach, key design parameters, performance considerations, and operational challenges are identified and documented. The study emphasizes understanding the relationships between different subsystems and their impact on vehicle stability, safety, and efficiency.

A significant contribution of this work is the development of a structured engineering database that compiles essential information such as material properties, dimensional specifications, load conditions, subsystem characteristics, and performance data. This database serves as a centralized platform for storing and organizing critical technical knowledge, enabling easier access, comparison, and future reference for researchers and engineers.

The findings highlight that a well-organized database combined with systematic study can support informed decision-making, reduce redundancy in research efforts, and improve the overall development process of electric three-wheelers. This work provides a valuable reference framework for further studies, optimization efforts, and future design initiatives in the field of electric vehicle engineering.



I.INTRODUCTION

Electric vehicles (EVs) are gaining importance due to increasing environmental concerns, depletion of fossil fuels, and the need for sustainable transportation solutions. Unlike conventional internal combustion engine vehicles, EVs operate using electrical energy stored in batteries, resulting in zero tailpipe emissions and improved energy efficiency.

In India, three-wheelers are widely used for passenger transport and goods movement due to their affordability and compact size. The transition to electric three-wheelers presents significant benefits, including lower operating costs, reduced emissions, and simplified maintenance. However, the integration of battery packs and electric drivetrains introduces new design challenges, particularly in chassis development.

The chassis plays a critical role in supporting vehicle components, ensuring safety, and maintaining structural integrity under dynamic loads. Therefore,

designing an optimized chassis that balances strength, weight, and cost is essential for improving vehicle performance and efficiency.

II.LITERATURE REVIEW

Rapid urbanization, rising fuel prices, and stringent emission regulations have accelerated the adoption of electric vehicles (EVs). In India, three-wheelers play a significant role in last-mile passenger and goods transportation due to their affordability and compact size. Conventional internal combustion engine (ICE) three-wheelers contribute substantially to air pollution and greenhouse gas emissions. Electric three-wheelers provide an eco-friendly lower operating cost, and reduced maintenance requirements [1], [11]. alternative by offering zero tailpipe emissions,

Power train Design and Motor Selection

O Tade and Kale [1] presented a comprehensive study on the sizing and simulation of an electric three-wheeler powertrain. Their work involved the calculation of tractive force, torque requirements, motor power rating, and battery sizing using the Indian Driving Cycle. The study emphasized that optimal selection of motor and transmission parameters is essential to achieve performance comparable to conventional ICE vehicles.

Varadharajan et al. [2] developed an electric powertrain for a three-wheel personal mobility vehicle using MATLAB-Simulink. Their research demonstrated that proper motor sizing, reduction ratio selection, and lithium-ion battery integration significantly improve vehicle efficiency and dynamic performance.

Further insight into motor and battery selection was provided by Sreejith and Rajagopal [3], who analyzed direct and geared drive configurations for three-wheeler EVs. The study highlighted the suitability of PM-BLDC motors due to their high efficiency and power density and compared lead-acid and lithium-ion battery technologies

Battery Technology and Energy Storage

Battery selection plays a crucial role in determining the range and efficiency of electric three-wheelers. Early EVs relied heavily on lead-acid batteries due to low cost; however, studies indicate that lithium-ion

batteries offer superior energy density, faster charging, longer cycle life, and reduced weight [3].

Zain et al. [7] experimentally investigated lithium-ion battery consumption under varying load and vehicle speed. The Study shoed increase in payload and speed leads to a higher voltage drop and greater energy consumption, highlighting the importance of accurate battery sizing.

Tasnim et al. [8] modeled a battery-driven three-wheeler electric vehicle using MATLAB-Simulink under standard driving cycles. Their findings indicated that driving conditions and vehicle load strongly affect battery state-of-charge (SOC) and overall energy usage.

