Design and Fabrication of 2-in-1 Trolley for Lifting and Ladder

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Abstract. The increasing demand for efficient and space-saving tools in workshops and households has led to the development of innovative solutions that combine multiple functionalities into a single product. This project focuses on the design and fabrication of a 2-in-1 trolley, which serves as both a load-carrying trolley and a ladder. The primary objective is to address common challenges faced by workers and individuals, such as transporting heavy items and accessing elevated storage areas, without the need for separate tools. Conventional methods require separate ladders and trolleys, resulting in higher costs, increased storage space, and reduced efficiency. The proposed design offers a compact, lightweight, and cost-effective alternative that enhances convenience and productivity. The 2-in-1 trolley is constructed using mild hollow steel for strength and durability, complemented by heavy-duty rubber wheels with locking mechanisms for mobility and stability. Anti-slip mats are integrated into ladder steps to ensure user safety during climbing. The design emphasizes ergonomics, portability, and ease of transformation between trolley and ladder modes. The fabrication process involves cutting, drilling, welding, and assembly of components, followed by surface finishing to prevent corrosion. Safety measures, including proper PPE usage and adherence to machining guidelines, were implemented throughout the fabrication process. Performance evaluation included pre-testing and post-testing phases, covering load capacity, stability, and usability. The trolley demonstrated the ability to carry loads up to 85 kg and function as a stable three-step ladder, meeting the design specifications. User surveys indicated high satisfaction, with over 90% of respondents agreeing that the product is compact, easy to use, and suitable for small spaces. Cost analysis revealed a total fabrication cost of RM 211.60, significantly lower than purchasing separate ladders and trolleys, confirming the economic viability of the design. The project has practical benefits, including reducing physical strain, saving time, and optimizing storage space, making it ideal for workshops, garages, and domestic use. Additionally, incorporating smart features such as sensors for stability monitoring could further enhance safety and functionality. In conclusion, the 2-in-1 trolley project successfully achieves its objectives by delivering a versatile, durable, and cost-effective

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solution for lifting and climbing tasks. This innovation demonstrates how thoughtful engineering design can solve everyday problems while promoting efficiency and user convenience. The product's adaptability and affordability position as a valuable tool for both industrial and household applications, contributing to improved workflow and reduced operational costs.

Keywords: Multipurpose Trolley, Ergonomic Design, Load-carrying Mechanism, Ladder Integration, Fabrication Process.

1 Introduction

Material handling and access to elevated working areas are common challenges in both domestic and industrial environments [1, 2]. Traditionally, trolleys are used to assist in transporting heavy or bulky items efficiently [3, 4], while ladders are employed to enable access to objects located at elevated positions [5-7]. These tools are essential in reducing physical effort, preventing injury, and improving task efficiency [8-11]. However, the need to store, transport, and operate these tools separately often results in increased space requirements, additional time consumption, and higher physical demand on users [12-14].

To address these limitations, the 2 in 1 trolley ladder is proposed as a multifunctional solution that integrates both a trolley and a ladder into a single unit [15-18]. This combined design offers significant advantages in terms of space efficiency, portability, and operational convenience [19-21]. Its lightweight structure and compact form factor allow users to minimize storage requirements while maintaining full functionality for material transport and height related tasks [22-24]. This makes the design particularly suitable for users who require frequent access to both tools but seek to avoid the inconvenience of handling them separately [25, 26]. The trolley has long been utilized to facilitate the movement of large quantities of heavy goods, enabling users to transport multiple items in a single operation rather than lifting them individually [27]. This not only saves time but also reduces physical strain and fatigue [2]. Meanwhile, ladders enable effective vertical space utilization by allowing access to items stored at height, such as shelves and cabinets [28-30]. The integration of these two functions into a single system provides a practical and ergonomic solution for multipurpose applications [24].

The proposed 2 in 1 trolley ladder can be configured either as a trolley for transporting goods or as a ladder for height access, depending on user requirements. In ladder mode, the design provides enhanced stability to ensure safe operation in both household and workplace environments [23]. The ability to switch efficiently between modes allows users to complete tasks more quickly while expending less physical effort, thereby improving productivity and reducing fatigue [2]. Its ergonomic design and robust frame further contribute to user safety and durability [14].

