DEVELOPMENT OF MOVABLE LADDER

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ABSTRACT

A ladder is a device that consists of various steps to go up and down to do any activity. Users need to focus on the safety aspects when using the ladder so that no incidents occur and more importantly to avoid incidents that can be fatal. A ladder is frequently used by technicians in Bukit Besi campus to do their tasks every day. There are some problems with the existing ladder. It is quite difficult if the worker tries to deflect the ladder by being on it. Instead, workers must go down and lift the ladder to the next position. This will cause them to take a long time to complete the work. Thus, we propose to design and fabricate a movable ladder that can move horizontally, left, and right, at a predetermined distance. The whole project involved various methods like product design specification, concept design, concept evaluation, CAD design followed by fabrication and testing. Testing was carried out to make sure that the product is functional and achieved the targeted objectives successfully.

Keywords: movable ladder, design, fabrication, concept generation, concept evaluation

1.0 INTRODUCTION

In general, with the passage of time, various types of ladders have been developed to suit various uses and purposes in daily tasks. Rigid ladders come in two types, self-supporting ladders, and flexible ladders. Aluminum ladders are more in demand because they are multi-functional, lightweight, and anti-rust. An existing ladder cannot move horizontally and is too difficult to move from one location to another while maintaining its structure. Therefore, this project is the creation of a movable ladder that can move horizontally using a mechanical mechanism.

For this project, the concept of a movable ladder is based on how it can move horizontally, left, and right, at a predetermined distance. Other than that, there were many studies on movable ladders with different concepts. Srivastava et al. [1] have designed and fabricated a multipurpose, portable, compact, and foldable ladder that serves multiple purposes with various utilities such as a platform, orchard ladder, step ladder, and others. Nakum et al. [2] have designed and fabricated a compact foldable ladder which consists of hinge lock, pin, braces, rungs, slope, plate, caster, and frame.

Safety when using the ladder also needs to be emphasized. Injuries from slips, falls and overexertion during ladder climbing activities are common in both occupational and non-occupational environments. Task, equipment, and user parameters that may cause these injuries. Schnorenberg AJ et al. [3] in their study to determine the effects of hand placement on muscle activation onset and peak activity timing in response to slipping on a ladder, and to sequence the timing of events following slip initiation. Pliner et al. [4] have studied about effects of foot placement, hand positioning, age, and climbing biodynamics on ladder slip outcomes.

A ladder is frequently used by technicians in Bukit Besi campus to do their tasks every day. There are some problems with the existing ladder. It is quite difficult if the worker tries to deflect the ladder by being on it. Instead, workers must go down and lift the ladder to the next position. This will cause them to take a long time to complete the work. It also carries the risk of the user slipping off the ladder because of frequent ascending and descending.

The objectives of this project are to design a movable ladder and to fabricate the movable ladder to be used by technicians on Bukit Besi campus. The concept of this movable ladder is that can move horizontally, left, and right, at a predetermined distance. There are limitations during completing this project. The first is a material limitation because the materials used are based on what is available in our workshop. Second, limitations of manufacturing processes that are available in our workshop according to the trajectory of centrifugal motion and the size of the coin according to the trajectory of centrifugal motion and the size of the coin

