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Redesigning of the Basketball Training Simulator Machine By DFMA Method

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Abstract

The research consists of the DFA analysis and DFM analysis of the original design of the basketball training simulator machine and the proposed basketball training simulator machine by using the Design for Manufacturing and Assembly (DFMA) method has been purposed. In this research, the redesign of the basketball training simulator machine was done using the DFMA method to reduce the manufacturing cost and increase the design efficiency. At the same time, the cost analysis will be done also to analyze the manufacturing cost of the basketball training simulator machine before and after the redesign. The key for this research is to compare the original design of the basketball training simulator machine and the proposed basketball training simulator machine which has superlative design efficiency and reduced cost of manufacturing. The original design has 14.26% of the design efficiency. After the improvement, the design efficiency of the proposed design increased from 14.26% to 28.74%. There have been 3 modifications made to improve the basketball training simulator machine. The total reduction part is reduced from 231 parts on the original design to 95 parts on the proposed design. From the DFM analysis, the results show that the total manufacturing cost of the original design is RM 2225.83, but the total manufacturing cost of the proposed design is RM 2050.05. Results from total absorption cost show that the original design of the basketball training simulator machine is estimated at RM 2226.93 while the proposed design cost is around RM 2051.26.

1. Introduction

Design for manufacturing and Assembly (DFMA) is one of the approaches that emphasizes manufacturing simplicity and assembly efficiency. DFMA is a practical design method that requires early consideration of the manufacturing and assembly aspect of production because it is a combination of Design for Manufacturing (DFM) and Design for Assembly (DFA) methods [1]. Basically, DFMA has been extended to many industries such as home appliances, computer hardware and computer software that require producing high-quality products, goods efficiently in large quantities and with a shorter lead time.

The aims of DFMA are to improve the use of manufacturing processes and decrease the number of components in the assembly or product. The amount of material used to make the product's pieces can be decreased by using the DFMA process early in the manufacturing process, which also reduces the amount of time needed for assembly. At the same time, it also reduces the cost of manufacturing process [2]. Apart from that, DFMA is also used as a benchmarking tool to study competitors' products, and as a should cost tool to assist in supplier negotiations.

This research fundamentally chose the basketball training simulator machine as a product to be studied. Basketball training simulator machine which also known as a basketball shooting device or basketball shooting machine, is an automated basketball shooting machine and rebounding tool. Basketball players can improve their shooting abilities by using this basketball training simulator machine. Under a basket, these high-tech machines will collect shots and pass the ball back to players [3]. Typically, the basketball training simulator machine is produced with the aluminum alloy, plastic and stainless steel. In this research, it is fundamentally focused on analyzing the basketball training simulator machine for redesign and cost reduction by implementing Design for Manufacturing and Assembly (DFMA).

2. Literature Review and Methodology

2.1 Design for Manufacturing (DFM)

Design for Manufacturing (DFM) describes the actions taken to ensure that the plan can be implemented properly during the actual planning stage. DFM used to create the collection of parts that will make up the product after assembly, optimize the manufacturing process, and incorporate manufacturability considerations at the design stage [4]. The aim of the DFM in the early stages of product design is to determine the most economical material and manufacturing process to be used. DFM can assist the designer in the development process to design an economically efficient products [5].

DFM is essential for efficiency, speed, and high rates of production for any company wanting to turn a profit and produce items that are profitable. DFM offers excellent capacity for cost reduction. The cost of the finished product would be much decreased by concentrating on the design phase, which is available through DFM. Additionally, it can make it possible to identify, measure, and eliminate of waste or inefficiencies at different stages of the manufacturing and production process. The advantages of DFM are [6]:

a. Lower production cost
b. Quicker time-to-market
c. Shortening of the product development process
d. Production will be faster
e. Parts may be combined to reduce assembly steps and quantity of parts
f. Find and removes mistakes or faults
g. Higher quality of a product, as design can be refined and enhanced at every stage.
h. As construction activities can be removed from a site and placed elsewhere, DFM can create a safer working environment

SolidWorks Costing used to do the DFM analysis. SolidWorks Costing is a feature within the SolidWorks software suite, which is a 3D computer-aided design (CAD) and computer-aided engineering (CAE) application. It is specifically designed to help users estimate the manufacturing cost of a part or assembly directly within the SolidWorks environment. It can automatize estimate the manufacturing cost of a part or assembly. It considers various factors such as materials, manufacturing processes, and custom operations. After that, this software also allows users to assign materials to different components of the design. It considers material costs based on the selected material type and quantity [11].