Electric Auto-Rickshaw and Retro fitment Studies

Retro fitment of conventional auto-rickshaws into electric vehicles is considered a cost-effective solution for reducing urban emissions. Pharande and Dalvi [4] designed and evaluated an electric drive-train retrofit kit for existing auto-rickshaws. The converted vehicle demonstrated reduced operational costs and satisfactory urban performance.

Student-level projects have also contributed valuable insights. Thangzamuana and John [5] designed and fabricated a foldable electric three-wheeler, focusing on cost reduction and compactness. Similarly, Ambatkar et al. [6] developed a low-cost three-wheel electric vehicle using DC motors and simple controllers suitable for short-distance travel.

Renewable Energy Integration

To further enhance sustainability, researchers have explored the integration of solar power into electric three-wheelers. Saran et al. [9] studied solar-assisted auto-rickshaws and demonstrated that rooftop photovoltaic panels can supplement battery charging under favorable conditions. Shankar et al. [10] proposed a low-cost solar-powered e-rickshaw design, showing marginal improvement in range and reduced dependency on grid charging.

Major Components of an Electric Vehicle

An electric vehicle consists of the following key components

Battery Pack

The battery pack is the primary energy source, commonly composed of Lithium-ion (Li-ion) cells due

to their high energy density, long cycle life, and high power capability. The Battery Management System (BMS) ensures safe operation by monitoring voltage, current, temperature, and state of charge (SoC).

Electric Motor

Electric motors such as Brushless DC (BLDC), Permanent Magnet Synchronous Motor (PMSM), and Induction Motors are widely used in EVs. These motors offer high torque at low speeds, fast response, and high efficiency.

Power Electronics

Power electronic converters, including DC-DC converters play an important role in maintaining stable and appropriate voltage levels across various electrical components within an electric three-wheeler. Although the battery supplies a constant DC voltage, different subsystems and inverters (DC-AC), regulate voltage and control motor speed and torque. These systems are critical for efficient energy utilization and vehicle performance.

Charger and charging Station

Chargers and charging stations are a key part of the electric vehicle (EV) system, as they allow the battery to be recharged from the power grid. In simple terms, chargers convert the AC electricity from the grid into DC power that can be stored in the EV battery. This conversion is done either by an on-board charger inside the vehicle for normal charging or by an off-board charger in fast-charging stations.

Charging stations are generally classified into three types. Level 1 charging is the slowest and uses a regular household power supply, making it suitable for overnight charging. Level 2 charging is faster and is commonly used in homes, offices, and public places. DC fast charging provides rapid charging in a short time and is mainly installed on highways and commercial locations for long-distance travel.

Overall, a well-developed and easily accessible charging infrastructure is essential for increasing the use of EVs. It helps reduce range anxiety, ensures convenience for users, and supports the smooth operation of electric vehicles in daily life.

Auxiliary Systems

Auxiliary components such as thermal management systems, braking systems, and vehicle control units

play an important role in safety and reliability.

Novel Contributions and Unique Aspects of the Study

Based on the reviewed literature [1]–[11], electric three wheelers present a promising alternative to conventional internal combustion engine (ICE) vehicles, particularly in the Indian context where last-mile connectivity is crucial. Numerous researchers have focused on electric powertrain design, motor selection, battery technologies, energy consumption modeling, and renewable energy integration, establishing the technical feasibility and environmental advantages of electric three wheelers.

