

Design, Fabrication, and Evaluation of an Innovative Mechanical Lifter

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Abstract

This study developed, fabricated, and evaluated an innovative mechanical lifter designed for the removal and installation of transmissions and differentials in automotive repair shops, particularly small facilities where space, portability, and versatility are critical. Unlike conventional manual lifters, the device was designed with a more stable, compact, and user-oriented configuration to address common operational limitations. Constructed from mild steel and equipped with a scissor-type lifting mechanism, the lifter showed a theoretical load capacity of about 4,000 kg; however, actual testing indicated a practical limit of approximately 600 kg due to the current caster wheel specification. Despite this constraint, structural analysis confirmed its stability and compliance with essential safety requirements. Performance evaluation showed consistently high ratings for effectiveness, efficiency, perceived ease of use, user experience, reliability, maintainability, and safety, with weighted mean scores ranging from 4.36 to 4.54, all interpreted as strongly agree. Respondents described the device as easy to operate, maneuverable, durable, and low in maintenance demand, and they noted its potential to reduce operator fatigue during lifting tasks. The findings suggest that the lifter is a compact, stable, and practical solution that can improve productivity and ergonomic safety in automotive servicing, with caster wheel upgrading recommended to maximize its full load capacity.

Keywords: mechanical lifter, structural stability, ergonomic design, load-bearing capacity, industrial lifting solutions

1. Introduction

In automotive servicing, lifting equipment is essential for the safe and efficient handling of heavy vehicle components because it helps reduce excessive force, awkward postures, and other ergonomic risk factors associated with manual material handling (National Institute for Occupational Safety and Health [NIOSH], 2024). In automotive servicing, lifting equipment is essential because it elevates vehicles or components to facilitate inspection, maintenance, and repair while improving operator access and work efficiency (Burlet-Vienney et al., 2022; Amedorme, 2023). Depending on the design configuration and operational requirements, lifting devices can be manually operated or driven by hydraulic, electrical, pneumatic, or mechanical systems (Dang & Nguyen, 2023). Given that automotive repair tasks frequently involve confined workspaces and heavy assemblies, appropriate lifting equipment is essential to maintain productivity while reducing risks to worker safety (Amedorme, 2023; NIOSH, 2024). In this context,

lifting devices have become indispensable tools in repair shops, service stations, and other automotive work environments.

Various forms of lifting equipment have been developed for automotive and industrial applications, with devices commonly operating through manual, hydraulic, electric, or pneumatic mechanisms depending on their design and intended use (American Society of Mechanical Engineers [ASME], 2022; Dang & Nguyen, 2023). ASME's hoist standard, for example, distinguishes hand-chain-operated, electric-powered, and air-powered hoists used for lifting and lowering loads, while recent engineering studies have identified hydraulic scissor lifts as practical lifting systems because of their compact structure, load-handling capability, and operational stability (ASME, 2022; Dang & Nguyen, 2023). In automotive servicing, these technologies are important because they allow technicians to raise vehicles or heavy components for inspection, removal, installation, and repair, and recent work on remotely controlled hydraulic bottle jacks further shows that lifting technology continues to evolve toward designs that reduce operator effort and improve convenience (Ikpe & Owunna, 2019). These developments suggest a continuing need for lifting devices that are compact, stable, and suitable for constrained automotive work environments, thereby justifying the development of the present innovative mechanical lifter (Dang & Nguyen, 2023; Ikpe & Owunna, 2019).

Despite the availability of vehicle lifts, hoists, and jacks, many existing lifting devices are primarily designed to raise entire vehicles for general maintenance and repair or to handle major assemblies such as engines, which means they do not always directly address the safe handling of under-vehicle components such as transmissions and similar assemblies during removal and installation (Burllet-Vienney et al., 2022; Noor et al., 2022). This limitation becomes particularly important in automotive repair settings where tasks are performed in restricted workspaces and where the manual handling of heavy parts remains common. Studies on vehicle repair workers and manual material handling have shown that such work is associated with a high prevalence of work-related musculoskeletal disorders, especially affecting the lower back and other body regions, thereby underscoring the importance of ergonomic lifting solutions for reducing physical strain and injury risk (Tamene et al., 2020; NIOSH, 2024). In this context, the need for a more compact, stable, and task-specific lifting device for transmission- and differential-related work is well justified, particularly where safety, precision, and ease of handling are essential (Noor et al., 2022; Burllet-Vienney et al., 2022).

