

Multipurpose Versa Trolley for Optimising Material Handling at Construction Sites

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Abstract

Manual material handling is one of work activities that have an effect on the physical aspect of workers in the construction industry. This study concentrates on creating a versatile trolley to support construction activities. Different kinds of trolleys are available in the construction for various types of applications. Depending on the particular application, one will choose the trolley, but it is limited to do a specific task. This study aims to design the Versa Trolley which could be used for multi-purpose and to obtain the maximum loads can be carried by the Versa Trolley. The development of trolley, which includes design on the basis of creativity skills and fabrication process. A versa trolley designed is the integration of platform trolley and a ladder. By using stability testing, a functional trolley can support the weight of both construction materials and humans while serving two distinct functions

Keywords: Ladder; Multipurpose; Trolley.

1.0 Introduction

Health problems and occupational accidents are always overlooked issues among construction workers. It has been identified that improper work environments lead to health problems. According to Canadian Center of Occupational Health and Safety, (2016); Stambolian et al., (2016); Ekpanyaskul & Padungtod, (2021), neck, back, and shoulder pain are examples of ergonomic health issues that have been exacerbated by a lack of back safety considerations and a suitable working environment. Manual handling tasks that involve lifting, pushing, tugging, carrying, and moving things by hand or with physical force are risky and raise a number of risk factors. In Malaysia, the construction industry has a weak safety record which results from a lack of safety concern among the management and the workers. This is based on report since January to September of 2022, 129 accident cases were reported by Malaysia's Department of Occupational Safety and Health (DOSH). 51 fatalities, 1 permanent handicap, and 77 cases of temporary disability were reported.

Over time, the growing number of injury cases will have an impact on worker productivity. In construction, the advantage of manual material handling compared to material handling that uses tools is the flexibility of the

movements carried out (Wayke Kusmasari et al.2024). However, behind the overall success, there are shortcomings, namely in terms of safety and occupational health. Thus, trolley is seen more efficient materials handling, particularly for transporting materials. While some trolleys are specialised for specific tasks. The trolley should be versatile enough to handle various construction materials and tasks, promoting efficiency and safety on the job site. The objective of this study is to design the Versa Trolley based on the creativity techniques for the multipurpose and to obtain the maximum loads can be carried by the Versa Trolley. Tests were conducted to evaluate the workability of transporting construction materials as a trolley and withstanding the respondent's weight when versa trolley used as a ladder.

Injuries from manual handling occur when workers improperly lift, carry, push or pull objects, resulting in strains, sprains, fractures or worse. According to McCormack et al. (2021), Manual material handling tasks involving hazardous loads present substantial ergonomic and safety risks, primarily due to direct biomechanical interaction between the human body and the material. Kazuyuki et al. (2025), emphasized the problem of worker injuries also present in eastern nations, where research indicates that nearly 25% of construction workers sustain injuries related to lifting and carrying heavy objects manually (National Institute of Occupational Safety and Health, Japan 2021). In accordance with the Ministry of Health, Labour and Welfare (2013) guidelines, the maximum recommended manual handling load is limited to 40% of body weight for men and 24% for women to reduce the risk of physical strain. While Malaysia encourages safe manual handling practices, ergonomics assessments and training based on risk factors such as posture, duration, repetition and load weight.

Oyejide et al., (2020) with their study using a convertible car trolley with sensor control (as shown in Figure 1) capable of transporting simple mechanical tools and thus reducing potential health hazards to humans. Meanwhile, the design of a mini forklift robot using Radio Frequency Identification technology by Liawatimena et al., (2011) is capable of storing and selecting objects but requires high costs (as shown in Figure 2). Mira Rahayu & Ade Malik (2023), stated hydraulic trolleys (Figure 3) equipped with Kansei Engineering technology can also help clients by converting their preferences into user-friendly design requirements. According Nagamachi & Lokman (2016), Kansei Engineering is a methodology that connects various research techniques and can be altered or modified according to goals like participant groups, collection, data reduction techniques, types of rating scales, and computerized data collection that connects Kansei words to product attributes. However the multi-purpose trolley, which combines the design concepts of airport trolleys and shopping mall trolleys, is capable of functioning manually and automatically according to user needs (Figure 4). According Virag et al. (2017), automation of wheel has been developed successfully and tested to reduce the human effort at the handle of the trolley for giving appropriate direction.



