

DESIGN AND FABRICATION OF FOLDABLE STORAGE RACK

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ABSTRACT

A storage rack can assist a range of human activities in daily life. The purpose of a rack is to conserve space by storing goods and items upright for short or lengthy periods. The issue constantly encountered is that storage racks consume an excessive amount of space. While the rack is not used, this will be a major problem for individuals, particularly those who live in homes or crowded places. Therefore, this study is focused on designing the foldable storage rack to overcome these problems. This rack will be equipped with a folding technology that will allow for significant space savings, particularly in tiny spaces. There are several stages involved in producing foldable storage racks, which are concept generation and evaluation, CAD design, fabrication, and testing. This storage rack can withstand 10 kg of load on each of its racks and is easily moveable other than its foldable function. In conclusion, by using this storage rack, one can save more space for storage.

Keywords: foldable rack, storage rack, design

1. INTRODUCTION

During the industrial revolution, cities attracted many people. This led to the growth of apartment living and living in small spaces. Cities' swamped population forced the majority to live in small, cramped quarters. Nonetheless, cities continue to be dominated by apartments and vertical living. Thus, foldable furniture would be an efficient and necessary method of conserving space while still providing people with requirements and enhancing their lives in a compact space.

The study of foldable furniture art begins with the introduction of folding furniture into people's life and the efficient role they play from the first collapsible piece of furniture to today's exceptionally clever ergonomic solutions for space saving. Additionally, this research intends to demonstrate a variety of different types of foldable furniture that are suitable for a variety of different locations, areas, and purposes.

Although the precedents for the evolution of folding for furniture are not easily discernible, there are some revolutionary examples that can be identified as key influences. Furniture designers were forced to develop practical design solutions in response to the pressing necessity for space reduction. One approach designer came up with to save space, initially without the use of mechanisms, was to create furniture that could stack on top of one another. By 1963, Robin Day had created the world's most famous stacking chair for a firm called S. Hille & Co. It was manufactured using polypropylene through the injection moulding process, hence its popular name "polyprop" [1].

In recent work, focus on Computer-Aided Design (CAD) developed by SolidWorks as a tool to visualize the outcomes of the intended product before continuing with the product fabrication. However, to complete the design projects well, the generation process and concept selection are required as it will affect the cost, quality, and performance of the final product. For the concept generation process, the Morphological Method is used. This method applies the following process in generating feasible concepts, which, breaking down a problem into sub-functions, generating an option solution for each sub-function, and selecting and combining the suitable option solution into an alternative concept solution. This method is advantageous in terms of generating novel concepts and able to represent a wide range of concepts which allows the unexpected matching of components to be considered [2].

Concept selection is the method used to determine the most suitable concept that follows all the specifications given in the decision-making criteria before proceed to the design stage process that allows a reduction to cost and time implication [3][4]. According to Augustine et al. [5], the right selection of design concepts will eliminate the cost of redesign of the final product and escalate the productivity in the project development process. This researcher has listed the possibility of multicriteria decisions to aid concept selection namely as Quality Function Deployment (QFD), Analytic Hierarchy Process (AHP), Pugh Matrix, multi-criteria optimization, and fuzzy logic methods. In this paper, Pugh Matrix or also known as Pugh Chart is selected as a systematic approach in selecting the best design from the three proposed design concepts.

Individuals who live in a tiny and crowded house sometimes find it difficult to manage their place due to furniture and huge things such as dining tables, refrigerators, televisions, and sofas. As a result, they must provide more storage space to ensure that the storage stuff is always nice and orderly to make their daily lives more comfortable. They can utilize miniature foldable storage racks to organize essential household things. This folding rack is not particularly large. Additionally, when the storage rack is not in use, the folding system's capabilities can provide additional storage space.

This design of foldable storage rack could help to save space and easy reinstallation without a need to disassemble the rack completely.

2. RESEARCH METHODOLOGY

The flowchart of the fabrication process of foldable storage rack is shown in Figure 1. It started with concept generation and evaluation (morphological chart and Pugh chart), CAD design using SolidWork, materials selection, fabrication of the product, and testing.