The system operates using a wheel assisted mechanism, typically incorporating wheels on each side of the base to allow smooth movement across flat surfaces. When converted into a ladder configuration, the unit functions as a stable three step ladder, enabling safe access to elevated areas. By combining transport and access capabilities, the 2 in 1 trolley ladder reduces physical workload, improves workflow efficiency, and is well suited for delivery personnel, warehouse operators, maintenance workers, and general users who require both mobility and height assistance in their daily tasks.

Workers and individuals frequently require different equipment for jobs like transporting big items and reaching high locations, both in domestic and industrial settings. Traditional ladders are rigid and hard to carry around; however conventional trolleys are effective for moving objects but do not have the functionality of ladders. Users have to spend more time, effort, and storage space switching between several tools, which leads to inefficiency. Furthermore, buying a trolley and a ladder together may be too expensive for small companies or individual households. Improper combination of solutions also increases the possibility of errors at work driven on by improper device usage. As a result, a multifunctional solution that performs the dual roles of a ladder for height access and a trolley for load carriage is required. In order to overcome these difficulties, this project will design and build a multifunctional trolley that is simple to transform into a ladder. This solution will be ergonomic, affordable, and suitable for both light industrial and residential applications.

2 Methodology

The computer aided design (CAD) methodology was employed to systematically develop the 2 in 1 trolley for lifting and ladder (Fig. 1 and 2), ensuring dimensional accuracy, functional feasibility, and ease of fabrication prior to physical construction. The design process was carried out using CAD software, which enabled three-dimensional visualization, component modeling, and assembly validation [31, 32]. This approach minimized fabrication errors and allowed design issues to be identified and resolved at an early stage. The CAD development process began with conceptual modeling, where the overall structure of the trolley ladder was defined based on functional requirements [33, 34]. Key design parameters such as overall dimensions, load carrying capacity, ladder height, step spacing, and wheel positioning were established. Separate models were created for the major components, including the trolley base frame, ladder body, rotating joint mechanism, ladder steps, support bars, and wheel assemblies. Each component was modeled individually using precise dimensions to reflect the actual materials intended for fabrication, such as hollow mild steel bars.

Following component modeling, a part-by-part detailing process was performed. Holes for bolts, rotating shafts, ladder steps, and support connections were accurately positioned using reference planes and constraints. Fillets and chamfers were applied where necessary to reduce sharp edges and reflect realistic manufacturing conditions. Material properties were assigned within the CAD environment to approximate structural behavior and mass distribution, allowing for better evaluation of ergonomics and stability. The individual components were then combined using an assembly modeling approach. Assembly constraints such as mates, alignments, and rotational joints were applied to simulate the relationship between the trolley and ladder components. This step was critical in verifying the transformation mechanism between trolley mode and ladder mode. The rotating joint was evaluated to ensure smooth motion without interference, while the ladder configuration was checked for stability and proper load distribution. Interference and clearance analysis were also conducted to confirm that all moving components functioned correctly without collision.

Fig. 1. CAD model trolley setup.

Once the assembly was validated, engineering drawings were generated directly from the CAD model. These drawings included orthographic views, dimensions, hole placements, and tolerances required for fabrication. The drawings served as a reference during manufacturing, ensuring consistency between the digital model and the physical prototype. The CAD methodology also facilitated design revisions, allowing dimensions or configurations to be adjusted efficiently based on fabrication constraints or testing requirements. Overall, the CAD methodology provided a structured and reliable framework for designing the 2 in 1 trolley ladder (Fig. 2). By enabling accurate visualization, assembly verification, and detailed documentation, the use of CAD significantly improved design quality, reduced development time, and enhanced the feasibility of the final fabricated product.

The experimental setup was designed to evaluate the effectiveness and load handling capability of the developed multifunctional trolley. Post testing focused on determining the maximum load that the trolley could support while maintaining structural stability. During the test, suitable material was prepared and gradually placed on the trolley platform. The load applied to the trolley was systematically increased while monitoring the total weight. This process continued until visible signs of deformation, such as bending or misalignment of the trolley frame, were observed. The load at which the trolley began to deform was recorded as the maximum load capacity, indicating the structural limit of the product under practical operating conditions.

