Design and Fabrication of Kayak Carrier

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Abstract. Kayak has become the most popular outdoor activities among the community of UiTM Cawangan Terengganu, Kampus Bukit Besi. It is due to the location of this campus is situated near Tasik Puteri. During kayak activities, the users need to bring the kayak from campus to the lake. The distance from the storage area to the lake is about 800 m. A minimum of two persons is required to carry the kayak due to its size and weight. Where the average recreational kayak weighs 16kg for a single kayak and 27kg for a tandem kayak. Therefore, this study is focused on designing the kayak carrier to overcome these problems. There are several stages involved in producing the kayak carrier, which are concept generation and evaluation, CAD design, fabrication, and testing. In a conclusion, by using this kayak carrier, only one person needed to carry the kayak from the storage area to the lake, and the traveling time also can be reduced as the person need to cycle instead of walking.

1. Introduction

A kayak is a vehicle used for transporting across the water. It is distinguished from canoeing by the sitting position of the paddlers and the number of blades on the paddle. Canoe-like boat in which the paddler sits facing forward, legs in front, using a double-bladed paddle to pull front-to-back on one side and then the other in rotation. Most kayaks have closed decks, although sit-on-top and inflatable kayaks are growing in popularity as well [1]. According to Hudson et al. [2], a kayak is economical transportation and has a small structure in size therefore it can be transported effortlessly using a car or manageable trailer from one location to another.

Kayaking is one of the most popular outdoor activities at the University of Technology MARA (UiTM), Terengganu Branch, Bukit Besi Campus due to its location next to Puteri Lake, Bukit Besi, Terengganu. Figure 1 shows the kayaking activity at Puteri Lake, Bukit Besi, Terengganu. It is customary for students to shuttle the kayak from the storage located on campus to Puteri Lake that takes 800 meters of travel. The kayak that available on the UiTM campus weights almost 21kg and usually needs two persons to carry it on their shoulders. From the observation, after done with the kayaking activity some difficulties occur to transport back the kayak to campus manually as there is a lack of energy left.
Industriales et al. [3] have stated that the European Conference of Ministers of Transport (ECMT) defined a trailer as “a vehicle without own propulsion to transport goods, intended to couple with an automobile, except semi-trailers”, where the dissimilarity between trailer and semi-trailer is the existence of the front axle. There are few studies on a trailer that has been done by previous researchers. Naukowe et al. [4][5] studied the strength analysis of the frame trailer used to carry personal watercraft such as boat and water scooters. The method used to analyze the strength analysis was the numerical mathematical method known as the finite element method (FEM). Ladra et al. [6] used the same method of FEM to study the strength analysis on the prototype of a multi-tasking trailer. The analysis was developed using the SolidWorks program and performed in the Simulation Module. The development of this prototype focus on specific design criteria for the trailer system functional in many tasks such as space, multifunctional folding frame, and backlight of the sliding back panel. A similar research project of trailer development has been studied by Agrait et al. [7]. The project is subjected to security and durability where it minimizes the disposal of the dysfunctional trailers that lead to contamination due to material selection.

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 [8].

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 [9][10]. According to Augustine et al. [11], the right selection of design concepts will eliminate the cost of redesign the final product and escalate the productivity in the project development process. This researcher has listed the possibility of multi-criteria 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 selected the best design from the three proposed design concepts.
Many studies on Pugh Matrix have been done previously by other researchers. Thakker et al. [12] study the Pugh method in the analysis concept of designing an impulse turbine using a 3DCAD environment. It was found out that this method successfully delivered the evaluation of alternate design by compared the impulse turbine rotor concepts in the product development process. Seperamaniam et al. [13] also used this method in developing the conceptual design of a hydrostatic bearing pad in a heavy-duty automotive application and effectively obtain the optimum design. Another study was done by Silaen et al. [14] as they used the Pugh concept to select the best design of lecture chairs at Sebelas Maret University and turn out the results show good time management throughout the assembly process.

This paper highlights the design and fabricate process of the kayak trailer which is also known as a kayak carrier using the Morphological Method and Pugh Chart as for the concept generation and selection method as for the decision-making criteria activity before proceeding with the fabrication process.