Ergonomic design principles provide an important basis for addressing the physical demands associated with lifting tasks in automotive servicing. Work-related musculoskeletal disorders are a major occupational health concern, and authoritative ergonomics guidance emphasizes that work systems should be designed to fit worker capabilities in order to reduce strain, discomfort, and injury risk (NIOSH, 2024; Occupational Safety and Health Administration [OSHA], n.d.). This concern is especially relevant in vehicle repair work, where musculoskeletal symptoms have been reported at high levels among mechanics and related workers exposed to manual handling and awkward postures (Tamene et al., 2020; Hafez, 2022). In response, ergonomically designed lifting devices help reduce physical load by supporting safer body mechanics and minimizing excessive force, awkward posture, and repetitive strain through features such as improved handle placement, better load control, and reduced manual lifting demands (NIOSH,

2024; OSHA, n.d.). Thus, incorporating ergonomic principles into lifting-device design is not merely a matter of convenience, but a practical strategy for improving worker protection, reducing injury risk, and enhancing the quality and efficiency of automotive servicing operations.

In response to these gaps, the present study focused on the design, fabrication, and evaluation of an innovative mechanical lifter specifically intended for the removal and installation of transmissions and differentials in automotive repair shops, particularly in smaller facilities. The device was initially conceptualized as a manual lifter for light-vehicle transmissions, but its design was later expanded to accommodate differentials in both light and heavy vehicles. Unlike conventional tubular lifters, the proposed device featured a rectangular, table-like configuration to improve stability during operation. It was also designed to be collapsible for space efficiency, portable for easier maneuverability, and height-adjustable to suit varying vehicle heights and service conditions. By providing mechanical lifting assistance, the device was expected to reduce technicians' physical strain, improve workplace safety, enhance service efficiency, and help protect the integrity of the components being handled. Guided by these objectives, the study sought to answer the following questions:

1. What processes are involved in the innovation of a mechanical lifter in terms of designing, fabricating, and evaluating structural stability?
2. What is the technology assessment of the innovative mechanical lifter in terms of effectiveness and efficiency? and
3. What is the acceptability of the innovative mechanical lifter in terms of perceived ease of use, user experience, reliability, maintainability, and safety?

2. Conceptual framework

The study is anchored on three major theoretical and design foundations (see Figure 1): the principles of mechanics, ergonomics, and user-centered design. These foundations collectively inform the adoption of the developmental evaluative approach, which serves as the central process for the systematic design, refinement, and assessment of the device, ultimately leading to the development of the innovative mechanical lifter.

Manual lifters, also referred to as mechanical lifting aids, are important tools in industries such as automotive service, construction, and warehousing because they help workers handle heavy loads with less physical strain and lower ergonomic risk (NIOSH, 2024; Wurzelbacher et al., 2020). Their development is grounded in the principles of mechanics and ergonomics, particularly the use of mechanical advantage to make lifting tasks easier and safer for the operator (Encyclopaedia Britannica, n.d.). Over time, simple force-amplifying mechanisms evolved into more specialized lifting devices as engineering design and knowledge of human factors improved. In contemporary work settings, these devices are increasingly designed not only to lift loads effectively but also to reduce awkward postures, excessive force, and other conditions associated with work-related musculoskeletal disorders, thereby improving both worker efficiency and safety (NIOSH, 2024; Tamene et al., 2020).

The principles of mechanics provide the technical foundation for the structure and operation of lifting devices. Concepts such as mechanical advantage, force distribution, and stability explain how a properly designed lifter enables users to raise heavier loads with less applied effort while maintaining safer and more controlled operation (Encyclopaedia Britannica, n.d.; Dang & Nguyen, 2023). In particular, leverage allows force to be amplified by positioning a pivot point and applying effort at a distance from the load, whereas the inclined plane reduces the force required to raise an object by distributing that effort over a longer path (Encyclopaedia Britannica, n.d.). These principles remain central to the design of modern lifting systems, including scissor-lift mechanisms, where load capacity, lifting height, and stability depend on the geometric and structural configuration of the device (Dang & Nguyen, 2023). In the present study, these mechanical principles guided the consideration of adjustable supports, lever-based action, and other structural elements intended to improve the efficiency, stability, and practical performance of the proposed device.

