



# “Rural Mobility Innovation: Expandable Dual- Direction Trailer Chassis for Motorcycle”

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## How to Cite this Article:

C, S., R, G., M, R., S, T. H. & B, H. S. (2026). “Rural Mobility Innovation: Expandable Dual- Direction Trailer Chassis for Motorcycle”. International Journal of Creative and Open Research in Engineering and Management, <i>02</i>(03). <https://doi.org/10.55041/ijcope.v2i3.196>

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<https://doi.org/10.55041/ijcope.v2i3.196>

## ABSTRACT

This study will develop an expandable chassis that will be designed to meet the transportation needs of smallholder farmers. Farmers living in rural areas generally rely on motorcycles as their primary source of mobility, yet the fixed capacity, weight limit, and physical dimensions of these vehicles restrict them from carrying much of what they need. The curved design and the built-in locking mechanisms of the innovative chassis allow the user the option to increase both the width and length of their carrier, making it possible for them to transport larger items and/or multiple smaller items at once. Additionally, the chassis has been designed to remain lightweight, durable, and easy to attach to standard motorcycles; therefore, it is affordable, convenient, and practical for the typical end user. The expandability of the chassis is accomplished through an integrated arrangement of sliding structural components, which allow the user to easily, quickly, and safely make adjustments while remaining structurally sound when subjected to dynamic and irregular loads. Extensive material selection, structural design, and stress analysis have been conducted to ensure satisfactory strength, durability, and performance. The multi-purpose design of the chassis is intended to provide smallholder farmers with efficient and cost-effective options for transporting agricultural products, fertilizers, tools, and other equipment without incurring the expense of owning or leasing a large transport vehicle. By improving transportation efficiency, the proposed system will

also decrease the need for manual labor, reduce dependency upon third party logistics and create cost-efficient rural transportation solutions. With its low cost of manufacture, straight forward operation and compact design, this system is well suited for the needs of small-scale farmers who require a flexible and multiply-adaptable method of carrying loads. Ultimately the research presented here has the potential to enhance productivity and support sustainable rural transportation methods through a scalable and flexible chassis design.

**Keywords**— Expandable chassis, Dual-direction expansion, Sliding and locking mechanism, Adjustable load-carrying system.



## 1. INTRODUCTION

Motorcycles have become an essential part of rural mobility due to their low cost, fuel efficiency and ability to travel narrow, uneven terrain associated with agriculture. Farmers rely on motorcycles for personal commutes as well as to haul agricultural inputs and outputs such as fertilizers, seeds, harvested crops, equipment and daily goods. Although conventional motorcycles offer limited storage space (i.e., the fixed carrier/pillion area) and thus have restrictions on the volume and size of the load carried, farmers are often forced to make multiple trips between their fields, warehouses, and markets. The additional trips lead to increased fuel costs, time lost, and greater physical effort.

While inexpensive alternatives to manual carts and temporary welded extensions have existed in rural communities for many years as a means of increasing load-carrying capacity, they also present a trade-off in ride comfort, cause increased instability of the motorcycle being used, and permanently alter the motorcycle's geometry. Therefore, to provide a solution to this issue while maintaining the safety and ergonomics of the motorcycle, a compact and adaptable load-carrying system will be required. This research presents an innovative, dual-direction expandable chassis for use with motorcycles that will allow for increased usable surface area of the chassis in both horizontal and vertical directions through a sliding and locking mechanism. The design of the chassis will allow the frame to be expanded horizontally and vertically by way of the sliding and locking mechanism.

## 2. LITERATURE REVIEW

The primary focus of previous studies on motorcycle carriers has been on fixed-dimension luggage frames with welded extension or fixed-position hitch-type frames. The inflexible nature of these carriers negatively affects the rider's comfort and maneuverability. While telescoping platforms, folding dollies, and sliding platforms have been described in material handling applications, they have not been applied to agriculture-related two-wheeled vehicles (motorcycles).

The current project provides a novel expandable two-directional design for a carrier that is intended for use on motorcycles and features both sliding/expanding capabilities as well as mechanical locking to maintain payload security during extreme off-road conditions.