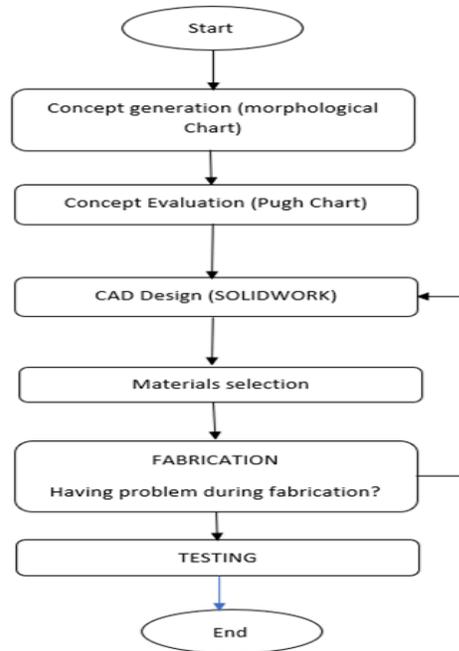


Figure 1: Flowchart of the fabrication process of foldable storage rack

First, the process started with the concept generation of the product by using the morphological table. It is based on function analysis. This table will list down all the sketch ideas for each function. According to the function of each part of the product, it is then selected to come out into several design concepts using a different option. There are at least three combination concepts that will be produced during this stage. Evaluation. All criteria are having a weightage to get the score for each design concept. Design concepts with the highest score will be selected.

The selected concept is then being created in a 3D design by using a Computer-Aided Design (CAD) software, Solidworks 2019 x64 Edition. This software can produce a detailed drawing of each part as well as the assembly drawing of a product with a specific dimension. With that, the blueprint of the product will be then produced and endorsed by the supervisor before entering the workshop, to proceed with the fabrication process.

The fabrication process includes cutting the raw materials, machining process, joining process either permanently or temporarily joined, and finishing process which is required for the aesthetic value and safety purpose. Therefore, by referring to the blueprint, the fabrication process will be managed properly as the detail dimension already stated, and the preparation of material will be easier, and the number of waste materials also can be reduced. Lastly, the prototype product will undergo the product testing process to make sure that the product is safe for the users.

3. RESULT AND DISCUSSION

3.1 Concept Generation

Product concept generation is a process that starts with a list of parameters based on customer's needs and specifications. Based on the requirements, concept generation helps to pinpoint a variety of possible solutions and ideas that answers those needs. A morphological table is a table based on the function analysis. Based on the requirements, concept generation helps to pinpoint a variety of possible solutions and ideas that answers those needs. A morphological table is a table based on the function analysis. On the left side of the table, the sub-functions are listed, while on the right side, different types which can be used to perform the functions listed are drawn. It is a visual aid used to come up with different ideas. The morphological table is used in concept generation and Figure 2 shows the morphological table of concept generation for foldable rack. Based on the table, there are five sub-functions listed in our product design, foldable rack. The six sub-functions are considered such as rack frame, rack board, storage, rack support, and wheel. There are three options for each sub-function. For example, two types of wheels are considered in our design which are ties and footpads.

Sub function	Option 1	Option 2	Option 3
Rack frame			
Rack board			
Storage			
Rack support			
Wheel	 8 tires	 4 footpads	 4 tires

Figure 2 : Morphological table of concept generation for foldable storage rack

Three different design concepts have been designed using different option solutions provided in Figure 2, to produce the three best designs. Figure 3a shows the design concept 1. In this design concept, the storage rack has four layers, providing plenty of space for consumers to store their belongings. This storage rack has eight tires, allowing the consumer to easily move the product. Hinges are placed in the middle of both sides of this storage rack so that users can fold and store it neatly when not in use. Figure 3b shows the design concept 2. In this design concept, all parts are tightly connected with each other and

become an inseparable whole part, which makes the steel furniture much more stable and durable, and it is rarely deformed. Figure 3c shows the design concept 3. This storage rack has frame support to increase the stability and strength. The storage rack has three layers, providing lots of space for customers to store their belongings. This storage rack has four tires, allowing the consumer to easily move the product. Hinges are placed in the middle of both sides of this storage rack so that users can fold and store it neatly when not in use. In addition, the foldable system in this rack is supported by triple stand support.

