

DEVELOPMENT OF RICE BUCKET TROLLEY WITH TRI-WHEEL STAIR CLIMBING

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ABSTRACT

The design and development of a rice bucket trolley with tri-wheel stair climbing aims to enhance the efficiency and ease of transporting rice buckets within a café setting. This project originates from the observation of workers manually moving rice buckets without dedicated transportation methods, leading to concerns about potential injuries and inefficiencies. The trolley's design incorporates features such as a handle, castor wheels, and tri-wheel stair climbing to improve functionality and maneuverability. Through extensive research and iterative design processes such as the House of Quality, Product Design Specification, Concept Design, and Concept Evaluation, the trolley's specifications were refined to meet the specific needs of café workers. Additionally, the fabrication process involved selecting suitable materials, estimating costs, and implementing safety measures. The final product addresses concerns related to worker safety and ease of use. Overall, the design and development of the rice bucket trolley with tri-wheel stair climbing represents a practical solution to streamline operations and promote a safer working environment in café settings.

Keywords: rice bucket trolley, tri-wheel stair climbing, design, fabrication, concept generation, concept evaluation

1.0 INTRODUCTION

The rice bucket trolley with tri-wheel stair climbing represents an evolution from traditional rice bucket stands to a more versatile trolley capable of navigating across various floor levels effortlessly. The utilization of tri-wheel stair climbing has become increasingly common, particularly in scenarios requiring the movement of loads across different floor levels. Research into the application of tri-wheel stair climbing extends across diverse fields, including robotics, medical devices, and everyday utility, reflecting its broad relevance and potential for enhancing mobility and efficiency. Kilari, Snehta, et al. [1], have developed and constructed a tri-wheel staircase-climbing hand trolley specifically designed to transport heavy loads over stairs. This trolley incorporates an enhanced wheel arrangement, resulting in reduced human effort and manufacturing costs compared to conventional models. Ahmad Bhat, Zubair, et al. [2], have developed a stair-climbing trolley equipped with an automated anti-slippage mechanism. Their design features a four-arm wheel mechanism incorporating braking pins that prevent the independent movement of wheels during stair ascent. Rohith R., et al. [3], have undertaken the design and development of a stair-climbing trolley specifically tailored for lifting 20-liter water cans. The trolley is constructed with a tri-star frame wheel system, enabling the transportation of loads up and down stairs with ease. In robotic field, Kim, Younghwan, et al. [4], have proposed a mobile robot platform that represents an enhanced iteration of LEVO. The LEVO employs both regular wheels and a curved spoke tri-wheel (CSTW) system to navigate flat terrain and ascend stairs. Lee, Yunhyuk, et al. [5], conducted an analysis to investigate the correlation between shape and trajectory, utilizing four shape elements of the Curved Tri-Wheel as design variables. Their study aimed to identify an optimized shape that facilitates more stable climbing of three different stairs by the Curved Tri-Wheel.

In the field of medical devices, Cho, Youngsu, et al. [6], have developed a stair-climbing electric wheelchair equipped with tri-spoke wheels and supporting legs to improve the convenience of electric wheelchairs.

The design and development of a rice bucket trolley with tri-wheel stair climbing represents an innovative approach to addressing the challenges faced by workers at the café of UiTM Bukit Besi when transporting rice buckets. In many establishments, manual handling of heavy rice buckets without dedicated transportation methods often leads to inefficiencies and safety concerns. The introduction of a purpose-built trolley aims to enhance operational efficiency, promote workplace safety, and improve overall productivity within the café environment.

The objectives of this project are to design and fabricate a rice bucket trolley equipped with tri-wheel stair climbing for use by workers at the café of UiTM Bukit Besi. The concept behind this trolley is to enable horizontal movement (left and right) with ease, while also incorporating tri-wheel stair climbing to facilitate navigation across different floor heights. However, there are certain limitations encountered during the completion of this project. Firstly, material limitations arise as the materials used are dependent on what is available in our workshop. Secondly, there are constraints related to the manufacturing processes available in our workshop.