2.2 Design for Assembly (DFA)

Designing a product to be simple to assemble is known as Design for Assembly (DFA). DFA used in the early stages of product design to determine the most economical material and manufacturing process to be applied. It only cares about reducing the cost of product assembly, for example, by reducing the number of assembly procedures [7].

The manual assembly strategy (including handling and tooling) is the focus of this study's examination of assembly methods. Manual assembly is employed as standard while assembly methods are investigated and evaluated in this study. The manual assembly process can separate to 2 stage which is insertion and handling [8].

Handling includes the acquisition, orientation, and movement of parts. Model components for the entrance axis' rotational and end-to-end symmetry. Create parts that are simply asymmetrical if the component cannot be made symmetrical under certain circumstances [8]. Insertion is a mating part to another component or set of parts. To enable the implementation of higher-volume processes that typically result in reduced product costs, standardize similar components, procedures, and practices across all models and product lines [1]. It offers a progressive assembly focused on one axis of reference by pyramid assembly.

There were two different types of part symmetry in the part symmetry effect on handling time which is the α symmetry and β symmetry. α symmetry depends on the angle at which the part must be turned around the axis perpendicular to the axis of insertion to repeat its orientation. β symmetry depends on the angle at which the part must be rotated along the insertion axis to repeat its orientation. The relationship between the amount of rotation required to guide the part and the time needed to execute the rotation has been evaluated based on the original classification of manual handling time and insertion handling times. The handling time used to fill in the manual assembly worksheet to do the manual DFA analysis.

2.3 Cost Analysis

The total cost of all resources used to produce a product is known as the cost of production and the process of determining the possible profits from a situation or project and subtracting all the costs necessary to complete it is called cost analysis [9]. Building rent, an advertising budget, organization services, and other costs that do not increase or reduce because modest increases in operation volume typically fall under the category of fixed costs. Supplies, salaries, and all other costs that affect the output level were considered as variable costs. The company's profits increase as production volume increases but its fixed costs stay the same. As a result, when the cost of production for each item decreases, the company's profitability will be increase [10].

Absorption costing is a management strategy that aims to have each product cover all its costs, whether they are fixed or variable, and leave some money left over for profits and return on investment [12]. This method is used to pay for both direct and indirect expenses, such as direct materials, direct labor, rent, and insurance. In addition to fixed overhead costs, absorption costs must be included in the cost of the product. Wages for workers who are physically involved in the manufacture of the product, raw materials applied in the production of the product, and other operating costs like the utility charges that are used in production make up a significant amount of the costs related to product manufacturing.

2.4 Methodology

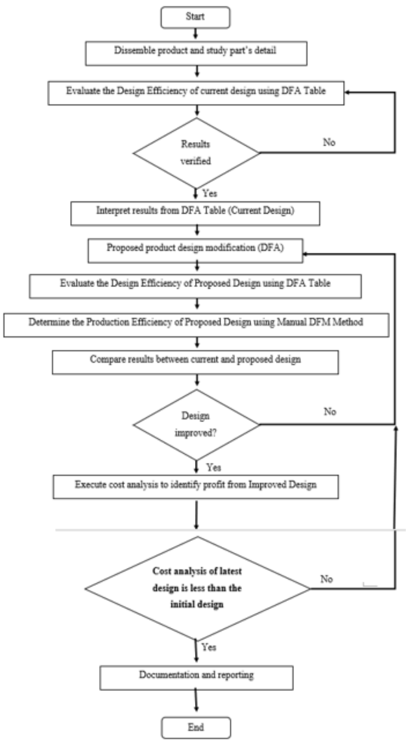


Figure 1: Study Flow Chart

Figure 1 shows the study flow chart process for this case study. The basketball training simulator machine consists of 231 parts including fasteners. The dimension for each part of the machine is measured in inch. The manual DFA analysis is conducted on the basketball training simulator machine to obtain the results in terms of assembly operation time, assembly operation cost, and product design efficiency by using the DFA worksheet. The Solidworks costing software used to estimate the manufacturing cost of the original basketball training simulator machine and proposed basketball training simulator machine. The absorption cost analysis used to calculate the total absorption cost. The result used to compare between the original basketball training simulator machine and proposed basketball training simulator machine.