Ergonomics provides the human-centered foundation for the design of lifting devices. Its principles are especially important in reducing the risk of work-related musculoskeletal disorders associated with manual handling tasks, particularly those involving forceful exertion, repetitive motion, and awkward postures (NIOSH, 2024; OSHA, n.d.). This concern is highly relevant in automotive servicing, as vehicle repair work has been identified as a high-risk occupation for musculoskeletal disorders (Tamene et al., 2020). In the present study, ergonomic principles guided the design toward minimizing user exertion, promoting proper body posture, and reducing the likelihood of injury during lifting operations. Accordingly, the proposed lifter considered features such as adjustable height, better handle positioning, and improved load handling to reduce awkward movement and physical strain, consistent with ergonomics guidance for safer manual material handling and work design (NIOSH, 2024; OSHA, n.d.).

Meanwhile, user-centered design (UCD) provides the human-centered framework for ensuring that the device responds to the actual needs, limitations, and preferences of its intended users. UCD emphasizes understanding user requirements, involving users throughout the design process, and conducting iterative usability evaluation to identify and resolve design problems before finalization (International Organization for Standardization [ISO], 2019; Luna et al., 2017). In the present study, this perspective supported the development of a mechanical lifter that is not only functional and efficient, but also practical, safe, and easy to use in actual work settings. By incorporating user feedback and usability-oriented design considerations, the study aimed to improve the fit between the device and the working conditions of automotive technicians, thereby enhancing acceptability and real-world applicability (ISO, 2019; Luna et al., 2017).



Figure 1. Conceptual framework

3. Methods

The study employed a developmental-evaluative research design and was anchored in the input-process-output (IPO) model. The input phase covered the preparation of the materials, tools, and equipment required for fabricating the innovative manual lifter, including angle bars, round bars, steel plates, caster wheels, and welding tools. The process phase involved the conceptualization, design, fabrication, and evaluation of the device, whereas the output phase was the completed manual lifter intended for lifting and lowering heavy automotive components in automotive servicing.

The study was conducted in automotive repair shops from selected municipalities of Southern Leyte. The respondents consisted of 15 mechanical engineers and 25 automotive mechanics who were selected on the basis of their technical expertise and practical experience. Data were collected using a checklist-questionnaire adapted from established frameworks, including the Modified Technology Acceptance Model, the DeLone and McLean model, and relevant ISO standards, particularly ISO/IEC 25010. The device also underwent five actual trials involving the lifting and lowering of heavy automotive components, with task completion time recorded for each trial to assess effectiveness and efficiency.

Prior to data collection, permission was secured from the respondents and shop owners. The device was then introduced through demonstration and actual use, after which respondents evaluated it following a two-week utilization period. The data were organized, tabulated, and analyzed using descriptive statistics, particularly the weighted mean, while trial times were summarized descriptively to support the evaluation results.

4. Results and discussion

Innovation of a mechanical lifter

This section highlights the development process of the device, from initial concept to actual construction. It also details how the device was tested to ensure it meets performance expectations. Specifically, the strength and durability of the lifter were evaluated through thorough analysis assessment.

Design. Figure 2 illustrates the front view of the innovated mechanical lifter in two configurations: (A) not expanded and (B) expanded. In configuration (A), the lifter maintains a compact form with a total saddle width of 22 cm, suitable for maneuvering in tight or limited spaces. The base width is 31 cm, supported by caster wheels (1), which ensure smooth mobility. All key components, such as the lifting arm (5), center shaft (7), and frame shaft assembly (4), remain aligned in a retracted state to maintain balance and portability.

In the expanded configuration (B), the saddle width extends to 30 cm, allowing for a broader support surface that can accommodate larger or heavier objects. This expanded stance improves operational stability, especially when aligning the lifter under mechanical assemblies. Despite the increased upper width, the base remains at 31 cm, indicating that the expansion is isolated to the upper portion. The design allows flexibility without compromising the integrity of the frame. Key components like the saddle bolt

stopper (11), roller (9), and rotating handle (8) are clearly positioned to facilitate adjustable and secure operation during both transport and lifting tasks.