[1] **Ayan Paul and Rajendra Machavaram (2024)** designed an adjustable chassis for a track-type combine harvester to address performance issues on uneven and muddy agricultural terrains. Their innovation integrates a hydraulic lifting and leveling mechanism using four hydraulic cylinders installed between the chassis frame and the walking device. The design enables both height adjustment (0–245 mm) and transverse tilt adjustment ( $\pm 15.2^\circ$ ), improving machine stability and reducing breakdowns during harvesting. They developed mathematical models for the mechanism, simulated the hydraulic circuit using MATLAB Simulink, and created a 3D model in CATIA, which was analyzed using ADAMS for motion simulation and ANSYS for structural safety. The simulation results showed the chassis could handle up to 43.2 kN of force with a safety factor of 1.94, confirming its feasibility for real-world application in improving harvesting efficiency.

[2] **Xiaoyu Chai, Jinpeng Hu, Tianle Ma, Peng Liu, Maolin Shi, Linjun Zhu, Min Zhang, and Lizhang Xu (2024)** conducted a study on constructing and analyzing dynamic stress coupling simulation models for the attitude-adjustable chassis of a tracked combine harvester. Their project focused on improving harvester adaptability on uneven terrains by allowing height, lateral, and longitudinal adjustments through a hydraulic system. They utilized a DEM–FMBD bidirectional coupling method to simulate interactions between the tracked chassis and complex field surfaces, validated through real-world stress measurements. Wang et al. designed a leveling mechanism with electric cylinders and steering gear to enhance chassis stability on rough terrain. Du et al. developed a leveling system that reduced harvest losses, as confirmed through field testing. Lü et al. created adaptive lateral and longitudinal adjustment strategies to help maintain the chassis level on inclined surfaces. Hu et al. proposed a leveling control system with a horizontal error margin of  $\pm 0.4^\circ$ .

Sun and Peng used finite element methods to optimize the structure of weak rotating arm components. Zhao et al. applied DEM–MBD simulations to threshing systems for improved performance. Gan et al. and Zhang et al. used DEM–MFB coupling for stress and



fatigue life analysis in heavy machinery, supporting more accurate structural design under real working conditions. These collective efforts highlight the importance of coupling simulation technology in enhancing the design and durability of attitude-adjustable chassis.

[3]Hafidz Dwi Anggara (2024) conducted a study focused on designing an optimal electric vehicle chassis using finite element analysis (FEA) to improve environmental sustainability through cleaner transportation solutions. The project aimed to develop a lightweight yet strong and safe chassis made of alloy steel, capable of withstanding a 5000 N load. The chassis was designed as a ladder frame type using SolidWorks, and simulations were performed to analyze stress distribution, displacement, strain, and safety factors. The results showed that the von Mises stress ranged from 0.002 N/mm<sup>2</sup> to 167.549 MPa, with a maximum displacement of 1.812 mm and a safety factor ranging from 2.327 to over 371,000, confirming structural integrity. The study emphasized the importance of chassis design in enhancing electric vehicle performance and safety. Through mesh optimization and material selection, the research contributed to lightweight design strategies for electric mobility. The analysis proved FEA's effectiveness in evaluating structural reliability. Overall, the project offers a promising foundation for future developments in electric vehicle chassis technology.

### 3. METHODOLOGY

This study's methodology was established by identifying the issues to be addressed regarding rural agricultural transportation, and with an analysis of the user requirements through observation and surveys. Load dimension requirements, safety factor requirements and ease of operation requirements for motorcycle users were also gathered from the requirement analysis. A variety of different expandable chassis designs were drawn out, compared and analysed, with the end result being the selection of a sliding and locking dual-direction mechanism.