2. Research Method
The process of fabrication of kayak carrier is shown in figure 2. It started with concept generation and evaluation, CAD design, fabrication of the product, and testing.

![Flowchart of kayak carrier fabrication](image)

Figure 2: Flowchart of kayak carrier fabrication

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.

Then, the next step is concept evaluation. The design concept produced will be then evaluated to select the best design. Several factors need to be considered in selecting the design concept. Since there is limited raw material provided by the organization, it is required to consider the availability of each part. It might be available from hardware or need to be fabricated based on the dimension. Other than that, in terms of ease of installation, durability, aesthetics value, safety, etc. Pugh Chart is used in concept
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 2013 x64 Edition. This software can produce a detail 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 aesthetical 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 material 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. Results 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. 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 Table 1 shows the morphological table of concept generation for kayak carrier. Based on the table, there are six sub-functions listed in our product design, kayak carrier. The six sub-functions are considered such as kayak stands, rear tire, front tire, chassis, chassis connector, and bicycle connector. There is three options solution for each sub-function. For example, three shapes of kayak stands are considered in our design which are rectangle bar, semi-circle bar, and V-bar.

Three different design concepts have been designed using different option solutions provided in Table 1, to produce the three best designs. We used a bicycle to pull the kayak carrier as a solution to avoid the users carrying the kayak on their shoulders. Figure 3a shows the design concept 1. The mechanism for this design concept is the kayak is placed on the V-bar stand. This design does not require a belt to grip the kayak because the shape of the V-bar is similar to the shape on the bottom surface of the kayak. Figure 3b shows the design concept 2. The mechanism for this design concept is the kayak is placed on the rectangle stands, which are located at the rear and front of the chassis. Then the kayak is held by the belt to avoid sliding or moving. Figure 3c shows the design concept 3. The mechanism for this design concept is the kayak is placed at the rear semi-circle stands only. Then the kayak is held by the belt to avoid sliding or moving.

Figure 3a: Design concept 1. Figure 3b: Design concept 2. Figure 3c: Design concept 3.
After the three design concepts were designed, the reason for choosing the material or shape was determined and listed in the table. Table 2 shows the list of parts for design concept 1, Table 3 shows the list of parts for design concept 2, and Table 4 shows the list of parts for design concept 3. For example, in Table 2, we choose the V-bar shape for kayak stands because the design can hold the kayak from sliding or moving, the go-kart tire is chosen for the rear tire because the design gives more stability for a variant type of road surface, the double trolley tire is chosen for front tire because the shape can support rear tire to make sure the carrier is stable, and so on.

Table 1: Morphological table of concept generation for kayak carrier

| Sub-function | Option solution | | | |
|--------------|-----------------|---|---|---|
| Kayak Stands | Rectangle bar | Semi-circle | V-bar |
| Rear Tire    | Bicycle tire | Wheelbarrow tire | Go-kart tire |
| Front Tire   | Single trolley tire | Round trolley tire | Double trolley tire |
| Chassis      | T-shape | Double T-shape | Single straight shape |
| Chassis Conneector | Square bearing | Round bearing | Rectangle bearing |
| Bicycle Conneector | Round | Double C-type | Moon Hook |
Table 2: List of part for Design Concept 1

| No | Sub-function | Option function | Reason |
|----|--------------|-----------------|--------|
| 1  | Kayak stands | V-bar           | Can hold the kayak from sliding or moving. |
| 2  | Rear tire    | Go-kart tire    | Give more stability for a variant type of road surface. |
| 3  | Front tire   | Double trolley tire | Support rear tire to make sure the carrier is stable. |
| 4  | Chassis      | Single straight shape | The design is simple and reduces the load that kayakers need to carry. |
| 5  | Chassis connector | Round bearing | Durable. |
| 6  | Bicycle connector | Round type | Easy to make a turn. |