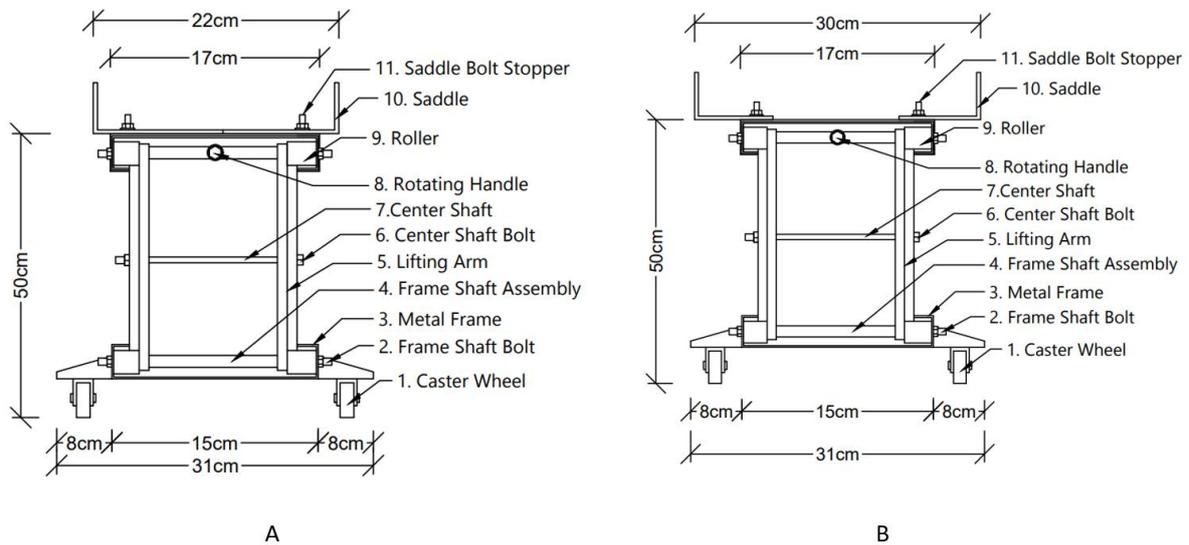


Figure 2. Front view of the innovated mechanical lifter. (A) not expanded. (B) expanded

Figure 3 presents the side view of the innovated mechanical lifter in two positions: (A) expanded and (B) not expanded, highlighting its adjustable height feature. In the expanded state, the lifter extends up to 50 cm in height through the deployment of its scissor-type lifting arms, controlled by a rotating handle and square thread screw mechanism that allows manual adjustment. In its retracted form, the lifter compresses to a compact 15 cm height, with the arms folded neatly into the metal frame, making it suitable for storage or low-clearance tasks. The inclusion of lock pins along the frame ensures secure positioning at various heights, supporting both safety and versatility in operation.

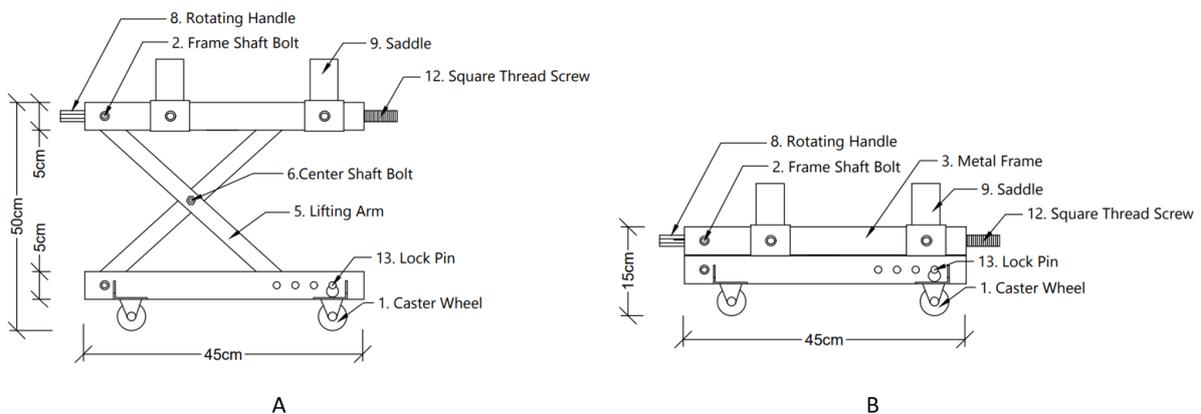


Figure 3. Side view of the innovated mechanical lifter. (A) expanded. (B) not expanded

Furthermore, Figure 4 shows the top view of the innovated mechanical lifter in two configurations: (A) saddle expanded and (B) saddle not expanded. In view A, the saddle components extend outward, increasing the total width from 30 cm to 31 cm with a saddle span of 22 cm, allowing the lifter to support

wider loads during operation. In view B, the saddle is retracted to a more compact position, reducing the saddle span to 15 cm and the overall width to 30 cm, making the device more space-efficient for transport or when lifting smaller components.