Figure 1: Convertible Cart – Trolley with sensor controlled

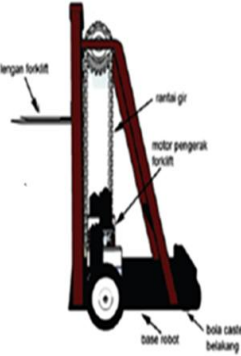


Figure 2: The Robot Structural design

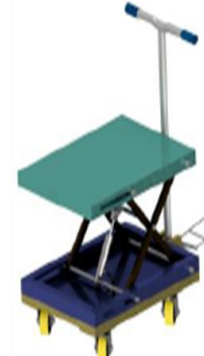


Figure 3: Hydraulic Trolley



Figure 4: Multi-Purpose Trolley

Although their numerous versions available, many of the trolleys are manually and automatic controlled and only have one function. Therefore, an innovation that is not currently on the market will be offered in this study that integrates two functionalities in a single design.

2.0 Methodology

In this study, designing Versa Trolley is used with the hope that the products developed will be more oriented towards consumers. The Versa Trolley (VT) was constructed using mild steel in order to ensure precise design in this study. Mild steel square hollow, plywood, stainless steel butt hinges, stainless steel flat bars, and stainless steel latches are the main parts of the VT.

The difficulties faced by construction workers, who frequently strain to transport heavy building materials to numerous sites, served as the impetus for the creation of the VT. The design of a trolley that can sustain a significant weight load was influenced by this. Because VT can change from a trolley to a ladder, it also lessens the requirement for a ladder for tasks that call for one. Before the final design was created, a number of preliminary designs were created. Important aspects including user comfort, simplicity of mobility, and the capacity to support a variety of loads are included in this final design. Each component of its design has been thoughtfully chosen to guarantee that the trolley and ladder both aesthetically satisfy and efficiently satisfy user needs.

The components of the product design are described, providing a comprehensive explanation of the project. The trolley is propelled by four wheels. The design has two mechanisms that allow it to function as a ladder when folded and as a trolley when stretched. Without the use of mechanical tools or the trolley's motor, it is implemented manually. When the trolley is converted into a four-step ladder, the plywood that was utilized as a base for the construction elements will act as support.

This stage involves the process of turning the planned design into a tangible entity. This stage involves measuring, cutting, welding, and inspecting the

finished product. With the assistance and supervision of skilled workshop personnel, this phase is completed. A nearby workshop is where the product is manufactured. It takes about three to four weeks to finish. To make sure the finished product satisfies the required requirements, a number of phases, including planning, production, and quality control, are completed within this period. Throughout the procedure, paying close attention to details is essential to getting the best results.

Measurement process:

- i. The measurement procedure for every mild steel square hollow is depicted in Figure 5(a). A measuring tape should be used to obtain precise measures before the cutting process actually begins. Using a certain kind of pencil or chalk to guide the cut, special markings are produced on the metal's surface. Measurements can be taken a few times to ensure that the same outcome is obtained each time
- ii. **Cutting Process**
The cutting procedure for the measured and marked Mild Steel Square Hollow is depicted in Figure 5(b). A Cut-off machine is used in this cutting procedure to produce a clean cut. This procedure needs to be done carefully since, if improperly used, it can be quite harmful.
- iii. **Welding Process**
Mild steel that has been cut to size is joined by the welding process. The entire strength of the trolley depends on the strong and long-lasting connection that this welding provides (Figure 5 (c)).
- iv. **Checking Product After Assemble**
As seen in Figure 5(d), the measurement check procedure entails confirming that component dimensions match specifications. This final step is essential for precision and a good fit, avoiding problems during assembly, and guaranteeing product quality. All of the welded components were put together during this step. Wheels, plywood boards for trolley bases, and other components are installed throughout the installation procedure.
- v. **Finishing Process**
Figure 5(e) demonstrates that after the assembly process is finished, the last finishing steps are carried out, such as painting to shield the product's surface from rust or corrosion. Additionally, this finish also gives a professional appearance to the product and increases the product's resistance to environmental elements.