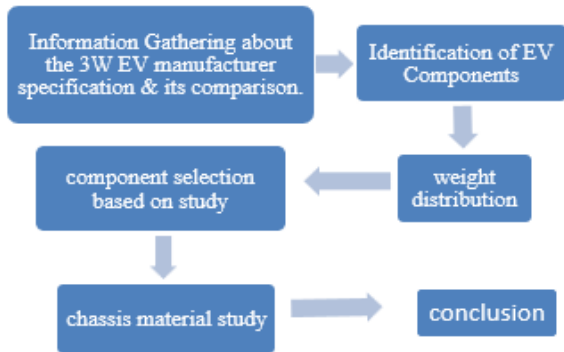
While power train and energy storage systems have been widely studied, chassis design remains a relatively underexplored yet critical area, especially for electric vehicles. The inclusion of battery packs and electric drive trains significantly alters the vehicle mass distribution, center of gravity, and structural load paths compared to ICE vehicles. As highlighted by Patil and Kulkarni [12] and Singh et al. [13], adapting conventional three-wheeler chassis designs without structural optimization can result in excessive stresses, reduced fatigue life, and compromised vehicle stability. Further insight into lightweight structural design is provided by Mr. Pankaj Nirmal of the Automotive Research Association of India (ARAI), who investigated the use of aluminum body structures for buses [14]. His work demonstrated that aluminum body construction offers substantial weight reduction, improved corrosion resistance, and enhanced energy efficiency, while still meeting structural strength and safety requirements. Although the study was conducted on buses, the findings are highly relevant to electric three wheelers, where lightweight chassis and body structures directly translate into increased driving range, improved performance, and reduced battery size requirements.

Minimal focus on cost-effective manufacturing and durability assessment for electric three-wheeler frames. This project aims to address these gaps by adopting a system-level design approach that integrates electric powertrain sizing, battery integration, and optimized chassis design, potentially incorporating lightweight materials inspired by ARAI's aluminium body research.

III.OBJECTIVE

- To study the 3-wheeler electric vehicles and it’s sub-systems.
- Comparison of existing vehicles.
- Study of Regulatory requirements for three wheeler EV
- EV Chassis material discussion

IV.METHDOLOGY



A comparative study of existing passenger electric three-wheelers in the market based on publicly available information.

Manufacturer	Model	Battery (kWh)	Torque	Battery Type
Mahindra	Treo	7.37	42	Li-ion
Piaggio	Ape E-City Ultra	10.2	45	LFP
Bajaj	GoGo	12.1	36	LFP
TVS	King EV Max	9.2	40	LFP

Manufacturer	Model	Top Speed (km/Hr)	Charging Time (Hr.)
Mahindra	Treo	55	4
Piaggio	Ape E-City Ultra	55	3.45
Bajaj	Bajaj GoGo	50	5.30
TVS	King EV Max	60	3.5

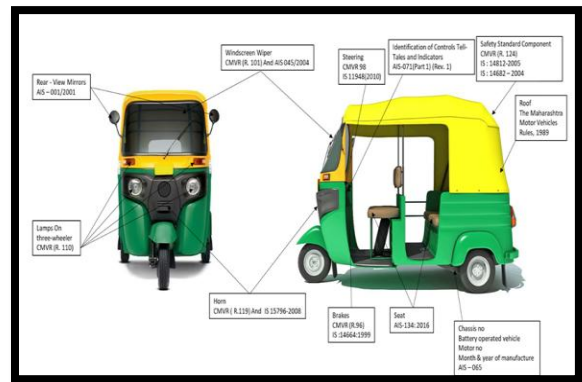
Manufacturer	Length (mm)	Width (mm)	Height (mm)	Wheelbase (mm)
Bajaj	2860	1350	1830	2020
Mahindra	2769	1350	1750	2073
Piaggio Ape	2752	1370	1780	1920
TVS King	2780	1320	1800	2000

Models	Kerb Weight (Kg)
Piaggio Vehicles (<i>Ape e-City</i>)	448
Mahindra Electric (<i>Treo</i>)	377
TVS Motor Company (<i>TVS King EV</i>)	457
Bajaj Auto (<i>GoGo</i>)	500–550*

*estimated

5 Regulatory Requirement

Electric three wheeler comes under L5M Category (Rickshaw) as per CMVR rule. It has to comply to regulatory requirements.