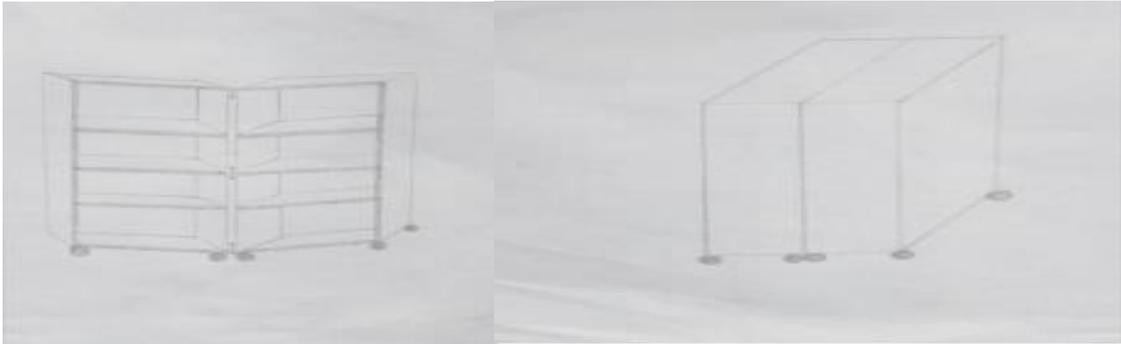


Figure 3a: Design concept 1

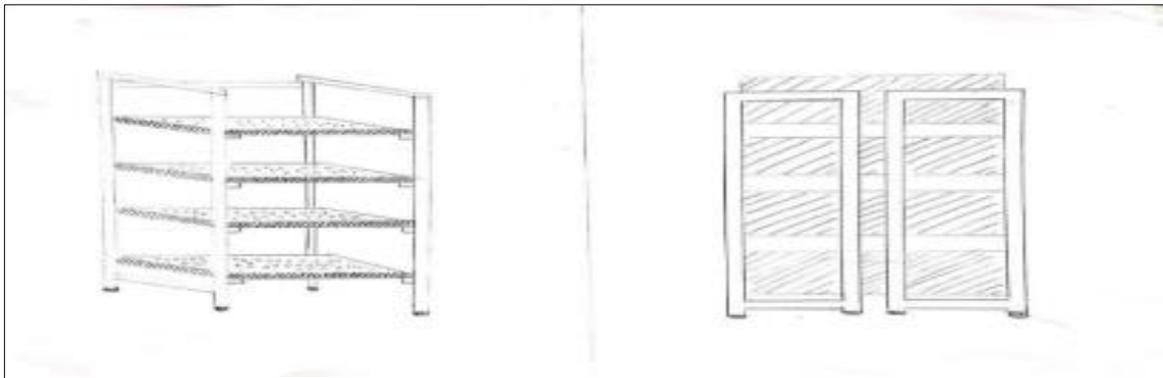


Figure 3b: Design concept 2

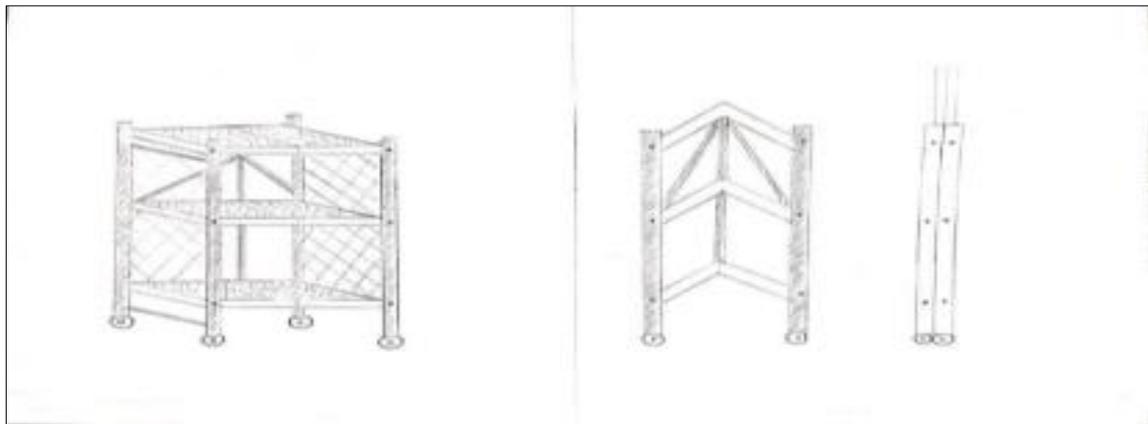


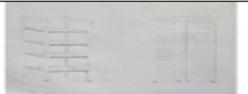
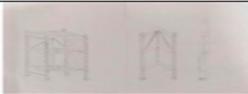
Figure 3c: Design concept 3

3.2 Concept Evaluation

A Pugh chart is a tool used for evaluating multiple options against each other and to consider the pros and cons of each design concept relative to design criteria. The Pugh Chart is used to compare the design concepts 1, 2, and 3. Table 1 which are durable, space saving, affordable, easy to use, weight, safety, and adjustable, aesthetics, and movability. Each criterion is given weightage according to how important it is. We use a scale of 1 to 3 where the larger scale indicates that the criteria are more important. Design 1 is chosen as a datum and set zero (0) scale. Then, each design is compared to the datum and evaluated using a scale [-, 0, +]. The total points for each design concept are calculated by multiplying the +'s and 's by their weights. Subsequently, the net score is calculated by subtracting the + points to - points. The design with the highest number is the best.