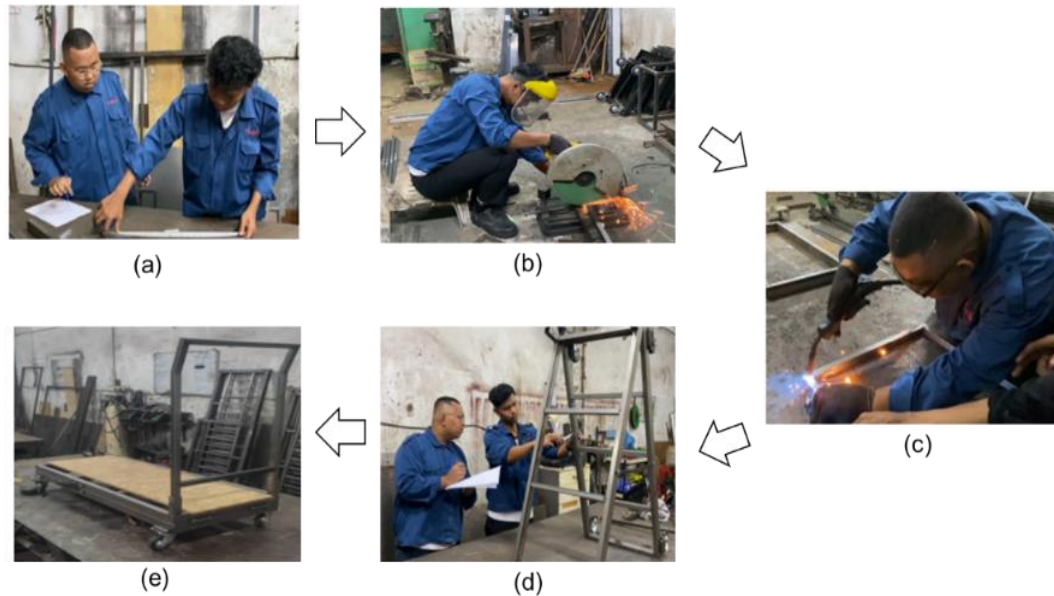


Figure 5:(a) Measurement process, (b) Cutting process, (c) Welding process, (d) checking product after assembly, (e) Finishing process

The study includes two tests: a workability test for the trolley and a stability test for the ladder. A sample of 19 respondents participated in this study, which focused on bricklaying students and construction workers. Ten of the respondents were construction workers, and nine were students who only utilized ladders for minor repairs.

The responders' capacity to carry a certain amount of building materials is evaluated to determine how feasible the trolley is. The building materials required to conduct the workability test are the cement bags, bricks, and tools. In order to acquire data for stability, respondents had to climb a ladder to complete simple activities. This is due to the fact that the respondent's body weight, which is based on the maximum load the ladder can support, dictates how stable the ladder are (Susanto et al.2022).

In order to compare the workability of innovative products with manual methods and existing equipment to carry construction materials, data comparisons will be made and recorded and translated in graphs. While for the stair stability test, the respondent's body weight will be recorded in percentage.

3.0 Results and Discussion

The study was conducted at brickwork workshop and construction site.

3.1 To Design the Versa Trolley

In this study, it was found that the trolley was successfully produced by the researcher according to the specifications and materials used. The ability of the trolley to be 2 functions, namely a trolley and a ladder for various uses, was also successfully proven through the pictures shown in Figure 6(a) and 6(b). The measurement details for the trolley and ladder are shown in Figure 7(a) and 7(b).