2.5 Basketball Training Simulator Machine

The analysis can start by listing the whole information and data for each part of the basketball training simulator machine. The information and the description of the part of basketball training simulator machine are respectively filled in Table 1.

Table 1 The List and Description of Part for The Basketball Training Simulator Machine

No	Name of Part	Number of Component	Description
1	1.05inch x 1.05inch x 52inch Square Hollow Tube	2	Used as the framework
2	1.05inch x 1.05inch x 26inch Square Hollow Tube	8	Used as the framework
3	2.10inch x 1.05inch x 19inch Rectangular Hollow Tube	1	Used as the framework
4	1.05inch x 1.05inch x 5inch Square Hollow Tube	2	Used as the framework
5	1.05inch x 1.05inch x 78inch Square Hollow Tube	2	Used as the framework
6	1.05inch x 1.05inch x 44.7inch Square Hollow Tube	2	Used as the framework
7	1.05inch x 1.05inch x 100inch Square Hollow Tube	4	Used as the framework
8	1.05inch x 1.05inch x 15.5inch Square Hollow Tube	7	Used as the framework
9	1.05inch x 1.05inch x 23inch Angle Bar	2	Used as the framework
10	1.05inch x 1.05inch x 21inch Angle Bar	2	Used as the framework
11	1.05inch x 1.05inch x 35inch Angle Bar	2	Used as the framework
12	0.85inch x 0.85inch x 17.5inch Square Hollow Tube	1	Used as the framework
13	0.85inch x 0.85inch x 19inch Square Hollow Tube	1	Used as the framework
14	0.85inch x 0.85inch x 40inch Square Hollow Tube	2	Used as the framework
15	0.85inch x 0.85inch x 12inch Square Hollow Tube	2	Used as the framework
16	15inch x 21inch x 0.2inch Hollow Plate	1	Used as the framework
17	15inch x 21inch x 0.2inch Plate	1	Used as the framework
18	0.8inch x 0.8inch x 39inch Angle Bar	2	Used as the framework
19	0.7inch Radius x 75inch Hollow Cylinder	2	Used as the storage and track to shoot out the basketball
20	8.57inch x 5inch x 0.5inch Plate	1	Weld inside the storage to avoid the basketball get out from the track
21	0.1inch Radius x 11inch Cylinder	1	To fix and connect the roller with the track
22	2.10inch Radius of Cylinder	1	Connect the base and the storage of the Basketball Training Simulator Machine
23	8.86inch Radius of Rim	2	• used to connect with the net to catch out the basketball • used as the framework
24	14inch Radius of Rim	1	Connect with the cover to avoid the basketball get out from the track
25	Side Upper Cover	2	The cover of the machine
26	Side Lower Cover	2	The cover of the machine
27	Front Cover	1	The cover of the machine
28	Upper Cover	1	The cover of the machine
29	Big Rim Cover	1	The cover of the machine
30	M10x40mm Hexagon Head Screw	77	Used to assembly the cover, wheel, and some parts
31	M10 Hexagon Nut	77	Used to assembly the cover, wheel, and some parts
32	Castel Wheel	4	Used as wheel to move
33	Rim Support	2	To support the rim to catch out the basketball

34	Grip	2	To allow the person can move the Basketball Training Simulator Machine easily
35	Screw Base Plate	8	The place that used to connect the parts, the screw and nut.
36	Half Rim	1	Weld inside the storage to avoid the basketball get out from the track
37	Roller	1	Connect the motor, rotate at high speed to shoot the basketball out of the machine
	Total	231	

3. RESULTS AND DISCUSSION

3.1 DFA Worksheet Analysis of the Original Basketball Training Simulator Machine

The DFA worksheet analysis was conducted on the original design of the basketball training simulator machine to obtain the total theoretical minimum parts number, total manual assembly time, and design efficiency as shown in Table 2.