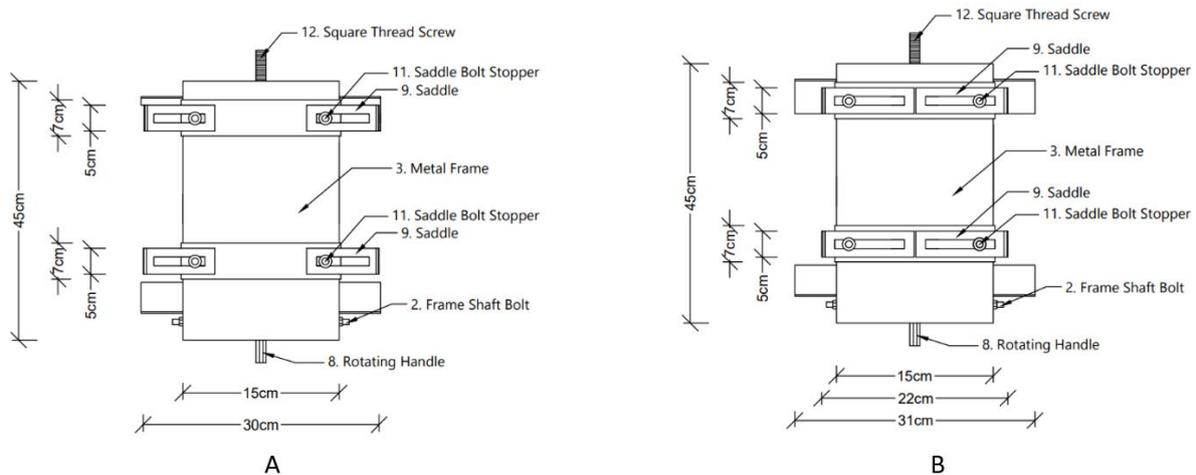


Figure 4. Top view of the innovated mechanical lifter (A) saddle expanded. (B) saddle not expanded

Lastly, Figure 5 presents rare view of the device and Figure 6 shows the isometric view of the mechanical lifter in both its fully extended (A) and not extended (B) configurations. The extended view highlights the lifter’s maximum working height and width, designed for improved load stability and operational reach. In contrast, the not extended view shows its compact form, ideal for easy storage and mobility in confined spaces.