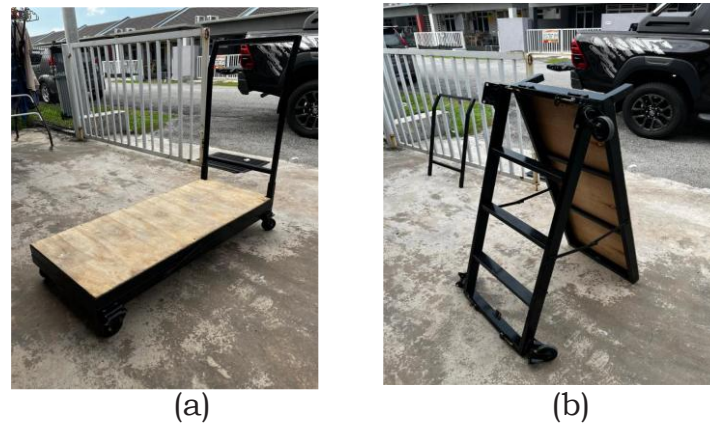


Figure 6:(a) Detailed Design for Trolley, (b) ladder

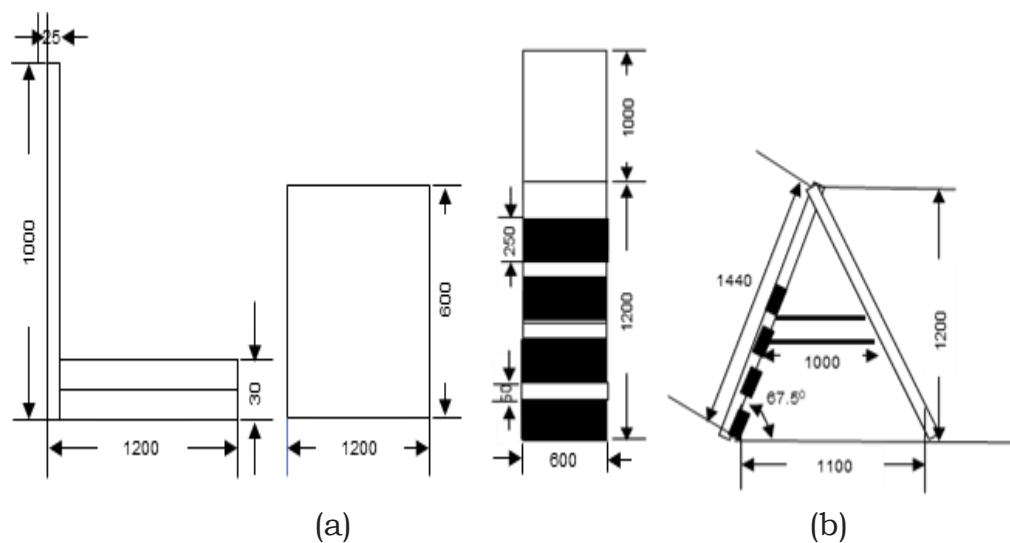


Figure 7:(a) Dimension view of the Trolley, (b) Ladder

The productivity of construction equipment has a significant impact on the industry's total productivity as well as the time and cost needed for a given construction project (Chandra et al., (2023). Thus, the utilization of a multifunction of equipment might contribute to a certain level of increased construction job productivity.

3.2 To Obtain the Maximum Loads That Can Be Carried by The Versa Trolley

For workability test, two methods that workers frequently use to carry building materials were employed in this study to compare the amount of load that the Versa Trolley can carry. Figure 8 shows a graph comparing the greatest amount of material that can be lifted using three distinct methods namely the Versa Trolley, wheelbarrow and manual handling. Bags of cement, bricks, and tools were used to test all three approaches.

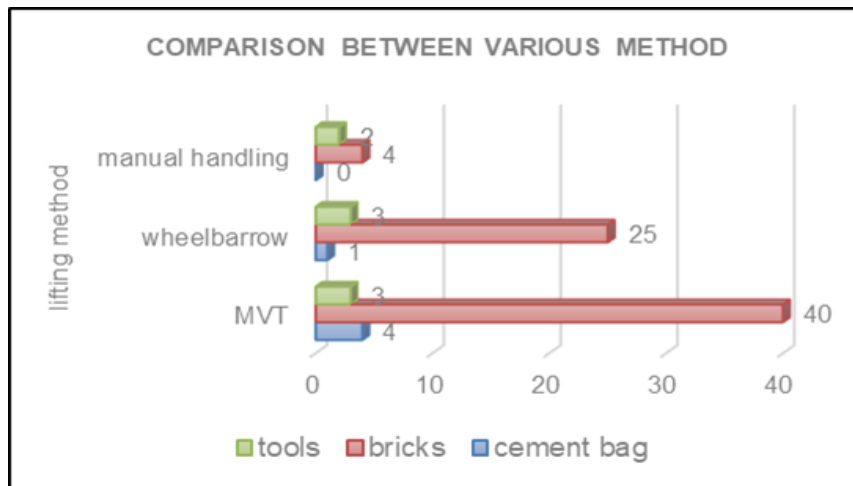


Figure 8: Comparing different approaches to lifting construction materials

The Versa Trolley can handle an average of four cement bags, which is significantly more than the wheelbarrow's one-bag capacity, while the manual handling method is not able to lift cement bags at all. Meanwhile, an average of 40 bricks can be carried by Versa Trolley compared to wheelbarrows which can only lift 25 bricks. However, manual handling can only lift 4 bricks. This notable distinction demonstrates how effective Versa Trolley in transporting bricks in large quantities. Finally, for tools, the Versa Trolley also performed best with an average of 5 units of tools such as a hoe, grinder, poker vibrator, concrete mixer and iron cutting tool compared to the wheelbarrow which could only lift 3 units of tools and the manual handling which lifted 2 units of tools.

In general, the Versa Trolley outperforms wheelbarrows and manual handling when it comes to lifting different kinds of construction materials. Compared to more conventional modes of transportation like wheelbarrows or manual handling, the Versa Trolley can boost labor productivity and lower the risk of harm by carrying heavier and more stable loads.