Table 2 Design for Manual Assembly Worksheet for The Original Basketball Training Simulator Machine

0	C1	C2	C3	C4	C5	C6	C7	C8	C9
Name of part	Part ID	No of operations carried out consecutively	Manual handling code	Manual handling time per part	Manual insertion code	Manual insertion time per part	Operation time C2(C4+C6)	Total angle of symmetry (α + β), deg (º)	Estimation for theoretical minimum parts
M10x40mm Hexagon Head Screw	1	77	00	1.13	38	6	549.01	360+0=360	0
M10 Hexagon Nut	2	77	02	1.88	30	2	298.76	180+0=180	0
Big Rim Cover	3	1	30	1.95	38	6	7.95	360+360=720	1
Upper Cover	4	1	30	1.95	38	6	7.95	360+360=720	1
Front Cover	5	1	20	1.80	30	2	3.80	360+180=540	1
Side Upper Cover	6	2	30	1.95	30	2	7.90	360+360=720	2
Side Lower Cover	7	2	30	1.95	30	2	7.90	360+360=720	2
8.86inch Radius of Rim	8	2	40	3.60	30	2	11.2	180+0=180	2
14inch Radius of Rim	9	1	40	3.60	30	2	5.60	180+0=180	1
8.57inch x 5inch x 0.5inch Plate	10	1	40	3.60	30	2	5.60	180+180=360	1
Half Rim	11	1	70	5.10	30	2	7.10	360+360=720	1
0.1inch Radius x 11inch Cylinder	12	1	03	1.69	01	2.50	4.19	180+0=180	1
Roller	13	1	00	1.13	30	2	3.13	180+0=180	1
0.7inch Radius x 75inch Hollow Cylinder	14	2	70	5.10	38	6	22.2	360+360=720	2
0.85inch x 0.85inch x 12inch Square Hollow Tube	15	2	40	3.60	38	6	19.2	180+90=270	2
0.85inch x 0.85inch x 40inch Square Hollow Tube	16	2	40	3.60	38	6	19.2	180+180=360	2

15inch x 21inch x 0.2inch Hollow Plate	17	1	40	3.60	38	6	9.6	180+180=360	1
15inch x 21inch x 0.2inch Plate	18	1	40	3.60	38	6	9.6	180+180=360	1
0.85inch x 0.85inch x 17.5inch Square Hollow Tube	19	1	40	3.60	38	6	9.6	90+180=270	1
0.85inch x 0.85inch x 19inch Square Hollow Tube	20	1	40	3.60	38	6	9.6	90+180=270	1
0.8inch x 0.8inch x 39inch Angle Bar	21	2	70	5.10	38	6	22.2	360+360=720	2
1.05inch x 1.05inch x 23inch Angle Bar	22	2	70	5.10	38	6	22.2	360+360=720	2
1.05inch x 1.05inch x 21inch Angle Bar	23	2	70	5.10	38	6	22.2	360+360=720	2
1.05inch x 1.05inch x 35inch Angle Bar	24	2	70	5.10	38	6	22.2	360+360=720	2
1.05inch x 1.05inch x 44.7inch Square Hollow Tube	25	2	00	1.13	30	2	6.26	180+90=270	2
1.05inch x 1.05inch x 100inch Square Hollow Tube	26	4	00	1.13	30	2	12.52	180+90=270	4
1.05inch x 1.05inch x 15.5inch Square Hollow Tube	27	7	40	3.60	38	6	67.2	90+180=270	7
1.05inch x 1.05inch x 78inch Square Hollow Tube	28	2	40	3.60	38	6	19.2	180+90=270	2
Rim Support	29	2	70	5.10	38	6	22.2	360+360=720	2
Grip	30	2	50	4.00	30	2	12	180+360=540	2
Screw Base Plate	31	8	60	4.80	30	2	54.4	360+180=540	0
2.10inch x 1.05inch x 19inch Rectangular Hollow Tube	32	1	40	3.60	38	6	9.6	180+180=360	1
1.05inch x 1.05inch x 5inch Square Hollow Tube	33	2	40	3.60	38	6	19.2	180+180=360	2
1.05inch x 1.05inch x 52inch Square Hollow Tube	34	2	40	3.60	38	6	19.2	180+180=360	2
2.10inch Radius of Cylinder	35	1	40	3.60	38	6	9.6	180+0=180	1
1.05inch x 1.05inch x 26inch Square Hollow Tube	36	8	40	3.60	38	6	76.8	90+180=270	8
Castel Wheel	37	4	20	1.80	30	2	15.2	360+180=540	4
$DE = \frac{3NM}{TM} = \frac{3(69)}{1451.27}$=0.1426@14.26%							TM=1451.27s		NM=69

Based on Table 2, indicates that the total assembly operational time for the original design of the basketball training simulator machine is 1451.27 seconds or approximately 25 minutes. In addition, the total theoretical minimum parts number of the original basketball training simulator machine is determined at 69. The design efficiency of the original basketball training simulator machine is 0.1426 or 14.26 %.