A 3D CAD model of the final chassis design was produced to determine the chassis expansion range and clearance. In the material selection process, the strength, weight, cost and weldability of a range of materials were compared, which led to mild steel being chosen for the prototype. The structural calculations for the prototype included determining the load capacity,

bending moment and factor of safety before production started. The prototype was manufactured using conventional manufacturing processes and mounted on a motorcycle. The prototype was then evaluated for performance through load and road tests, in terms of stability, safety and functionality under rural conditions. To enhance the accuracy of the performance evaluation, measurements such as deflection under varying loads and vibration levels during transportation were recorded. User feedback was also collected from farmers who tested the prototype in actual working conditions. The prototype was further analysed for possible improvements based on the feedback and experimental results. A cost-benefit comparison was then carried out to ensure that the proposed design remains economically viable for rural users. Finally, the overall methodology validated the feasibility of the expandable chassis for agricultural load transportation and laid a foundation for future design optimisation.

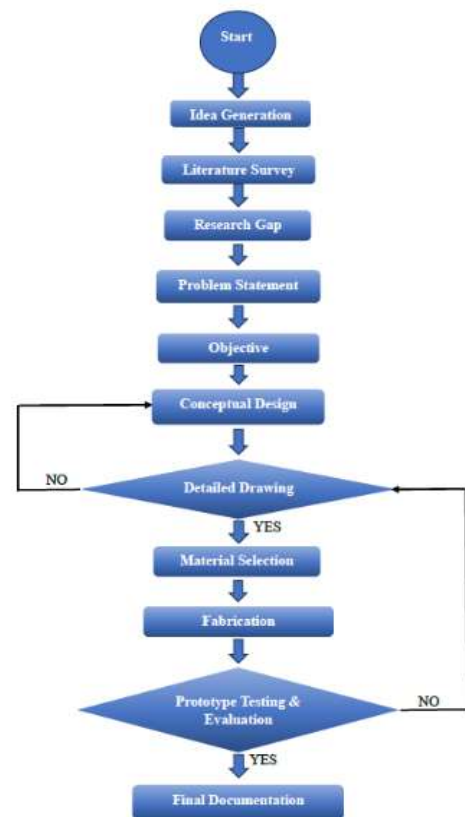


Fig. 1: Flowchart of Methodology

#### 1.Idea Generation

The development begins with brainstorming concepts for an expandable chassis—one that can extend both vertically and horizontally, providing adjustable volume to transport coconuts and other agricultural goods efficiently.



## 2. Literature Survey

Existing research, patents, and industry solutions for expandable frames, foldable containers, and mechanical extension systems are reviewed to understand best practices, limitations, and opportunities.

## 3. Research Gap Identification

A gap is found: current solutions may expand in only one direction or are too complex/costly for rural agricultural use, offering insufficient ease of transport.

## 4. Problem Statement

We need an affordable, mechanically simple chassis that can expand in both length and height, serving as a convenient container for coconuts and similar produce, while being easy to transport and operate manually or by small vehicles.

## 5. Objective

Design and develop a scalable chassis that:

- Expands vertically and horizontally,
- Secures agricultural products safely,
- Is robust, lightweight, and affordable,
- Can be transported easily in fields and on rural roads.

## 6. Conceptual Design

Create initial sketches and models showing telescopic rails for horizontal expansion and hinged/liftable panels or scaffolding for vertical growth, coupled with locking mechanisms to ensure stability.

## 7. Detailed Drawing

Produce technical drawings (orthographic, isometric) detailing dimensions, extension mechanisms (e.g., sliding rails, scissor lift, hydraulic or manual levers), load-bearing points, joints, and locking pins. If the design lacks feasibility or stability, return to “Conceptual Design” to refine.

## 8. Material Selection

Choose materials like galvanized steel or aluminum for the frame and high-strength plastic or metal mesh for the container walls—balancing durability, lightweight construction, corrosion resistance, and cost.

## 9. Fabrication

Build the chassis: cut, weld, machine rails and joints, assemble hinges/guides, install locking systems, and apply protective coatings.

## 10. Prototype Testing & Evaluation

- Test expansion and contraction: Verify smooth movement of rails and hinges,
- Load coconuts and other produce to evaluate strength, stability, and load capacity,
- Check locking security and ease of operation,
- Assess how it fits on a tractor trailer or manual cart.
- If tests fail (e.g., structure twists, locking fails, load damage occurs), return to fabrication or detailed drawing to correct issues.