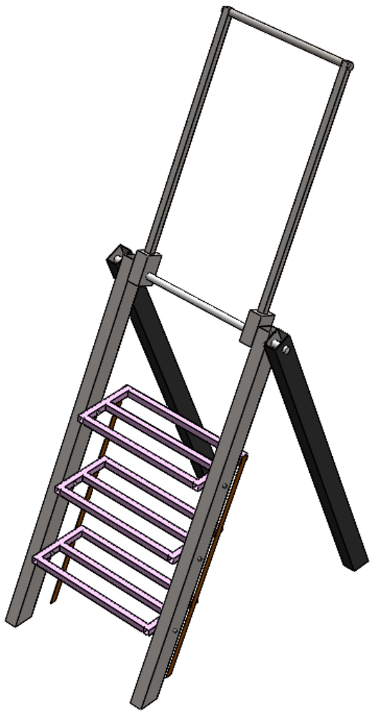
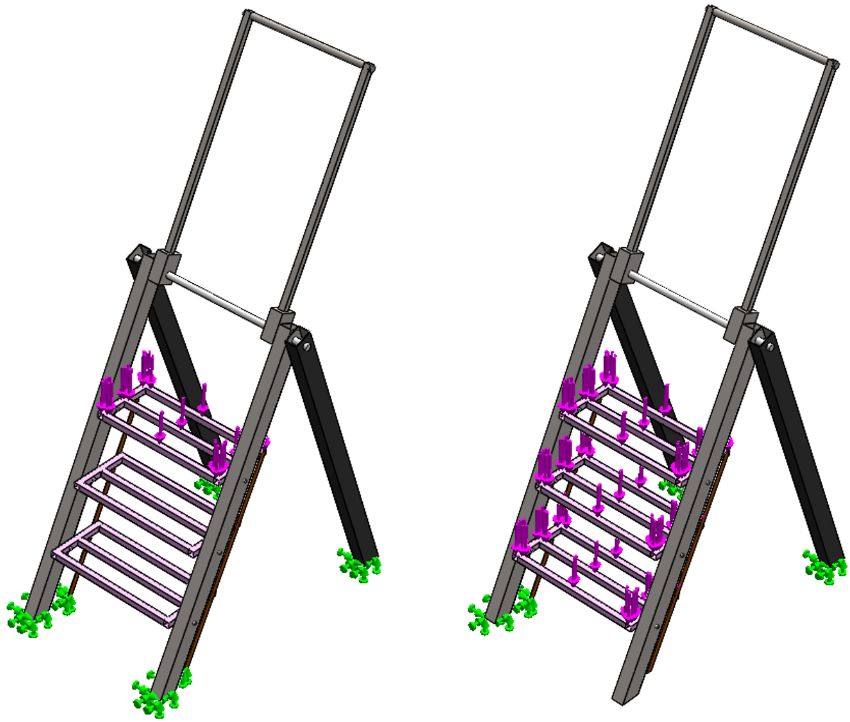


Fig. 2. CAD model ladder setup.

In addition to the physical load testing, user feedback was collected to assess the practical usability, ergonomics, and overall performance of the trolley. A structured questionnaire was distributed after the completion of the prototype to obtain user perceptions and evaluations. The questionnaire was administered using an online platform to ensure ease of access and efficient data collection. Once the responses were obtained, the data were analyzed quantitatively by calculating the mean scores for each evaluation criterion. This approach provided structured insight into user satisfaction and helped validate the effectiveness of the trolley from both technical and user centered perspectives. Fabrication is a critical phase in the development of the project, as it involves the physical construction of the multifunctional trolley. In this project, several fabrication techniques were applied to ensure structural strength, functionality, and safety. The process began with cutting hollow steel bars of size 60 × 40 mm to a length of 150 cm, where four pieces were prepared to form the base structure of the trolley. Following this, holes were drilled at designated locations to accommodate the rotating shaft mechanism and the ladder steps. Subsequently, mild steel hollow bars of size 20 × 20 mm were cut to a length of 100 cm, with two pieces used to construct the main vertical body of the trolley frame.