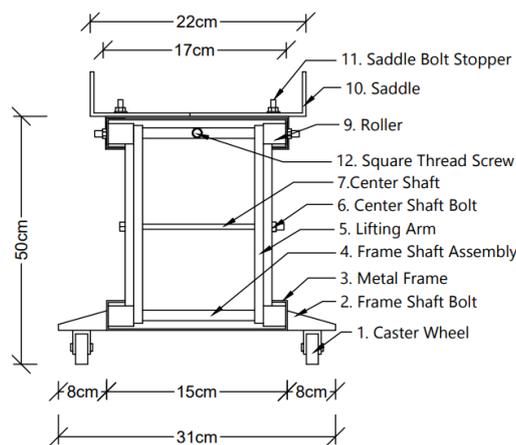


Figure 5. Rear view of the innovated mechanical lifter

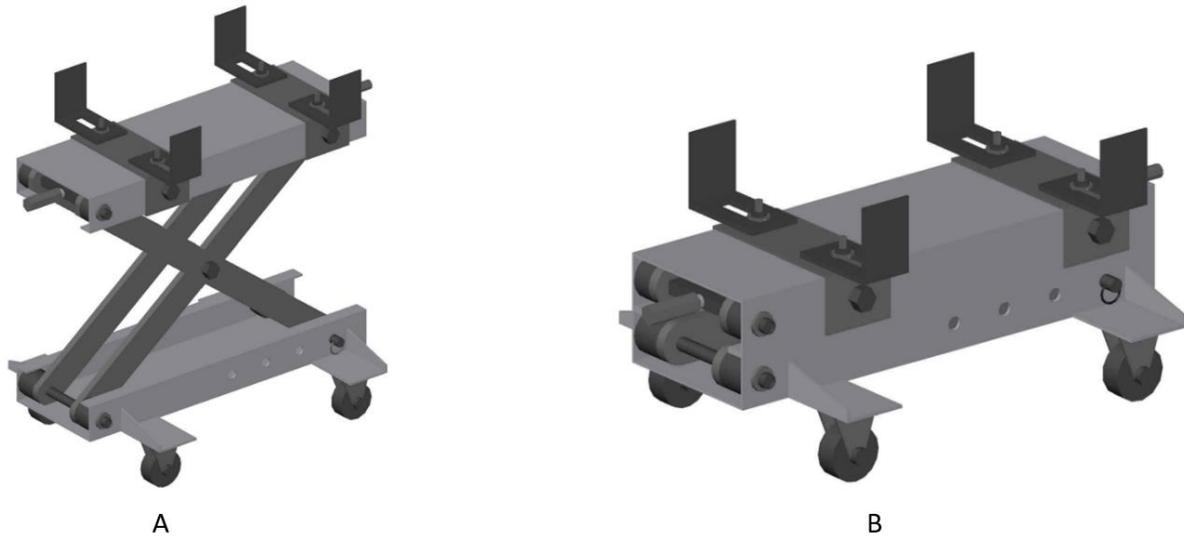


Figure 6. Isometric of the innovated mechanical lifter. (A) Fully Extended. (B) not Extended

Fabrication. This section details the fabrication process of the innovative mechanical lifter. It includes a comprehensive listing of all materials and tools used to build the device, ensuring accuracy and reproducibility. Additionally, the step-by-step fabrication procedure is outlined to show how each component was assembled to form the final working prototype. On the fabrication of the mechanical lifting equipment, the following device supplies and materials and tools are needed as shown in Tables 1 and 2 respectively.

Table 1. List of needed supplies and materials

No.	Description	Specification	Quantity
1	Angle bar	2"x2"x3/16"	1 pc
2	Flat Bar	2"x3/16"	1 pc
3	Channel Bar	6mmx75mm150mm	1 pc
4	Caster Wheel	2"	4 pcs
5	Bearing Roller	6202	4 pcs
6	Square Head Machine Bolts	5/8 "X 24"	1 pc
7	Round bar	8mm	1 pc
8	Welding rod	6013	2 kg
9	Cutting Disk	4"	6 pc
10	Grinding Disk	4"	1 pc

Table 2. List of tools

No.	Quantity	Unit	Description
1	1	pc	Allen wrench 10mm
2	1	pc	Locking plier
3	1	pc	Angle grinder 750 watts
4	1	pc	Welding machine 200 watts
5	1	pc	Open end wrench 10-11

6	1	pc	Welding mask
7	1	pc	Face shield
8	1	pc	Ballpeen hammer

Meanwhile, Figure 7 presents the fabrication process of the mechanical lifter.



Figure 7. Fabrication procedure

Evaluating structural stability. This part presents the analysis of the device’s structural stability, focusing on its capacity to carry loads safely without tipping, buckling, or failing (see Table 3). It evaluates the strength of key components based on material properties, dimensions, and safety factors to ensure the device’s reliability during use. The results confirm that while the frame can support heavy loads, the overall stability is limited by the capacity of the caster wheels and must be addressed to maximize performance.

Table 3. Evaluation of the structural stability of the mechanical lifter

Particulars	Results
Load-bearing capacity of critical parts	<p>Properties of materials</p> <p>Assume the material is mild steel:</p> <ul style="list-style-type: none"> • Yield Strength (σ_y) \approx 250 MPa • Ultimate Strength (σ_u) \approx 400 MPa • Young’s Modulus (E) \approx 200 GPa <p>Cross-sectional Area and Moment of Inertia</p> <ul style="list-style-type: none"> • Angle Bar (2"x2"x3/16"): • Area (A) = 4.61 cm² • Moment of Inertia (I_{total}) = 0.910 cm⁴ • Flat Bar (2"x3/16"): • Area (A_{flat}) = 2.418 cm²

	Determine axial and bending load capacity Using Euler’s Buckling Load formula: $P_{cr} = \pi^2 \times E \times I / (K \times L)^2$ Calculated $P_{cr} \approx 80,240 \text{ N} \approx 8,180 \text{ kg}$. After applying safety factor of 4: Allowable Load $\approx 2,045 \text{ kg}$ per arm. Two arms: $\sim 4,000 \text{ kg}$ total theoretical capacity.
Caster wheel capacity	Caster wheels 2” typically support around 150 kg each. Total caster support = $4 \times 150 = 600 \text{ kg}$. Wheels are the limiting factor.
Stability check	Base width to height ratio = 1.0 Meets minimum anti-tip stability requirement.