2.0 RESEARCH METHODOLOGY

Figure 1 shows the flowchart of the process of making a rice bucket trolley with tri-wheel stair climbing. The project starts with the House of Quality, which is a quality management tool used in the field of product development. Secondly, the product design specification, where several factors in making a rice bucket trolley with tri-wheel stair climbing are considered, such as target market, purpose, maintenance requirement, product life span, quality control, etc. Next, the concept generation for the product is accomplished through the utilization of the morphological table. This table will document all sketch ideas corresponding to each function. For each part of the product, three design concepts are generated, each employing distinct options, and their respective advantages and disadvantages will be outlined. The project proceeded to concept evaluation, which is conducted to determine the best concept for this trolley using the Pugh Chart. Cost estimation will be calculated to determine the total cost. The subsequent step involves converting the best design concept into CAD design through Solidworks software. Details drawing for each part, as well as assembly and exploded assembly drawings with their respective dimensions, are created. The fabrication procedure encompasses cutting raw materials, machining, welding, and finishing the rice bucket trolley with tri-wheel stair climbing. Safety precautions must be adhered to throughout the fabrication process in the workshop. Several factors must be taken into account in this project due to the limited raw materials provided by the organization. Depending on the dimensions, the materials may need to be purchased from a hardware store or constructed on-site. Finally, the prototype product will undergo a product testing procedure to verify its functionality. In the event of any malfunction, a root cause analysis will be conducted, followed by the repetition of the fabrication process.

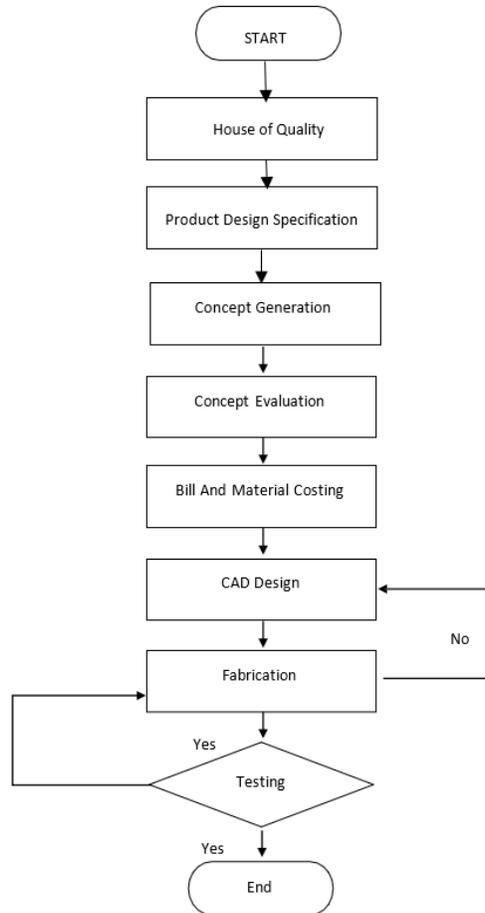


Figure 1: Flowchart of the process of making a rice bucket trolley with tri-wheel stair climbing.

3.0 RESULTS AND DISCUSSION

3.1 House of Quality (HOQ)

The House of Quality (HOQ) serves as a quality management tool utilized in product development, specifically within the design of new products or services. It commonly manifests as a matrix or diagram that aligns and correlates customer requirements (the desired aspects in a product or service) with the functional requirements or attributes necessary for meeting those customer needs. This tool aids in converting customer requirements into precise engineering or design characteristics.

Figure 2 displays the House of Quality for the rice bucket trolley with tri-wheel stair climbing. Eight customer requirements are listed for this product, including safety, latest design, product cost, movement, durability, size, ergonomic design, and weight. Seven functional requirements are also listed, such as installation, type of handle, wheel size, body frame size, type of wheel, handle size, and minimum maintenance requirement. From Figure 2, the type of wheel has the highest technical importance rating and relative weight, scoring 589.7 and 23%, respectively.