After completing the main structural frame, the assembly process was carried out to integrate the ladder functionality. Mild steel hollow sections were cut and shaped to form three ladder steps, which were positioned and aligned accurately to ensure stability during use. Bolts and nuts were installed at the rotating joint locations to allow smooth and controlled transformation between trolley and ladder modes. Additionally, two mild steel hollow bars of identical dimensions were cut and installed as support bars for the ladder steps, enhancing strength and load stability during ladder operation. Throughout the fabrication and assembly stages, safety considerations were strictly observed. Proper personal protective equipment (PPE), including safety gloves and safety goggles, was worn at all times, particularly during cutting, drilling, and grinding operations. These precautions were essential to reduce the risk of injuries and ensure a safe working environment during the fabrication process. Load analysis is performed on the product during ladder setup. 1000 N and 1500 N loads are applied on the steps separately and all together (Fig. 3). The constraints are fixed at the bottom of the ladder structure.

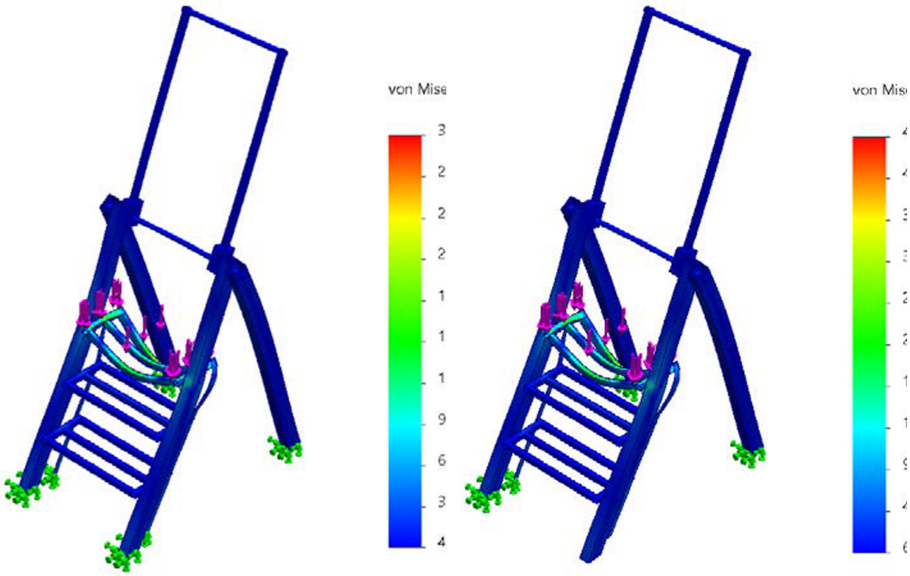


(a) (b)

Fig. 3. Load analysis (a) single step, (b) all steps.

3 Results and Discussion

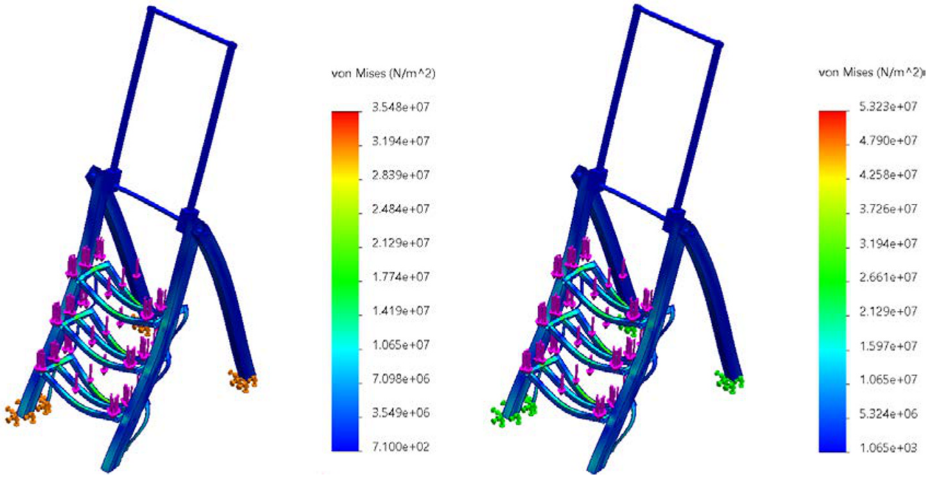
The completed 2-in-1 trolley ladder successfully meets the primary design objectives of multifunctionality, portability, structural stability, and user convenience. The final prototype demonstrates effective integration of both trolley and ladder functions within a single compact structure, allowing the product to perform dual roles without compromising safety or usability. Fig. 4 shows the stress distributions results for single step load analysis of 1000 N and 1500 N. It can be observed that the stress is 32.28 MPa and 48.41 MPa for the analysis respectively. The factor of safety compared to the yield strength of a mild steel 206.8 MPa are 6.4 and 4.3. These show that the ladder can withstand up to 153 kg mass of a person. When all steps are analyzed with the same loads (Fig. 5), the stress' are larger 35.48 MPa and 53.23 MPa for both loads. Compared to the yield strength, the factor of safety are 5.3 and 3.9 respectively.