2.0 RESEARCH METHODOLOGY

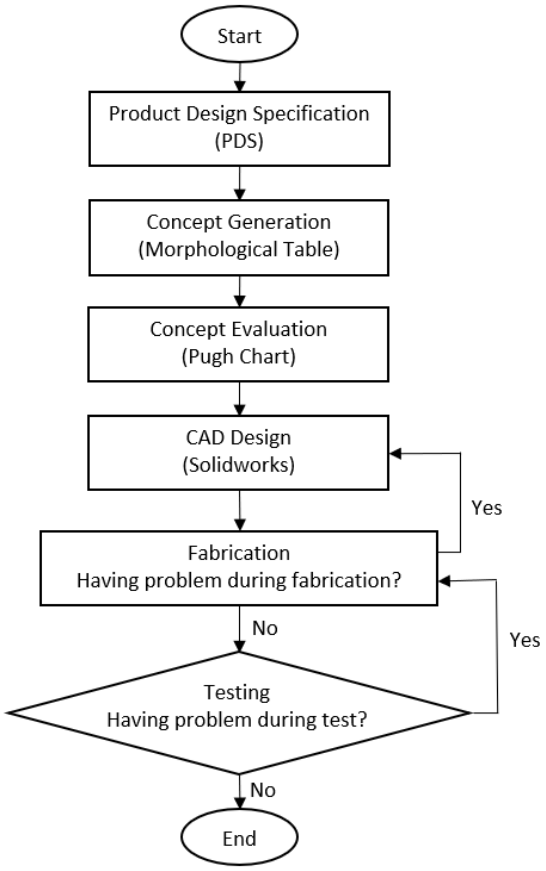


Figure 1: Flowchart of the process of making a movable ladder.

Figure 1 shows the flowchart of the process of making a movable ladder. The project starts with the Product Design Specification (PDS) where several factors in making a movable ladder are considered, such as performance, life expectancy, maintenance, size, weight, safety, etc. Secondly, the concept generation of the product is produced by using the morphological table. This table will list down all the sketch ideas for each function. According to the function of each part of the product, three design concepts are created using a different option and the advantages and disadvantages of the design concepts will be listed. There are several factors that need to be considered in this project because of the limited raw material provided by

the organization. It might be purchased from a hardware store or built depending on the dimensions. After that, the design concepts will be evaluated using Pugh Chart to select the best design. This process is called concept evaluation. All criteria are having a weightage to get the score for each design concept. The design concept with the highest score will be selected. The next process is to transform the best design concept into CAD design using Solidworks software. In this process, a detailed drawing with the dimensions for each part, assembly drawing and exploded assembly drawing are provided. The cost estimation will be calculated to determine the total cost.

The fabrication process includes the cutting of raw materials, the machining process, the welding process, and the finishing process is carried out to produce the movable ladder. Safety precautions need to follow during the fabrication process in the workshop. Lastly, the prototype product will go through a product testing procedure to ensure that it is functional. If the product does not work, the cause will be investigated, then the fabrication process will be repeated.

3.0 RESULTS AND DISCUSSION

3.1 Product Design Specification (PDS)

Product Design Specification (PDS) is used as an outline of the requirements for what the customer wants the product to achieve. Table 1 shows the PDS of the movable ladder where several factors are considered, such as performance, life expectancy, maintenance, size, weight, safety, etc.

Table 1: Product design specification of the movable ladder

No.	Factors	Considerations	No.	Factors	Considerations
1.	Performance	The product must strong enough to support the human weight.	6.	Material	The material used must be anti-rust.
2.	Environment	Each component should not be affected by the environment and weather.	7.	Safety	The design should provide safety features to the user.
3.	Life expectancy	The product should last long even though it has been used roughly.	8.	Quality and reliability	The material should be high quality.
4.	Maintenance	The product should not require frequent maintenance and should consist of replaceable components in case there are broken parts.	9.	Installation and operation	Each component of the product should be easily installed.
5.	Size and weight	The product must not be too heavy and too big.	10.	Aesthetics and finish	The design should appeal to the target audience.

3.2 Concept Generation

A morphological table is used in concept generation, where all the sketch ideas for each function are listed. A visual aid is used to come up with different ideas [5, 6]. Table 2 shows the morphological table of concept generation for the movable ladder. There are four sub-functions listed in our product design and three or fewer options for solutions for each sub-function. According to the table, three design concepts are created using different options. Table 3 shows Design Concept 1, Design Concept 2, and Design Concept 3, and their advantages and disadvantages.