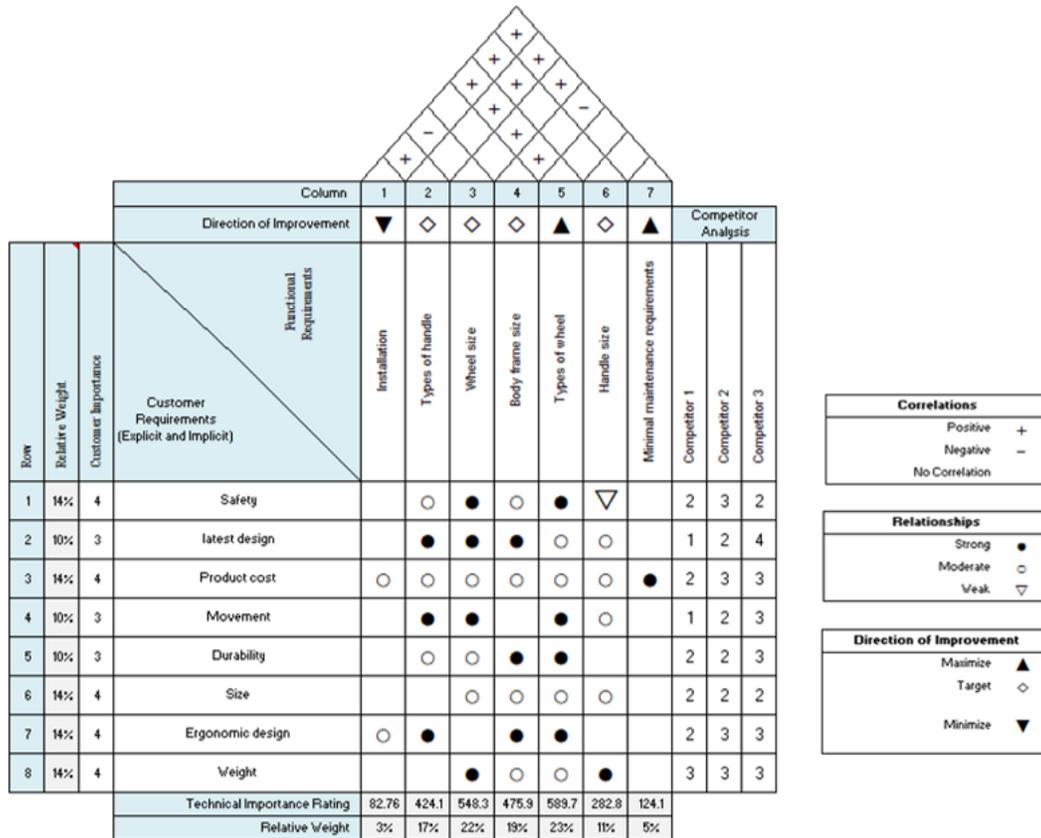


Figure 2: House of quality of rice bucket trolley with tri-wheel stair climbing

3.2 Product Design Specification (PDS)

The Product Design Specification (PDS) serves as a framework outlining the requirements for what the customer desires the product to accomplish. Table 1 displays the PDS for the rice bucket trolley with tri-wheel stair climbing, encompassing various factors including size, weight, material, pattern, etc.

Table 1: Product design specification of the rice bucket trolley with tri-wheel stair climbing

No.	Factors	Considerations	No.	Factors	Considerations
1.	Size	The product must not be too big and should be easy to store.	5.	Ergonomic and Safety	The product should have an ergonomic handle to prevent strain injuries for the user.
2.	Weight	The product should not be too heavy for female workers to use.	6.	Product Cost	The product will be affordable, and the production cost will be kept as minimal as possible.
3.	Material	The materials used should be anti-rust, either aluminum or stainless steel.	7.	Product Lifespan	The rice bucket trolley with tri-wheel stair climbing will be designed to last a lifetime and longer.

4.	Pattern	Standard rice bucket stands already exist in the market, but those with 3-wheel stair climbing are rare.	8.	Maintenance Requirement	The product should be easy to maintain, especially the wheels.
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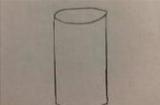
3.3 Concept Generation

A morphological table serves as a tool for concept generation, listing all sketch ideas for each function. Visual aids are employed to generate various ideas [7]. Table 2 presents the morphological table for concept generation concerning the rice bucket trolley with tri-wheel stair climbing. The main materials considered for this project are aluminum and stainless steel. Additionally, for the handle, three concepts are proposed: upright handle, pushcart handle, and no handle. Regarding the body shape, options include either cuboid or cylindrical shapes. Lastly, for the wheel, three concepts are considered: tri-wheel stair climbing, castor wheel, or no wheels. Based on this table, three design concepts are developed using different options. Table 3 displays Design Concept 1, Design Concept 2, and Design Concept 3, along with their respective advantages and disadvantages.