3.2 DFA Worksheet Analysis of the Proposed Basketball Training Simulator Machine

The DFA worksheet analysis was conducted on the proposed design of the basketball training simulator machine to obtain the total theoretical minimum parts number, total manual assembly time, and design efficiency as shown in Table 3.

Table 3 Design for Manual Assembly Worksheet for The Proposed Basketball Training Simulator Machine

0	C1	C2	C3	C4	C5	C6	C7	C8	C9
Name of part	Part ID	No of operations carried out consecutively	Manual handling code	Manual handling time per part	Manual insertion code	Manual insertion time per part	Operation time C2(C4+C6)	Total angle of symmetry (α + β), deg (º)	Estimation for theoretical minimum parts
M10x40mm Hexagon Head Screw	1	8	00	1.13	38	6	57.04	360+0=360	0
M10 Hexagon Nut	2	8	02	1.88	30	2	31.04	180+0=180	0
Big Rim Cover	3	1	30	1.95	38	6	7.95	360+360=720	1
Upper Cover	4	1	30	1.95	38	6	7.95	360+360=720	1
Front Cover	5	1	30	1.95	30	2	3.95	360+360=720	1
Side Cover	6	2	30	1.95	30	2	7.90	360+360=720	2
8.86inch Radius of Rim	7	2	40	3.60	30	2	11.2	180+0=180	2
14inch Radius of Rim	8	1	40	3.60	30	2	5.60	180+0=180	1
8.57inch x 5inch x 0.5inch Plate	9	1	40	3.60	30	2	5.60	180+180=360	1
Half Rim	10	1	70	5.10	30	2	7.10	360+360=720	1
0.1inch Radius x 11inch Cylinder	11	1	03	1.69	01	2.50	4.19	180+0=180	1
Roller	12	1	00	1.13	30	2	3.13	180+0=180	1
0.7inch Radius x 75inch Hollow Cylinder	13	2	70	5.10	38	6	22.2	360+360=720	2
0.85inch x 0.85inch x 12inch Square Hollow Tube	14	2	40	3.60	38	6	19.2	180+90=270	2
0.85inch x 0.85inch x 40inch Square Hollow Tube	15	2	40	3.60	38	6	19.2	180+180=360	2
15inch x 21inch x 0.2inch Hollow Plate	16	1	40	3.60	38	6	9.6	180+180=360	1
15inch x 21inch x 0.2inch Plate	17	1	40	3.60	38	6	9.6	180+180=360	1
0.85inch x 0.85inch x 17.5inch Square Hollow Tube	18	1	40	3.60	38	6	9.6	90+180=270	1
0.85inch x 0.85inch x 19inch Square Hollow Tube	19	1	40	3.60	38	6	9.6	90+180=270	1
0.8inch x 0.8inch x 39inch Angle Bar	20	2	70	5.10	38	6	22.2	360+360=720	2
1.05inch x 1.05inch x 23inch Angle Bar	21	2	70	5.10	38	6	22.2	360+360=720	2
1.05inch x 1.05inch x 21inch Angle Bar	22	2	70	5.10	38	6	22.2	360+360=720	2
1.05inch x 1.05inch x 35inch Angle Bar	23	2	70	5.10	38	6	22.2	360+360=720	2