Overall Dimension of L5M category vehicle (RICKSHAW) CMVR (R, 190- Characteristics of vehicle to be tested shall be as per following table, namely: - TABLE-H)

Sr. No.	Details	3 Wheeler	
		Min	Max
1	Front axel wt. (Kg)	90	260
2	Rear axel wt (Kg)	205	780
3	Kerb wt (Kg)	203	800
4	GVW (Kg)	610	2150
5	Wheel base	1590	3070
6	Wheel track mm rear	1150	1540
7	Length (mm)	2080	3100
8	Width (mm)	1100	1520
9	Height (mm)	1635	2070
10	Over Hang Rear (mm)	443	790

Based on study of existing vehicle specification Component Mounting Locations

- Rear Motor Mounting location.

Requirement	How Rear-Mounted Motor Helps
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Better Torque at Wheels	Motor torque is directly transferred to rear axle through differential
Minimum Power Loss	Short driveline → less friction & mechanical loss
Good Traction	More load on rear wheels improves grip
Efficient Load Carrying	Ideal for passenger & cargo vehicles
Durability	Proven layout used by all major OEMs

- ✓ Energy Density higher (Heavier/Larger)
- ✓ Lower cost Over Lifetime

Chassis Material Study






In three-wheeler electric vehicles, the selection of chassis structural members is a critical mechanical design decision. Commonly used structural sections include C-channels, Square (Box) channels, and I-channels. Each type has distinct mechanical properties and is selected based on load, stiffness, weight, and manufacturing requirements.

➤ Controller & Auxiliary Components Placement

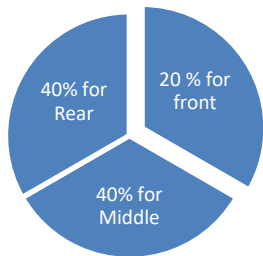
Component Type	Placement Logic
High-current components	Near source (battery / motor)
Control electronics	Center, vibration-isolated
Heavy auxiliaries	Low & central
Heat-generating parts	Ventilated areas

Comparison of Channel Sections

Section Type	Torsional Strength	Weight	Cost
C-Channel 	Low	Low	Low
Square Pipe 	High	Medium	Medium
I-Channel 	Low	Medium-High	High

Weight Distribution:

Weight distribution tells us where the vehicle’s weight should be located and how much load each area carries.



Based on a market survey of existing electric three-wheeler vehicles, appropriate specifications are determined to ensure optimal range, gradeability, and passenger comfort

The selection of channel sections depends on:

- Vehicle type (Passenger / Cargo)
- Wheelbase length
- Load-carrying requirement
- Battery weight and mounting location

Battery Type	Battery (kWh)	Motor	Charging Time (Hrs)	Max Torque (Nm)	Application
LFP	12.1	PMSM	4.5	40	Passenger

Required stiffness and safety standards

In electric three-wheelers, square channels are increasingly preferred due to their superior rigidity and ability to withstand handle battery loads/forces and vibrations coming from the road surfaces.

Study highlights:-

PMSM motors is widely used as compared to BLDC motor due to

- ✓ High Efficiency (90%–95%)
- ✓ Lower/Economical cost
- ✓ Low (smooth drive) Torque Ripple

Material Selection

Material selection for the chassis significantly influences vehicle performance, durability, and cost. Traditionally, mild steel is widely used due to its high strength, ease of fabrication, and affordability.

LFP battery is widely used as compared to Li-Ion due to

- ✓ High (High Thermal Stability)
- ✓ Very High Lifespan

However, its higher density increases the overall vehicle weight, which affects energy efficiency in electric vehicles.

Aluminium alloys offer a lightweight alternative with good corrosion resistance and potential improvements in vehicle range. However, their lower stiffness and higher manufacturing cost require careful design considerations such as increased section thickness and advanced joining techniques.

Therefore, while mild steel remains suitable for cost-sensitive and high-load applications, aluminium can be considered for lightweight designs where improved efficiency is a priority.