3.4 Concept Evaluation

The Pugh Chart is utilized to compare Design Concept 1, Design Concept 2, and Design Concept 3. Table 4 illustrates the Pugh Chart for the rice bucket trolley with tri-wheel stair climbing. Five criteria are considered to select the best design, which include durability, targeted product cost, weight and size, ergonomic design, and mobility. Each criterion is assigned a weight based on its importance, with a larger scale indicating greater importance. An existing product in the market is chosen as the datum and set at zero (0) scale. Then, all design concepts are compared to the datum and evaluated using a scale of [-, 0, +]. A scale of + indicates that the design concept is superior to the datum for that criterion, while 0 signifies equivalence, and - indicates inferiority. The total points for each design concept are calculated by multiplying the + and - points by their respective weights. Subsequently, the net score is calculated by subtracting the + points from the - points. The design with the highest net score is deemed the best design. According to the table, the third concept has been chosen because it has the highest net score which is three.

Table 2: Morphological table of concept generation for the rice bucket trolley with tri-wheel stair climbing

Sub function	Option solution		
	1	2	3
Main material	 Aluminium	 Stainless steel	
Handle	 Upright handle	 Pushcart handle	No handle
Body shape	 Cuboid	 Cylindrical	

Wheel	 Tri-wheel stair climbing	 Castor wheel	No wheel
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Table 3: Design concepts, and their advantages and disadvantages

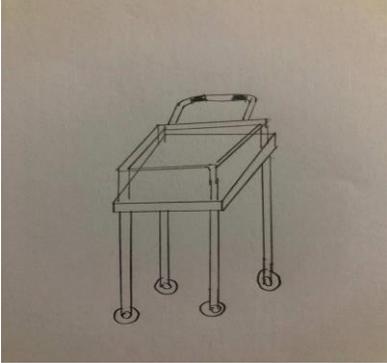
Design Concept 1: Stainless steel rice bucket trolley 1	Design Concept 2: Aluminium rice bucket trolley	Design Concept 3: Stainless steel rice bucket trolley 2
		
<p>Advantages:</p> <ol style="list-style-type: none"> Durability: As it is constructed from stainless steel, it offers a high level of durability. Outdoor Storage: The trolley can be stored outdoors without concern for damage. Horizontal Mobility: With castor wheels, it can move horizontally (left and right) with ease. <p>Disadvantages:</p> <ol style="list-style-type: none"> Limited Vertical Mobility: It struggles to navigate through varying floor heights easily. Weight: It is heavier compared to an aluminum trolley. 	<p>Advantages:</p> <ol style="list-style-type: none"> Lightweight: It is more lightweight compared to stainless steel materials. Horizontal Mobility: With castor wheels, it can move horizontally (left and right) with ease. <p>Disadvantages:</p> <ol style="list-style-type: none"> Costly: It tends to be more expensive. Handling Difficulty: The handle design can make it more challenging to control. Limited Vertical Mobility: It struggles to navigate through varying floor heights easily. 	<p>Advantages:</p> <ol style="list-style-type: none"> Durability: As it is constructed from stainless steel, it offers a high level of durability. Outdoor Storage: The trolley can be stored outdoors without concern for damage. Triwheel Stair Climbing: Equipped with tri-wheel stair climbing to facilitate navigation through different floor heights. <p>Disadvantages:</p> <ol style="list-style-type: none"> Weight: It is heavier compared to an aluminum trolley. Cost: It can be more expensive due to the advanced feature of tri-wheel stair climbing.

Table 4: Pugh Chart of the rice bucket trolley with tri-wheel stair climbing

Description		Design-concept			
					
Criteria	Weight	Datum	Design Concept 1	Design Concept 2	Design Concept 3
Durability	4	0	0	-	0
Target product cost	3	0	+	-	+
Weight and size	1	0	0	+	0
Ergonomic design	2	0	+	-	+
Mobility	2	0	-	-	+
+		0	2	1	3
-		0	1	4	0
0		5	2	0	2
Net score		0	1	-3	3

3.5 CAD Design using Solidworks

The Solidworks 2020 Edition software is employed to create the drawing of the rice bucket trolley with tri-wheel stair climbing. This trolley comprises several parts, including the Handle of The Trolley, Body Support Part, Leg of The Trolley, Platform of Trolley, Tri-wheel Stair Climbing, Castor Wheel, and Stainless-Steel Shaft. Figure 3 illustrates an assembly drawing of the rice bucket trolley with tri-wheel stair climbing.



Figure 3: An assembly drawing of rice bucket trolley with tri-wheel stair climbing

3.6 Material Selection

List of material and its quantity that needs to be used for this project are shown in table 5.