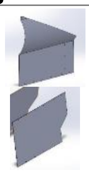
1.05inch x 1.05inch x 44.7inch Square Hollow Tube	24	2	00	1.13	30	2	6.26	180+90=270	2
1.05inch x 1.05inch x 100inch Square Hollow Tube	25	4	00	1.13	30	2	12.52	180+90=270	4
1.05inch x 1.05inch x 15.5inch Square Hollow Tube	26	7	40	3.60	38	6	67.2	90+180=270	7
1.05inch x 1.05inch x 78inch Square Hollow Tube	27	2	40	3.60	38	6	19.2	180+90=270	2
Rim Support	28	2	70	5.10	38	6	22.2	360+360=720	2
Grip	29	2	50	4.00	30	2	12	180+360=540	2
Screw Base Plate	30	8	60	4.80	30	2	54.4	360+180=540	0
2.10inch x 1.05inch x 19inch Rectangular Hollow Tube	31	1	40	3.60	38	6	9.6	180+180=360	1
1.05inch x 1.05inch x 5inch Square Hollow Tube	32	2	40	3.60	38	6	19.2	180+180=360	2
1.05inch x 1.05inch x 52inch Square Hollow Tube	33	2	40	3.60	38	6	19.2	180+180=360	2
2.10inch Radius of Cylinder	34	1	40	3.60	38	6	9.6	180+0=180	1
1.05inch x 1.05inch x 26inch Square Hollow Tube	35	8	40	3.60	38	6	76.8	90+180=270	8
M20 Hexagon Nut	36	4	02	1.88	30	2	15.52	180+0=180	0
Castel Wheel	37	4	20	1.80	30	2	15.2	360+180=540	4
$DE = \frac{3NM}{TM} = \frac{3(67)}{699.35}$ = 0.2874@28.74%							TM=699.35s		NM=67

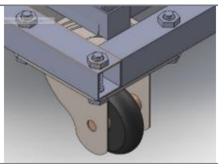
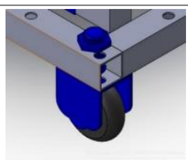
Based on Table 3, indicates that the total assembly operational time for the proposed design of the basketball training simulator machine is 699.35 seconds or approximately 12 minutes. In addition, the total theoretical minimum parts number of the proposed basketball training simulator machine is determined at 67. The design efficiency of the proposed basketball training simulator machine is 0.2874 or 28.74 %.

3.3 Improvement of the Proposed Basketball Training Simulator Machine

Table 4 below shows the 3 modifications process that involved in combining and reducing the number of parts and fasteners from the original design of the Basketball Training Simulator Machine to the proposed design of the Basketball Training Simulator Machine to increase the design efficiency and decrease the manufacturing cost and assembly cost.

Table 4 Design improvement for the Basketball Training Simulator Machine

No	Original Design	Proposed Design	Modification
1			For the original design, the side cover was separated to 2 part which is the side upper cover and side lower cover. As an improvement, I combine these 2 parts of the cover to the 1 side cover only.
2			For the original design, the cover was assembly with the screw and nut. As a modification, the side cover and the front cover was charged to the snap fit joint. These covers can just plug in to assembly. This improvement will reduce total 57 of the screws and 57 of the nuts.

3			For the original design, the wheel needed 3 screw and 3 nut to assembly. As the last improvement, I change the structure of the wheel to a wheel with a M20 screw. It can just assembly with a nut easily. It will reduce total number of 12 extra screws and 12 extra nuts but add 4 M20 nut.

3.4 DFM Analysis of Original Basketball Training Simulator Machine

The DFM analysis was conducted on the original design of the basketball training simulator machine to obtain the total manufacturing cost as shown in Table 5. The cost of the purchased component and the materials cost are recorded in Table 6.

Table 5 Total of DFM Concurrent Costing for The Component of The Basketball Training Simulator Machine