(a) (b)

Fig. 4. Load analysis on single step (a) 1000 N, (b) 1500 N.

In trolley mode (Fig. 6), the finished product can transport loads smoothly across flat surfaces using its wheel-based mobility system. The wheel arrangement enables easy movement while minimizing the physical effort required by the user. During practical testing, the trolley maintained structural balance under load, indicating that the frame design and material selection provide sufficient strength for everyday handling tasks. The ergonomic handle height and compact frame contribute to improved maneuverability, especially in confined spaces such as workshops, storerooms, and residential areas.



(a) (b)

Fig. 5. Load analysis on all steps (a) 1000 N, (b) 1500 N.

Fig. 6. Trolley mode demonstration.

When converted into ladder mode (Fig. 7), the product functions effectively as a stable three step ladder. The transformation mechanism allows the trolley to be reconfigured smoothly without the need for complex tools or excessive force. Once fully deployed, the ladder provides adequate stability and secure footing for users performing height related tasks. The ladder steps are evenly spaced and firmly supported, resulting in improved user confidence and reduced risk of slipping or instability during use.

Fig. 7. Ladder mode demonstration.

The structural performance of the finished product indicates that the mild steel frame provides sufficient load bearing capacity for both operational modes. No permanent deformation, misalignment, or structural failure was observed under normal working conditions. The rotating joints and fasteners operated as intended, demonstrating reliable transformation between trolley and ladder configurations. These results confirm that the fabrication process and assembly accuracy were successful. From a functional perspective, the completed 2 in 1 trolley ladder effectively reduces the need for separate tools, addressing common issues related to storage space, equipment transportation, and task efficiency. By combining two essential functions into one product, the design minimizes operational time and physical strain associated with switching between a trolley and a ladder. This makes the product particularly suitable for light industrial use, maintenance work, delivery tasks, and household applications. Overall, the results show that the finished 2 in 1 trolley ladder achieves its intended purpose as a practical, cost effective, and ergonomic solution. The prototype demonstrates reliable performance, improved usability, and strong potential for real world application in environments where both load handling and height access are frequently required. The total cost is RM 211.60.

4 Conclusion

This study has presented the complete development, analysis, testing, and evaluation of the 2 in 1 trolley ladder, with emphasis on its design effectiveness, fabrication feasibility, and practical performance. The project aimed to address common challenges faced by users who require both material transportation and height access tools by integrating these functions into a single, compact solution. The results obtained from experimental testing, user evaluation, and practical observation demonstrate that the proposed design fulfils its intended purpose and offers meaningful advantages in terms of functionality, cost, and space efficiency. The design is safe for payloads of up to 153 kg. The first objective, which focused on the design and fabrication of a multifunctional trolley capable of operating as both a trolley and a ladder, was successfully achieved. The final prototype demonstrates smooth transformation between the two configurations and maintains stability and safety in both modes.

The integration of a foldable structure, durable frame, and supportive ladder steps ensure versatility while maintaining user safety and ease of operation. These results confirm that a single product can effectively replace two conventional tools without compromising performance. The total fabrication cost of RM 211.60 indicates that the product is economically competitive when compared to purchasing a separate trolley and ladder. Overall, this project demonstrates how innovative and user centered design can address everyday equipment limitations by improving efficiency, reducing physical effort, and minimizing cost and space usage. The findings show that the 2 in 1 trolley ladder is a practical, affordable, and safe solution with strong potential for real world applications in both residential and light industrial settings.

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Disclosure of Interests. The authors have no competing interests

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