Table 5: List of material and its quantity for the rice bucket trolley with tri-wheel stair climbing

No	Material	Function	Quantity
1.	Circular Hollow Mild Steel	Use as handle of the trolley	2
2.	Rice Bucket Stand	Use as main part of the product	1
3.	Castor Wheel	Used to help the trolley moved to left and right	2
4.	Stainless Steel Shaft	Used to connect the tri-wheel stair climbing	1
5.	Tri-wheel Stair Climbing	Used to help the trolley move pass through different level of floor	2

3.7 Cost Estimation

The cost estimation for producing this rice bucket trolley with tri-wheel stair climbing is presented in Table 6. Certain parts are readily available at the workshop, while others must be procured from a hardware store. The circular hollow mild steel is utilized to construct the handle of the trolley, and as it is available at the UiTM Bukit Besi workshop, there is no associated cost for this material. According to the table, the estimated cost for this project amounts to RM117.60.

Table 6: Cost estimation to make the rice bucket trolley with tri-wheel stair climbing

No	Material	Description/Quantity	Cost	Source
1.	Rice Bucket Stand	1	RM80.30	Shopee
2.	Castor Wheel	2	RM4.90	Shopee
3.	Tri-wheel Stair climbing	2	RM22.00	Shopee
4.	Stainless Steel Shaft	1	RM5.50	Shopee
Total			RM117.60	

3.8 Fabrication

For the fabrication of the rice bucket trolley with tri-wheel stair climbing, it was fabricated in the welding workshop at UiTM Bukit Besi, Terengganu. The fabrication processes involved in completing this project included drilling, cutting, grinding, and welding. The fabrication process took approximately 2 weeks to complete. Several safety measures were implemented during fabrication, including the use of equipment such as adjustable welding helmets, clear safety face shields, pairs of gloves, and pairs of welding gloves to ensure safety.



Figure 4(a): Drilling process



Figure 4(b): Cutting process



Figure 4(c): Grinding process



Figure 4(d): Welding process



Figure 4(e): Final product

Figure 4(a) illustrates the drilling process conducted with a bench drilling machine. The purpose of this process is to create holes for inserting the stainless-steel shaft to connect the two tri-wheel stair climbing components. In Figure 4(b), the cutting process is depicted using a rotary handheld cutting machine. This process involves cutting the materials intended for use in constructing the handle of the trolley. Figure 4(c) portrays the grinding process, which is carried out subsequent to the cutting process to eliminate excess material from the surface of the workpiece. Figure 4(d) demonstrates the welding process utilizing an MIG welding machine. This process involves assembling the handle and castor wheels onto the rice bucket stand. Finally, Figure 4(e) displays the completed rice bucket trolley with tri-wheel stair climbing, representing the final product.

3.9 Product Testing

During product testing, various workers from the UiTM Bukit Besi café utilized the rice bucket trolley with tri-wheel stair climbing to assess its functionality. Testing revealed that the trolley could effectively maneuver to the left and right as intended. Furthermore, it successfully navigated through different floor levels at the café, demonstrating its versatility. The tri-wheel stair climbing feature facilitated the trolley's movement through varying floor levels, while the handle was designed to aid in navigation from one location to another and minimize the force required to maneuver the trolley. Similarly, the castor wheel was designed to assist in movement, although with a different function compared to the tri-wheel stair climbing feature. Specifically, the castor wheel enabled easy lateral movement of the trolley to the left and right.

During the testing process, a single issue or weakness of the trolley was identified, along with proposed ideas on how to address this issue for future improvements. Table 7 describes the identified problem or weakness of the rice bucket trolley with tri-wheel stair climbing and offers suggestions on how to overcome it.

Table 7: Problems or weakness of the rice bucket trolley with tri-wheel stair climbing and its solution

No.	Main Problem	Solution
1	The trolley shifts from its place when the trolley is in an uneven area.	Used castor wheels that have a brake system so that the trolley did not easily shift.

4.0 CONCLUSION AND RECOMMENDATION

In summary, the rice bucket trolley with tri-wheel stair climbing has been successfully designed and fabricated. This trolley serves to aid workers at café UiTM Bukit Besi in effortlessly transporting rice buckets from the back area to the dining area, thus saving them time and energy in their daily tasks. Additionally, the inclusion of tri-wheel stair climbing facilitates easy navigation of the trolley through various floor levels. Despite encountering material limitations, the primary goal was achieved. However, there remains room for enhancement to ensure greater functionality and effectiveness. Suggestions for improvement include the development of a foldable rice bucket trolley with tri-wheel stair climbing for convenient storage.

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