The structural evaluation of the innovative mechanical lifter indicates a strong theoretical capacity, as shown in Table 4, the lifter estimated at approximately 4,000 kilograms based on the material properties and design of the lifting arms using angle bars (2”×2”×3/16”) under mild steel assumptions. Even when applying a safety factor of four, the lifter can still safely support around 2,000 kilograms. However, the analysis reveals that the practical load capacity is limited to approximately 600 kilograms due to the constraints of the 2-inch caster wheels, which are critical components supporting the lifter during movement and operation. This finding emphasizes that while the frame design and materials provide high mechanical strength, auxiliary components such as caster wheels must be carefully selected to match or exceed the structural capabilities to ensure operational safety and reliability. In light of this, it is recommended that industrial-grade caster wheels rated for higher loads (at least 300–400 kilograms per wheel) be installed to fully utilize the mechanical potential of the device and accommodate loads ranging from 500 kilograms to 1 ton without risking structural failure (Beer et al., 2015). Furthermore, ensuring high-quality welding, precise fabrication, and adherence to stability ratios such as maintaining a base width equal to or greater than half the height enhances the lifter’s tipping resistance and safety, especially under dynamic load conditions. This analysis underscores the importance of holistic design considerations where both structural elements and peripheral components must be engineered cohesively to achieve optimal performance and user safety.

Table 4. Summary of structural stability

Item	Value
Maximum structural capacity (theoretical)	~4000 kg
Allowable structural load with safety factor	~2000 kg
Caster wheels load limit	~600 kg
Limiting factor	Caster wheels
Stability (Anti-tip ratio)	Passed

Technology assessment and acceptability of the innovative mechanical lifter

This section presents the assessment of the innovative mechanical lifter in terms of its effectiveness, efficiency, and overall acceptability. The evaluation was conducted through actual device utilization, during which the participants used the lifter for vehicle lifting, as shown in Figure 8. Following the testing procedure, the participants completed a standardized checklist and questionnaire to evaluate the device systematically. The assessment focused on the participants' perceptions and actual experience with the mechanical lifter after use. Through these instruments, data were gathered on the device's performance and acceptability based on key evaluation criteria. This approach provided a structured basis for determining how the innovative mechanical lifter was received by the respondents in terms of its practical application and user experience.



A



B

Figure 8. Testing and evaluation of innovated mechanical lifter

Table 5 indicates that the mechanical lifter received a highly favorable assessment across all evaluated dimensions, as all mean scores fell within the “strongly agree” range. Among the indicators, perceived ease of use obtained the highest mean (4.54), suggesting that respondents found the device easy to operate and practical for actual use. This was followed by user experience (4.50) and efficiency (4.49), which imply that the lifter provided a generally positive user interaction while also helping respondents perform lifting tasks with less time and effort. Similarly, reliability (4.48) and maintainability (4.47) were rated very highly, indicating that the device was viewed as dependable and manageable in terms of upkeep and adjustment. Effectiveness also received a strong rating (4.42), showing that the lifter was able to perform its intended function satisfactorily. Although safety recorded the lowest mean (4.36), it still remained within the strongly agree category, suggesting that respondents generally considered the device safe to use.

Table 5. Technology assessment and acceptability of the mechanical lifter

Dimension	Mean	Description
Effectiveness	4.42	Strongly agree
Efficiency	4.49	Strongly agree
Perceived ease of use	4.54	Strongly agree
User experience	4.50	Strongly agree
Reliability	4.48	Strongly agree
Maintainability	4.47	Strongly agree
Safety	4.36	Strongly agree

Note: 4.21-5.00- strongly agree; 3.41-4.20- agree; 2.61-3.40-neutral; 1.81-2.60-disagree; 1.00-1.80-strongly disagree

The results indicate that the mechanical lifter demonstrated high acceptability across all assessed dimensions, supporting its potential utility in automotive and related service settings. Respondents strongly agreed that the device was effective, efficient, easy to use, reliable, maintainable, and safe, while also reporting a positive user experience. This pattern suggests that the lifter was able to perform its intended function in a manner that was both practical and acceptable to users. Such findings are consistent with the view that well-designed engineering systems can improve operational efficiency and support safer work performance through dependable and optimized design. Moreover, the device’s strong performance across multiple indicators reflects human-centred design principles that emphasize usability, responsiveness to user needs, and practical fitness for real-world application (Das, 2024; ISO, 2019).