No	Name of Part	Quantity, Q	Price per part, C (RM)	Total Cost, TC (RM) TC=Q×C
1	1.05inch x 1.05inch x 52inch Square Hollow Tube	2	21.39	42.78
2	1.05inch x 1.05inch x 26inch Square Hollow Tube	8	18.88	151.04
3	2.10inch x 1.05inch x 19inch Rectangular Hollow Tube	1	20.09	20.09
4	1.05inch x 1.05inch x 5inch Square Hollow Tube	2	16.89	33.78
5	1.05inch x 1.05inch x 78inch Square Hollow Tube	2	23.89	47.78
6	1.05inch x 1.05inch x 44.7inch Square Hollow Tube	2	20.69	41.38
7	1.05inch x 1.05inch x 100inch Square Hollow Tube	4	25.98	103.92
8	1.05inch x 1.05inch x 15.5inch Square Hollow Tube	7	17.91	125.37
9	1.05inch x 1.05inch x 23inch Angle Bar	2	17.49	34.98
10	1.05inch x 1.05inch x 21inch Angle Bar	2	17.44	34.88
11	1.05inch x 1.05inch x 35inch Angle Bar	2	18.00	36.00
12	0.85inch x 0.85inch x 17.5inch Square Hollow Tube	1	17.03	17.03
13	0.85inch x 0.85inch x 19inch Square Hollow Tube	1	17.07	17.07
14	0.85inch x 0.85inch x 40inch Square Hollow Tube	2	17.81	35.62
15	0.85inch x 0.85inch x 12inch Square Hollow Tube	2	16.84	33.68
16	15inch x 21inch x 0.2inch Hollow Plate	1	27.32	27.32
17	15inch x 21inch x 0.2inch Plate	1	43.33	43.33
18	0.8inch x 0.8inch x 39inch Angle Bar	2	17.07	34.14
19	0.7inch Radius x 75inch Hollow Cylinder	2	28.76	57.52
20	8.57inch x 5inch x 0.5inch Plate	1	25.56	25.56
21	0.1inch Radius x 11inch Cylinder	1	16.56	16.56
22	2.10inch Radius of Cylinder	1	20.83	20.83
23	8.86inch Radius of Rim	2	16.98	33.96
24	14inch Radius of Rim	1	17.12	17.12
25	Side Upper Cover	2	18.28	36.56
26	Side Lower Cover	2	25.75	51.50
27	Front Cover	1	19.34	19.34
28	Upper Cover	1	20.04	20.04
29	Big Rim Cover	1	22.96	22.96
30	Rim Support	2	53.67	107.34
31	Grip	2	17.91	35.82
32	Screw Base Plate	8	16.47	131.76
33	Half Rim	1	17.35	17.35
34	Roller	1	17.03	17.03
	Total	73	1511.44	

Table 6 The Cost of The Purchased Component and The Materials Cost

No	Name of parts	Quantity, Q	Price per part, C (RM)	Total Cost, TC (RM) TC=Q×C
1	M10x40mm Hexagon Head Screw	77	1.60 per piece	123.20
2	M10 Hexagon Nut	77	0.54 per piece	41.58

3	Castel Wheel	4	4.89 per piece	19.56
4	7079 Aluminum Alloy	30kg	13.04 per kg	391.20
5	HDPE	9kg	5.57 per kg	50.13
		Total		625.67

To calculate the electricity energy cost and the fillet materials cost as the welding cost, the welding power consumption and the Malaysia electricity price per kWh which is 21.8 sen/kWh is needed [13]. The average power used of the MIG weld machine is 5000 watts [14]. The time needed to manufacture a basketball training simulator machine is 8 hours. The formula to calculate welding power consumption is the welding power used × the time used (hours) [16]. So, the electricity cost will equal to Welding power consumption × 21.8 sen/kWh [15].

Electricity cost= Energy Consumption (kWh) × Energy Cost ($/kWh)
= 5 kw × 8 × 21.8sen/kwh
= Rm 8.72

Welding cost = Electricity cost + Filler Materials Cost
= Rm 8.72 + RM 80
= RM 88.72

Based on Table 5 and 6, indicates that the total manufacturing cost for the original design of the basketball training simulator is RM 2225.83.

3.5 DFM Analysis of Proposed Basketball Training Simulator Machine

The DFM analysis was conducted on the proposed design of the basketball training simulator machine to obtain the total manufacturing cost as shown in Table 7. The cost of the purchased component and the materials cost are recorded in Table 8.

Table 7 Total of DFM Concurrent Costing for The Component of The Proposed Basketball Training Simulator Machine