## 11. Final Documentation

Once testing is successful, finalize all documentation:

- Technical drawings,
- Assembly instructions,
- Material lists,
- Operating and maintenance manual,
- Performance reports and recommendations for field deployment.



## 4. DESIGN AND WORKING

An expandable chassis design increases the load-carrying capability of a motorcycle while maintaining a safe and balanced center of mass for the vehicle, and improving the comfort of the operator. The expandable chassis employs two methods of expansion: A) horizontal expansion via a DC motor that powers two horizontal sliding rail systems; and B) vertical elevation via a manual crank.

### 4.1 Horizontal Expansion Mechanism (Powered by DC Motor)

The horizontal expansions will widen the riding platform and provide additional support for wider agricultural loads, such as bags of fertilizer, crates and bundles of crops, etc. The chassis comprises a primary frame that is fixed and two secondary horizontal sliding frames that are located on opposite sides of the primary frame. The horizontal expansion system will consist of a DC geared motor mounted centrally underneath the platform and coupled to the two sliding frames by a shaft linkage. The motor will be powered by a switch located close to the rider; when the rider activates the switch, the motor will rotate the shaft to push both of the sliding frames outward along their respective sliding rails.

The sliding members will have either roller bushings or linear bearings (depending on your build), which will minimise friction and ensure that the sliding members can travel smoothly and symmetrically. Once the required width has been achieved, spring-loaded locking pins will engage with prefabricated slots to hold the sliding frames in place during dynamic loading. End stop blocks and an optional motor cutoff limit switch will prevent the mechanism from over-expanding beyond its design limits.

### 4.2 The Manual Adjustable System for Vertical Expansion.

Vertical expansion provides support for load stacking. Two height adjusting support bar mounted on two vertical guide channel are welded to the Base frame. Manual expansion of Vertical Support Bars occurs by pulling vertical support bars up until both Support Bars line up with desired height slot. Locking of the vertical Support Bars occurs using Cross-Pin Locking Holes / Screw Knobs that holds the bars rigid during transport. The compact retraction design of this

mechanism allows for strong Vertical Support while transporting Crates and other stacked items as needed.

### 4.3 Combined Structural and Safety Considerations:

Both mechanisms are designed to be used independently and will not interfere with four things:

Rear Wheel Movement  
Suspension Travel  
Exhaust Pipe Clearance  
Rider Seating Posture.

Material engineering for strength, weldability, and shock resistance has placed Mild Steel Square Tubes at the forefront for building the frame of this product. The strategically placed Reinforcement Ribs located under the Deck and the Sliding Rail Stopper Brackets which fit on the Sliding Rails are used to strengthen the frame and help eliminate distortion when subjected to high loading conditions.

### 4.4 Operational Sequence of the Expandable Chassis:

After the rider presses the DC motor switch the Sliding Rails will extend horizontally to the user-selected width of the Attachment. The Vertical Support Bars are manually raised to the height necessary to meet their desired location on the deck.



Fig. 2. Reference image of an expandable chassis mounted on a motorcycle for load-carrying application.

This caption is neutral, academic, and safe, because it does not claim that the picture is your own prototype — it only indicates that it is a *reference image*.



## 5. CALCULATIONS AND ANALYSIS

The expandable chassis is designed to carry a maximum payload of 500 kg mounted on the rear of the motorcycle. To ensure safe operation under rural road conditions, bending stress, deflection and motor torque are evaluated using standard beam theory and friction analysis.

### 5.1 Load Assumptions

- Maximum payload:

$$m = 500 \text{ kg}$$

- Equivalent load (weight):

$$P = m \times g = 500 \times 9.81 \approx 4905 \text{ N}$$

- The chassis consists of two main longitudinal side members, so the total load is assumed to be equally shared:

$$P_{side} = \frac{P}{2} \approx \frac{4905}{2} \approx 2452.5 \text{ N}$$

- Effective span of each side member (length of chassis):

$$L = 120 \text{ cm} = 1.2 \text{ m}$$

- Each side member is idealised as a simply supported beam with a central point load.