Table 2: Morphological table of concept generation for the movable ladder

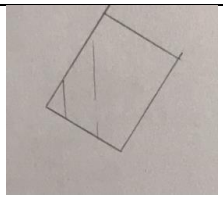
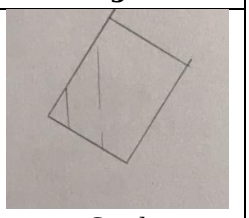
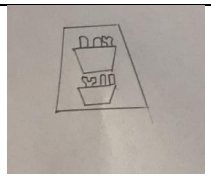
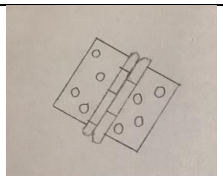
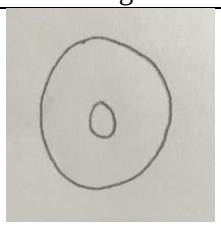
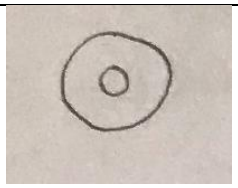
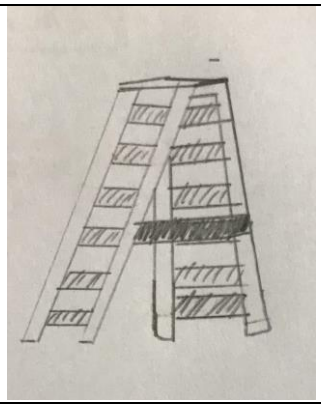
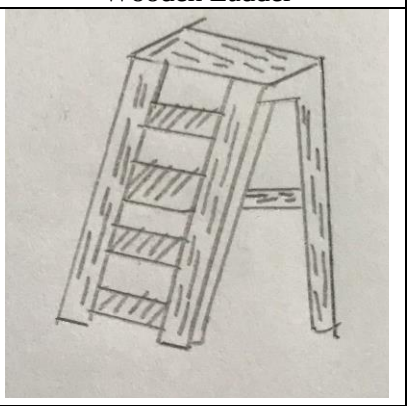
Sub function	**Option solution**		
	1	**2**	**3**
The main material	 Aluminium	 Wood	 Steel
Provide space for tools	 Tool pocket	No tool pocket	
To save space	 Hinge	No hinge	
Provide motion	 Big wheel	 Small wheel	No wheel

Table 3: Design concepts, and their advantages and disadvantages

Design Concept 1: Steel Ladder	**Design Concept 2:** Aluminium Moveable Ladder	**Design Concept 3:** Wooden Ladder
		
Advantages: 1. Durable because it is made from steel. 2. Can be stored outdoors without worrying about the ladder getting damaged. Disadvantages: 1. Cannot move horizontally (left and right) at a predetermined distance because it does not have wheels. 2. Susceptible to electric shocks and rapid temperature changes. 3. Heavier than an aluminium ladder.	Advantages: 1. Can move horizontally (left and right) at a predetermined distance because the design has wheels. 2. More lightweight. 3. Can move easily. Disadvantages: 1. Expensive. 2. Cannot be folded making it difficult to transport from one place to another.	Advantages: 1. Inexpensive. 2. Readily available. Disadvantages: 1. Cannot be folded because it does not have a hinge, not a space saver. 2. Cannot move horizontally (left and right) at a predetermined distance because it does not have wheels. 3. Cannot be exposed to the outside weather.

3.3 Concept Evaluation

Pugh Chart is used to compare Design Concept 1, Design Concept 2, and Design Concept 3. Table 4 shows the Pugh Chart of the movable ladder. Five criteria are considered to choose the best design which are durability, mobility, targeted product cost, safety, and size and weight. Each criterion is weighted according to its importance, where the larger the scale, the more important the criteria. Design Concept 1 is chosen as a datum and set zero (0) scale. Then, Design Concept 2 and Design Concept 3 are compared to the datum and evaluated using a scale [-, 0, +]. Scale + shows that the design concept is better than the datum for that criterion. If the scale is 0, the design concept is equivalent to the datum for that criterion. Whereas scale - shows the design concept is worse than the datum for that criterion. 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 of net scores is the best design. According to the table, the best design is Design Concept 2 with a total of 5 net scores.

Table 4: Pugh Chart of the movable ladder

Description		**Design Concept**		
				
Criteria	**Weight**	**Design Concept 1 (Datum)**	**Design Concept 2**	**Design Concept 3**
Durability	3	0	+	-
Mobility	3	0	+	-
Targeted product cost	2	0	-	+
Safety	2	0	0	+
Size and weight	1	0	+	-
+		0	7	4
0		11	2	0
-		0	2	7
Net Score		0	5	- 3

3.4 CAD Design using Solidworks

Solidworks 2013 x64 Edition software is used to draw the movable ladder. The movable ladder consists of the part of Brake Structure, Movement Paddle, Movement Platform, ladder, and wheels. Figure 2(a) shows the Brake Structure, where the function is to make the movable ladder move horizontally and function as a brake. Figure 2(b) shows the Movement Platform, where the function is to move the ladder when users step on the Movement Platform. Whereas the function of the Movement Platform is to move the movement paddle when users step on it as shown in Figure 2(c). Figure 2(d) shows an assembly drawing of the movable ladder.