➤ Mild Steel (MS) as Chassis Material

Mechanical Properties

- Density: ~ 7850 kg/m³
- Young’s modulus (E): ~ 200 GPa
- Yield strength: 240–260 MPa (typical)
- Good fatigue strength

Advantages

- High strength and stiffness
- Excellent weldability and ease of fabrication
- Low material and manufacturing cost
- Better impact resistance and crashworthiness
- Suitable for rough road conditions (typical for 3-wheelers)

Limitations

- High density increases vehicle weight
- Lower corrosion resistance without coating
- Reduced vehicle range due to higher mass

Applications in 3W EVs

- Passenger 3-wheelers
- Cargo 3-wheelers
- Ladder or tubular chassis frames

➤ Aluminum as Chassis Material

Mechanical Properties

- Density: ~ 2700 kg/m³ (≈ 65% lighter than MS)
- Young’s modulus (E): ~ 70 GPa
- Yield strength (alloy-dependent): 150–300 MPa
- Good corrosion resistance

Advantages

- Significant weight reduction (30–50%)

- Improved vehicle range and energy efficiency
- Better corrosion resistance
- Reduced load on suspension and tyres.

Limitations

- Lower stiffness (requires thicker sections)
- Higher material and fabrication cost
- Difficult welding (TIG/MIG + skilled labor required)
- Lower fatigue life compared to steel

Applications in 3W EVs

Suitable for:

- Lightweight passenger EVs
- Battery trays and sub-frames
- Body-integrated semi-monocoque structures
- Rarely used in heavy cargo EV chassis.

➤ Effect on Vehicle Performance

Parameter	Mild Steel	Aluminum
Weight	High	Low
Strength	High	Medium–High
Stiffness	Very High	Lower
Cost	Low	High
Fabrication	Easy	Difficult
Range Impact	Lower	Higher

➤ Design Considerations for Aluminum Chassis

To compensate for lower stiffness:

- Larger or thicker cross-sections are used
- Box or square channels preferred
- Reinforcements added at suspension and battery mounts

This partially offsets weight benefits but still yields a net reduction.

➤ Material Selection Summary (Engineering Decision)

- Mild Steel is preferred when:
 - Cost is critical
 - High load capacity is needed
 - Vehicle operates on rough roads
 - Cargo 3-wheelers are designed
- Aluminum is preferred when:
 - Lightweight design is a priority
 - Passenger EV range optimization is required
 - Advanced manufacturing facilities are available.

V.CONCLUSION

Electric vehicles (EVs) offer significant advantages over conventional internal combustion engine (ICE) vehicles, including zero emissions, higher energy efficiency, and lower operating and maintenance costs. They also provide quieter operation and better compatibility with modern technologies, making them a cleaner and more sustainable solution for future transportation.

The battery and motor are the key components of an EV, responsible for storing energy and converting it into motion. Modern EVs commonly use Lithium Iron Phosphate (LFP) batteries, which are known for their high safety, long life, and thermal stability. These batteries achieve an efficiency of about 90–95%, ensuring effective use of stored energy. For propulsion, Permanent Magnet Synchronous Motors (PMSM) are widely adopted due to their high efficiency (90–97%), smooth operation, and excellent control over speed and torque. This combination improves acceleration, energy utilization, and performance on slopes.

However, some challenges still exist. One major issue is the limited availability of roadside service support, as users often have to visit specialized centers even for minor repairs. In addition, spare parts are not easily available in local markets, which can increase maintenance time and inconvenience. Improving service accessibility and spare part availability is essential for wider adoption of EVs.

From a materials perspective, optimizing the chassis plays an important role in improving overall efficiency. Reducing weight in non-critical areas helps increase the vehicle's driving range. A combination of steel and aluminium provides a practical solution—steel offers strength and durability, while aluminium reduces weight by around 30–40% and resists corrosion. Using steel in load-bearing areas and aluminium in lighter sections helps achieve a balanced, safe, and efficient structure.

Overall, EVs present a promising future for transportation, but improvements in infrastructure, service support, and material optimization are necessary to fully realize their potential.

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