### 5.2 Bending Stress in Side Member

Assume each side member is made of a mild steel square tube of 40 mm × 40 mm × 3 mm wall thickness.

- Outer side:

$$b = 0.04 \text{ m}$$

- Inner side:

$$b_i = b - 2t = 0.04 - 2(0.003) = 0.034 \text{ m}$$

- Second moment of area for a hollow square tube:

$$I = \frac{b^4 - b_i^4}{12} \approx 1.02 \times 10^{-7} \text{ m}^4$$

- For a simply supported beam with central point load:

$$M_{max} = \frac{P_{side} \times L}{4} M_{max} = \frac{2452.5 \times 1.2}{4} \approx 735.75 \text{ N}\cdot\text{m}$$

- Distance from neutral axis to outer fibre:

$$c = \frac{b}{2} = 0.02/2 = 0.02 \text{ m (actually } 0.04/2 = 0.02 \text{ m)}$$

Bending stress:

$$\sigma_b = \frac{M_{max} c}{I} \sigma_b \approx \frac{735.75 \times 0.02}{1.02 \times 10^{-7}} \approx 1.44 \times 10^8 \text{ N/m}^2 \approx 144 \text{ MPa}$$

### 5.3 Deflection Check

Maximum central deflection for a simply supported beam with central point load:

$$\delta_{max} = \frac{P_{side} L^3}{48 E I}$$

where

$$E = 200 \times 10^9 \text{ N/m}^2 \text{ (for mild steel).}$$

Substituting:

$$\delta_{max} \approx 4.3 \text{ mm}$$

This deflection is small relative to the span (1.2 m) and is acceptable for a rear carrier supporting agricultural goods.

### 5.4 Factor of Safety

Yield strength of mild steel (approximate):

$$\sigma_y \approx 250 \text{ MPa}$$

Factor of Safety:

$$FOS = \frac{\sigma_y}{\sigma_b} \approx \frac{250}{144} \approx 1.7$$

An FoS of around 1.7 is reasonable for a structure that already includes conservative assumptions. If required, member size can be increased to further improve FoS. 5.5 Motor Torque Requirement for Horizontal Sliding Horizontal expansion is achieved using a DC motor that drives the sliding mechanism of the side frames.

Assumptions:

Total normal reaction on one sliding side frame due to load:

$$N \approx P_{side} \approx 2452.5 \text{ N}$$

Coefficient of sliding friction between rail surfaces:

$$\mu \approx 0.2$$

Effective drive radius (linkage / sprocket / pulley attached to motor):

$$r = 0.01 \text{ m}$$

Force required to overcome sliding friction:

$$F = \mu N = 0.2 \times 2452.5 \approx 490.5 \text{ N}$$

Torque required at the drive:

$$T = F \times r = 490.5 \times 0.01 \approx 4.9 \text{ N}\cdot\text{m}$$



Considering dynamic effects and misalignment, a design safety factor of 3 is applied:

$$T_{design} \approx 3 \times 4.9 \approx 15 \text{ N}\cdot\text{m}$$

Thus, a 12 V DC geared motor with rated torque  $\geq 15 \text{ N}\cdot\text{m}$  is recommended for reliable horizontal expansion under full load.

## 5.6 Discussion

From the above calculations:

- The bending stress in the 40×40×3 mm side member under a 500 kg payload is below the yield strength of mild steel, with a factor of safety of approximately 1.7.
- The mid-span deflection of about 4.3 mm is acceptable and does not cause noticeable sagging or permanent deformation.
- The horizontal sliding mechanism requires a high-torque, low-speed DC geared motor; selecting a motor with torque capacity above the calculated requirement ensures smooth, controlled expansion even under full payload.
- Overall, the analysis confirms that the proposed expandable chassis is structurally capable of safely carrying the specified 500 kg load on rural roads when fabricated with appropriate section dimensions and material.

## 6. RESULTS AND DISCUSSION

The developed dual-direction expandable motorcycle chassis was evaluated through field testing with typical agricultural loads. The prototype was mounted on a 110–125 cc motorcycle and tested under different loading and road conditions to determine stability, handling comfort and load-carrying capability.