Figure 2(a): Brake Structure

Figure 2(b): Movement Platform

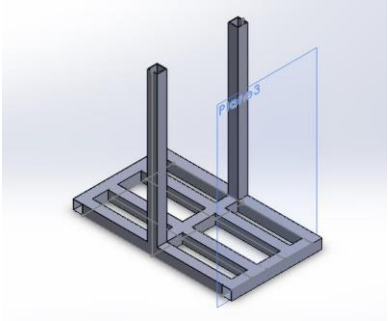


Figure 2(c): Drilling process

Figure 2(d): An assembly drawing of the movable ladder

3.5 Material Selection

List of material and its quantity that needs to be used for this project are shown in table 5. Those materials are ladder, hollow steel 1x1, wheels and hinge.

Table 5: List of material and its quantity for the movable ladder

No.	Material	Quantity
1	Ladder	1
2	Hollow Steel 1x1	19
3	Wheels	4
4	Hinge	1

3.6 Cost Estimation

The cost estimation to make this movable ladder is shown in table 6. Some parts are available at the workshop and some parts need to purchase at a hardware shop. The ladder used is a ladder taken from the home. Based on the table, the estimated cost for this project is RM25.90.

Table 6: Cost estimation to make the movable ladder

No.	Material	Quantity	Price (RM)	Source
1	Ladder	1	RM 0.00	Home
2	Hollow Steel 1x1	19	RM 0.00	UiTM Bukit Besi Workshop
3	Wheels	4	RM 5.80 x 4	Shopee
4	Hinge	1	RM 2.70	Mr. DIY
		TOTAL	RM 25.90	

3.7 Fabrication

For fabrication of the movable ladder, it was fabricated in the welding workshop in UiTM Bukit Besi, Terengganu. The processes involved in fabricating this project were the cutting process, welding process, and drilling process. It takes 2 weeks to finish fabricating this product.

Figure 3(a): Cutting process

Figure 3(b): Welding process

Figure 3(c): Drilling process

Figure 3(d): Assembly process

Figure 3(a) shows the first process of this fabrication is to cut the Hollow Steel 1x1 to get 19 units with different dimensions. Figure 3(b) shows the welding process using gas metal arc welding (GMAW) to join all the Hollow Steel 1x1 to make the Brake Structure, Movement Paddle, and Movement Platform. Figure 3(c) shows the drilling process to make holes for wheel installation. Figure 3(d) shows the finished product of the movable ladder after assembly process.

3.8 Product Testing

For product testing, several people from light weight to normal weight have used the movable ladder to test the function of the ladder. The movable ladder can move horizontally without having to get off the ladder when in use, and it works well. The ladder can also be moved from one place to another easily because it has wheels. In addition, there is a stopper on the wheel so that the wheel is in a static state when in use and to ensure the safety of the user. From the test, the main problems or weaknesses of the movable ladder have come out with some ideas on how to overcome the problems to be improved in the future. Table 7 shows the problems or weaknesses of the movable ladder and ways to overcome them.

Table 7: Problems or weaknesses of the movable ladder and ways to overcome them

No.	Main Problem	How to overcome
1	The movable ladder is heavy.	The ladder used is an aluminium type. However, the Brake Structure, Movement Paddle, and Movement Platform are fabricated using hollow steel because of the limitation of materials in the workshop. Therefore, the hollow steel used can be replaced with aluminium to reduce the total weight of the movable ladder.
2	Cannot be folded making it difficult to transport from one place to another.	Design a movable ladder that can be folded into a compact size and has a handle for easy hand carry.

4. CONCLUSION AND RECOMMENDATION

In conclusion, the movable ladder was designed and fabricated successfully. This movable ladder can help technicians on Bukit Besi campus to do their tasks every day. The goal was achieved despite material limitations. However, it still needs to be improved and more functional for better results. To improve the movable ladder, there are some recommendations such as making the ladder foldable, adding the tool pocket to help the workers put their tools when doing work, and adding one more function to make the ladder turn to the left and right.

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