According to studies by Nimbarte (2014) and Peolsson (2013), manual material handling tasks pose a high risk of injury, particularly due to cervical spine extension movements performed within the lifting range around elbow height. These movements require up to 50% of muscle strength, resulting in significant muscular strain in the posterior neck region. Therefore, the introduction of this trolley innovation facilitates the lifting of bulk construction materials to the desired height, enabling faster and safer lifting operations while minimizing physical strain and the risk of musculoskeletal disorders. Figure 9(a) shows the workability test in brickwork workshop and (b) workability test at construction site



Figure 9:(a) Workability test in brickwork workshop, (b) Workability test at construction site

For stability test, Malaysian Standard MS 1009:1986, which has since been withdrawn, does not specify the standards for ladder stability testing; rather, it only outlines the specifications for portable aluminum ladders intended for single-person use (Standard Malaysia, 1986). Based on the 67.6 degrees opening of the ladder with only 4 steps, it can still be considered balanced for light use. However, according to the principle of equilibrium, if the purpose of the ladder is for high or heavy work, this angle is not suitable and needs to be redesigned to the optimal inclination of 75 degrees (Ghorashi & Ghorashi, 2019). Figure 10(a) shows the stability test in brickwork workshop and (b) stability test at construction site.

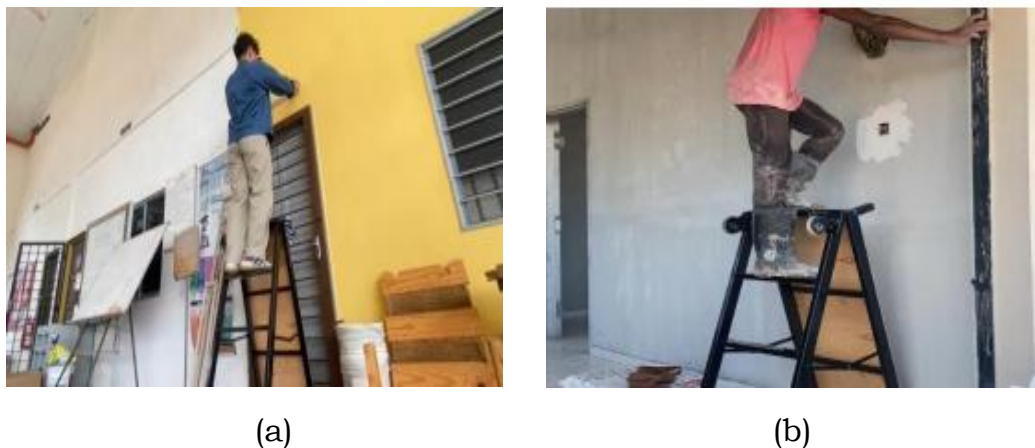


Figure 10:(a) Stability test in brickwork workshop, (b) Stability test at construction site

According to Table 1, the study's respondents fall into a range of body weight categories, from under 40 kg to over 90 kg. This demonstrates how well the Versa Trolley supports a range of body weight categories, from low body weight respondents (less than 40 kg) to heavy body weight respondents (more than 90 kg).

Table 1: Body weight of respondents

Body weight	Number of users
<40	0
41-50	2
51-60	1
61-70	4
71-80	6
81-90	1
>90	5

The ability of Versa Trolley's support the various categories of body weight of users demonstrates that the design and structure of this product is safe and suitable for use in real work conditions.

4.0 Conclusion

This study shows that Versa Trolley is able to increase the efficiency of lifting construction materials and reduce the risk of injury among workers. The stated objective of the study, which is to design Versa Trolley and to obtain the maximum loads can be carried by the Versa Trolley, has been achieved. By using Versa Trolley, manual lifting of construction material can be avoided and will indirectly increase work productivity. This product needs to be improved by using larger tire sizes because it is able to accommodate more loads. Meanwhile, modifications can also be made by using a hydraulic system to allow the construction materials being carried to be lifted up without the need for workers to bend over to pick up the construction materials that are inside the Versa Trolley.

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Author Contributions

E.M. Mazlan: Conceptualisation, Methodology, Writing; **M.Q. Zainal, M.N.M.M. Johari, M.S. Samsul:** Original draft Preparation, Data Collection, **N.A. Abdul Rahman;** Validation, Reviewing; **H. Ab Karim;** Editing.

Conflicts of Interest

The manuscript has not been published elsewhere and is not under consideration by other journals. All authors have approved the review, agree with its Submission and declare no conflict of interest in the manuscript.

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