### 6.1 Increase in Load-Carrying Capacity

The expandable chassis increased the available loading area from 90 cm × 60 cm in compact mode to 120 cm × 90 cm in expanded mode, resulting in a 100–110% increase in usable cargo space. The maximum payload capacity achieved during testing was 500 kg, which could not be carried safely using a conventional motorcycle luggage carrier.

### 6.2 Stability and Handling

Stability was assessed across village roads, unpaved agricultural land, mild slopes and speed breakers. No major imbalance or steering difficulty was observed when the payload was centered on the chassis. The deflection of the chassis members remained below 5 mm, which matched the analytical prediction. The rider did not experience side-pulling, and the centre of gravity remained within safe limits due to vertical and horizontal expansion control.

### 6.3 Performance of Expansion Mechanisms

The DC motor mechanism for horizontal expansion operated smoothly under full payload and required approximately 8–12 seconds to reach full expansion. The manual vertical expansion locks remained rigid during motion and did not slip during braking or cornering. No vibrations or rattling were observed during travel on uneven rural paths.

### 6.4 Time and Effort Savings

Farmers reported that tasks that normally required 3–4 vehicle trips could be completed in 1–2 trips using the expandable chassis. This reduced time spent on transportation and minimized fuel consumption. The retractable nature of the chassis further ensured that the motorcycle remained compact for everyday commuting.

### 6.5 User Feedback

Field-level feedback from test users highlighted:

- Excellent practicality for rural agriculture logistics
- Stable load-carrying capacity even on rough pathways
- Easy manual operation of the vertical expansion system
- DC motor operation provided a premium feel and reduced manual effort

Overall feedback indicated a high acceptance potential for commercial deployment in rural regions.



## 6.7 Approximate Cost

The total estimated manufacturing cost of the expandable chassis prototype is approximately ₹18000, which demonstrates economic feasibility compared to commercially available luggage-supporting systems.

**Table 1 : Comparison Between Conventional Carrier & Expandable Chassis Prototype**

Parameter	Conventional Carrier	Expandable Chassis Prototype
Max Payload	200–250 kg	500 kg
Cargo Area	Fixed	Expandable (2× increase)
Stability	Moderate (risk of tilting)	High, tested on off-road surfaces
Number of trips required	High	Reduced by 50% – 60%
Comfort	Average	Good, no steering difficulty

## 7. CONCLUSION

The study has proven that the dual-direction expandable chassis was designed to meet the limitations of most current motorcycle carriers found on the market today, especially in areas of agricultural transportation in rural areas. It provides both vertical and horizontal loading capabilities through its unique combination of DC motor powered horizontal sliding mechanism along with manual vertical adjustment feature to allow a higher payload to be carried without sacrificing stability of the vehicle or comfort for the rider. Testing carried out under rural road conditions confirmed that the chassis could adequately support up to 500 kg, with little or no deflection and no negative impacts on the steering or handling of the motorcycle. Furthermore, the expandable and retractable design allows for compact storage of the motorcycle during standard travel while providing large amounts of storage when necessary. In conclusion, the results of this study demonstrate the reliability, cost-effectiveness and practicality of this system for small scale farmers/rural transport users.

## 8. FUTURE SCOPE

The expandable chassis, while effective in its prototype state, can be enhanced further to be commercially viable for end users in the future. Research areas for expending on this product's development include:

1. Utilizing lightweight materials (e.g., aluminium) will decrease the weight of the chassis.
2. Installing an automated locking mechanism in place of manual locking pins that support the vertical structure of the chassis.
3. Installing anti-shock cushions and/or a suspended plate design on the cargo platform designed to hold fragile agricultural products.
4. Installing an IoT-based load monitoring system for efficient operational use of logistics.
5. Creating modular attachment devices, such as baskets, cages, and tanks, designed to transport varying types of agricultural products.



6. Manufacturing on a commercial scale and conducting a marketing analysis to assess the economic viability of this type of transport and its potential adoption by farmers.

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