The particularly high ratings for perceived ease of use, user experience, efficiency, and reliability suggest that the lifter was viewed as both technically sound and user-friendly. These findings imply that the device reduced the effort required to perform lifting tasks, supported smoother operation, and minimized the likelihood of performance disruptions. This is important because ease of use is a well-established determinant of technology acceptance and adoption, influencing user willingness to use a system and shaping satisfaction with its operation (Cheung & Vogel, 2013). In the same way, the positive assessment of efficiency points to the lifter’s potential to improve task productivity and reduce operator strain, which is consistent with evidence linking ergonomic performance to occupational health, safety, and productivity outcomes (Tao et al., 2024). The favorable user experience further suggests that the device contributed positively not only to functional performance but also to user engagement and comfort, both of which are important to sustained acceptance and meaningful use of a technology (Hassenzahl, 2010). More broadly, these results are also consistent with human-centred design principles, which emphasize usability, usefulness, and responsiveness to user needs as key factors in the successful adoption of designed systems (ISO, 2019).

The strong ratings for reliability, maintainability, and safety further reinforce the mechanical lifter’s potential for broader application. High perceived reliability suggests that the device can support user trust, reduce operational interruptions, and contribute to consistent performance, which are important indicators of product quality and sustained usability (International Organization for Standardization/International Electrotechnical Commission [ISO/IEC], 2023; Tweeddale, 2003). Likewise, the favorable rating for

maintainability indicates that the device was designed to allow easier servicing, adjustment, and continued operation, which are essential for minimizing downtime and reducing repair-related burden over the product's service life (Dhillon, 2006; ISO/IEC, 2023). Although safety obtained the lowest mean among the indicators, it still fell within the strongly agree range, indicating that respondents generally considered the lifter safe to use. This suggests that the device incorporated protective features and design considerations that can help reduce workplace risk and support safer manual handling practices (NIOSH, 2024; OSHA, n.d.). At the same time, the slightly lower safety rating points to the value of continued user-centered refinement and operator training, as training is a recognized element of effective ergonomics and safety programs that helps workers understand hazards and use equipment more safely and confidently (OSHA, n.d.; NIOSH, 2024).

5. Conclusions

This study was conducted to develop and evaluate an innovative mechanical lifter intended to improve the lifting and lowering of heavy automotive components in industrial and service settings. Specifically, the paper aimed to assess the device in terms of design, strength, usability, reliability, effectiveness, efficiency, and safety to determine its practical applicability and acceptability among users. Based on the findings, the innovative mechanical lifter generally met the essential standards for mechanical lifting devices in terms of design, strength, usability, and reliability. The results showed that its mechanical frame possessed strong structural capacity, although its full performance potential could still be enhanced through improvements in ancillary components, particularly the caster wheels. The positive evaluations of its effectiveness, efficiency, and ease of use indicate that the device is suitable for application in industrial and service environments where stability, maneuverability, and compact design are important. Although the lifter already incorporated safety features and demonstrated dependable performance, minor refinements to further strengthen users' sense of safety during operation may improve its overall usability and effectiveness.

In light of these findings, several recommendations are proposed to further optimize the device. First, the caster wheels should be upgraded to heavy-duty industrial-grade units with a load rating of at least 300–400 kilograms per wheel to maximize lifting capacity and fully utilize the frame's structural strength. Second, user training on safe operation and ergonomic handling should be provided to improve user confidence and reinforce safety in actual use. Third, the design may be further refined by incorporating user-centered features such as non-slip platforms, improved handle grips, and integrated locking mechanisms to enhance comfort and usability. Finally, regular evaluation and systematic user feedback collection should be institutionalized to support continuous product improvement and ensure that the lifter remains responsive to industry standards and user needs.

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