Table 3: List of part for Design Concept 2

| No | Sub-function | Option function   | Reason |
|----|--------------|-------------------|--------|
| 1  | Kayak stands | Rectangle bar     | Can carry many types of kayak. |
| 2  | Rear tire    | Wheelbarrow tire  | Easy to maintain. |
| 3  | Front tire   | Single trolley tire | Quick response when changed direction. |
| 4  | Chassis      | Double T-shape    | Better hold of the kayak at its place. |
| 5  | Chassis connector | Rectangle bearing | Can take out if bearing broken and easy to install. |
| 6  | Bicycle connector | Double C-type | A variety of types of a bicycle can use. |

Table 4: List of part for Design Concept 3

| No | Sub-function | Option function | Reason |
|----|--------------|-----------------|--------|
| 1  | Kayak stands | Semi-circle     | Can hold the kayak from sliding or moving. |
| 2  | Rear tire    | Bicycle tire    | Lighter compared to other designs. |
| 3  | Front tire   | Round trolley tire | Wireless tire so no issue of puncture. |
| 4  | Chassis      | T-shape         | This chassis design for a kayak that has a length of fewer than 2.2 meters. |
| 5  | Chassis connector | Square bearing | Able to carry more weight compared to other designs. |
| 6  | Bicycle connector | Moon hook | The carrier can pair with many types of vehicles such as a motorcycle. |

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 5 shows the Pugh Chart of kayak carrier. The design criteria are listed in the left column. Eight criteria are considered, which are durable, portable, affordable, aesthetics, easy to use, weight, safety, and adjustable. 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 the table 5, the best design concept selected is Design 2 with a total 4 net score. The most important criteria that have been observed before selecting the best design is how the design help kayakers carry the kayak without using lots of energy. Design 2 has fulfilled these most important criteria like easy to use, adjustable, and portable.

Table 5: Pugh chart of kayak carrier

| Description | Design 1 (Datum) | Design 2 | Design 3 |
|-------------|-----------------|----------|----------|
| Durable     | 2               | 0        | -        |
| Portable    | 2               | +        | +        |
| Affordable  | 2               | 0        | +        |
| Aesthetics  | 1               | -        | +        |
| Easy to Use | 3               | 0        | +        |
| Weight      | 2               | 0        | +        |
| Safety      | 3               | 0        | -        |
| Adjustable  | 2               | 0        | +        |
|             | +               | 0        | 7        |
|             | 0               | 17       | 7        |
|             | -               | 0        | 3        |

Net Score: 0  4  -1

Scale Indicator:
[+] = greater than datum
[0] = as per datum
[-] = lesser than datum

3.3. **Detail Design**

Solidworks 2013 x64 Edition software is used to draw the kayak carrier. Figure 4 shows the assembly drawing of the kayak carrier. The overall dimension of this kayak carrier is 2300 x 600 x 250 mm (LxWxH).
3.4. Fabrication
The process of fabrication is included prepare material and components, measure raw material, cut the raw material, drilling process, welding process, and assembly of the material until the kayak carrier is completed. Figure 5 shows the fabrication process to produce the kayak carrier.

3.5. Testing
After finished the fabrication and assembly process, the kayak carrier is tested to ensure a kayak can fit onto the kayak carrier. Figure 6 shows the picture of a kayak carrier that is attached to a bicycle and carries a kayak. From the test run, several issues were found, and the team has discussed and proposed solutions. Table 6 shows the three main issues of the kayak carrier according to its priority and the proposed solution to overcome.
Table 6: Three main issues of the kayak carrier according to its priority and the proposed solution to overcome.

| No | Main Issues                                                                 | A proposed solution to overcome                                      |
|----|------------------------------------------------------------------------------|-----------------------------------------------------------------------|
| 1  | The kayak was off from its place when the bicycle was pedaled especially when cycling on a bumpy road. | To design proper kayak holder according to kayak shape e.g. protruded bar. |
| 2  | The Double-C type connector was unable to hold the kayak carrier when the bicycle braking causing the carrier to hit the rear bicycle's tire. | To use a better and reliable connector.                                |
| 3  | A biker will have trouble and feel heavier on pedaling when making turning at a corner. | To use a bigger tire at the front of the kayak carrier.               |

4. Conclusion

The design of the kayak carrier 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 kayak carrier, only one person needed to carry the kayak instead of two persons. For the next project, it is proposed to design a kayak carrier which able to carry two kayaks at one time.

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