Based on Table 1, the best design concept selected is Design 3 with a total 14 net score. The most important criteria that have been observed before selecting the best design is how the design helps save space and is movable without compromising its function. Design 3 has fulfilled these most important criteria like easy to use, adjustable, and portable.

Table 1: Pugh chart of foldable storage rack

Description		Design concept		
				
Criteria	Weightage	Design 1	Design 2 (Datum)	Design 3
Durable	3	-	0	+
Save space	2	+	0	+
Affordable	2	+	0	+
Easy to use	2	+	0	+
Weight	2	-	0	-
Safety	3	-	0	+
Adjustment	2	+	0	0
Aesthetic	2	0	0	+
Movable	2	+	0	+
	+	10	0	16
	0	2	20	2
	-	8	0	2
	Net worth	2	0	14

Scale Indicator:

[+] = greater than datum

[0] = as per datum

[-] = lesser than datum

3.3 Detail Design

Solidworks 2019 x64 Edition software is used to draw the kayak carrier. Figure 4 shows the assembly drawing of the foldable rack. The overall dimension of this kayak carrier is 640 x 360 x 875 mm (LxWxH).



Figure 4: An assembly drawing of foldable storage rack

3.4 Fabrication

The process of fabrication includes preparing material and components, measuring raw material, cutting the raw material, grinding process, drilling, welding process, polishing and assembly of the material until the foldable rack is completed. Figure 5 shows the fabrication process to produce the foldable rack.

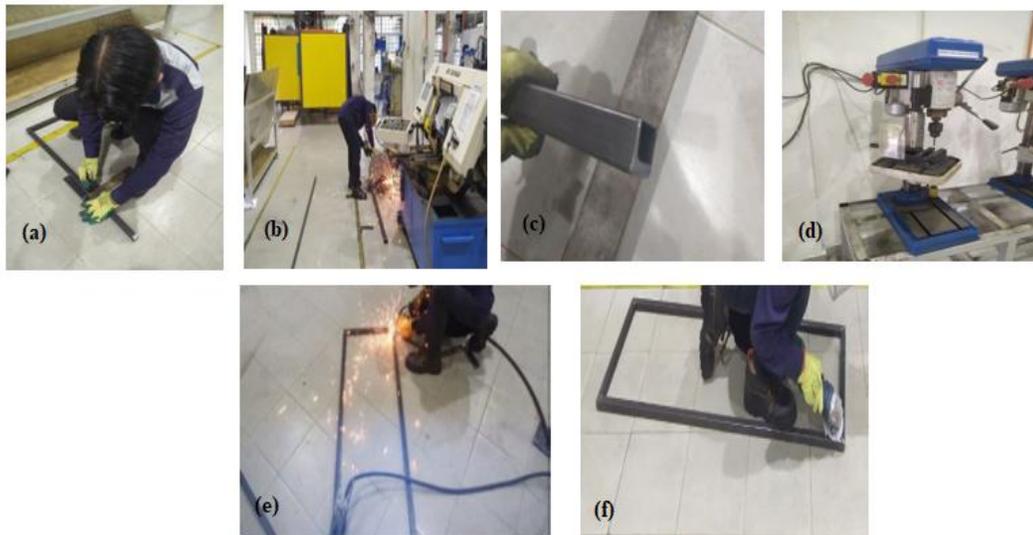


Figure 5: Fabrication process to produce foldable storage rack. (a) measuring raw materials, (b) cutting raw materials, (c) grinding process, (d) drilling process, (e) welding process, (f) polishing process.

3.5 Testing

After finishing the fabrication and assembly process, the foldable rack is tested to fold and withstand weight. Figure 6 shows the picture of a foldable rack with 10kg weight on each layer of its racks and its movability.



Figure 6: Foldable storage rack

From the test run, several issues that can be improved, first, the design could use the bigger size of mild steel square hollow for the main frame body to improve the strength and be able to accommodate heavier load. Second, to Make sure the rack board has holes to avoid stagnant water on the rack, that will give a bad impact to consumer items such as causing the item to rust and improving on design, so the rack does not need to reinstall back support every time it needs to be assembled.

4. CONCLUSION AND RECOMMENDATION

The design of the foldable rack was completed as per the planned design. Fabrication processes were carried out accordingly. Then, the product has undergone testing to ensure all the safety aspects and the objectives of this project were achieved. Based on that, it is concluded with this foldable rack, can withstand 10 kg load on each of its rack and can be folded and moved easily. For the next project, it is proposed to design the rack without reinstallation of rack support.

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