No	Name of Part	Quantity, Q	Price per part, C (RM)	Total Cost, TC (RM) TC=Q×C
1	1.05inch x 1.05inch x 52inch Square Hollow Tube	2	21.39	42.78
2	1.05inch x 1.05inch x 26inch Square Hollow Tube	8	18.88	151.04
3	2.10inch x 1.05inch x 19inch Rectangular Hollow Tube	1	20.09	20.09
4	1.05inch x 1.05inch x 5inch Square Hollow Tube	2	16.89	33.78
5	1.05inch x 1.05inch x 78inch Square Hollow Tube	2	23.89	47.78
6	1.05inch x 1.05inch x 44.7inch Square Hollow Tube	2	20.69	41.38
7	1.05inch x 1.05inch x 100inch Square Hollow Tube	4	25.98	103.92
8	1.05inch x 1.05inch x 15.5inch Square Hollow Tube	7	17.91	125.37
9	1.05inch x 1.05inch x 23inch Angle Bar	2	17.49	34.98
10	1.05inch x 1.05inch x 21inch Angle Bar	2	17.44	34.88
11	1.05inch x 1.05inch x 35inch Angle Bar	2	18.00	36.00
12	0.85inch x 0.85inch x 17.5inch Square Hollow Tube	1	17.03	17.03
13	0.85inch x 0.85inch x 19inch Square Hollow Tube	1	17.07	17.07
14	0.85inch x 0.85inch x 40inch Square Hollow Tube	2	17.81	35.62
15	0.85inch x 0.85inch x 12inch Square Hollow Tube	2	16.84	33.68
16	15inch x 21inch x 0.2inch Hollow Plate	1	27.32	27.32
17	15inch x 21inch x 0.2inch Plate	1	43.33	43.33
18	0.8inch x 0.8inch x 39inch Angle Bar	2	17.07	34.14
19	0.7inch Radius x 75inch Hollow Cylinder	2	28.76	57.52
20	8.57inch x 5inch x 0.5inch Plate	1	25.56	25.56
21	0.1inch Radius x 11inch Cylinder	1	16.56	16.56
22	2.10inch Radius of Cylinder	1	20.83	20.83
23	8.86inch Radius of Rim	2	16.98	33.96
24	14inch Radius of Rim	1	17.12	17.12
25	Side Cover	2	21.85	43.7
26	Front Cover	1	19.34	19.34
27	Upper Cover	1	20.04	20.04
28	Big Rim Cover	1	22.96	22.96

29	Rim Support	2	53.67	107.34
30	Grip	2	17.91	35.82
31	Screw Base Plate	8	16.47	131.76
32	Half Rim	1	17.35	17.35
33	Roller	1	17.03	17.03
	Total	71	1467.08	

Table 8 The Cost of The Purchased Component and The Materials Cost

No	Name of parts	Quantity, Q	Price per part, C (RM)	Total Cost, TC (RM) TC=Q×C
1	M10x40mm Hexagon Head Screw	8	1.60 per piece	12.80
2	M10 Hexagon Nut	8	0.54 per piece	4.32
3	M20 Hexagon Nut	4	2.20 per piece	8.80
4	Castel Wheel	4	6.75 per piece	27
5	7079 Aluminum Alloy	30kg	13.04 per kg	391.20
6	HDPE	9kg	5.57 per kg	50.13
	Total			494.25

The same way as above used to calculate the welding cost.
Welding cost = RM 88.72

Based on Table 7 and 8, indicates that the total manufacturing cost for the proposed design of the basketball training simulator machine is RM 2050.05.

3.6 Absorption Cost Analysis of Original Basketball Training Simulator Machine

Table 9 below shows absorption costing analysis for the original design of the basketball training simulator machine. The cost is summed by determining the direct cost, indirect cost, and overhead cost of the original basketball training simulator machine.

Table 9 Absorption Cost Analysis of The Original Basketball Training Simulator Machine

Steps	Notes		Unit Cost, RM
1. Define unit	Original Basketball Training Simulator Machine		-
2. Determine no of units	231		-
3. Calculate the direct cost			
Material Cost	1. 7079 Aluminum Alloy	30kg	391.20
	2. HDPE	9kg	50.13
Other	1. 1.05inch x 1.05inch x 52inch Square Hollow Tube	2	42.78
	2. 1.05inch x 1.05inch x 26inch Square Hollow Tube	8	151.04
	3. 2.10inch x 1.05inch x 19inch Rectangular Hollow Tube	1	20.09
	4. 1.05inch x 1.05inch x 5inch Square Hollow Tube	2	33.78
	5. 1.05inch x 1.05inch x 78inch Square Hollow Tube	2	47.78
	6. 1.05inch x 1.05inch x 44.7inch Square Hollow Tube	2	41.38
	7. 1.05inch x 1.05inch x 100inch Square Hollow Tube	4	103.92
	8. 1.05inch x 1.05inch x 15.5inch Square Hollow Tube	7	125.37
	9. 1.05inch x 1.05inch x 23inch Angle Bar	2	34.98
	10. 1.05inch x 1.05inch x 21inch Angle Bar	2	34.88
	11. 1.05inch x 1.05inch x 35inch Angle Bar	2	36.00
	12. 0.85inch x 0.85inch x 17.5inch Square Hollow Tube	1	17.03
	13. 0.85inch x 0.85inch x 19inch Square Hollow Tube	1	17.07
	14. 0.85inch x 0.85inch x 40inch Square Hollow Tube	2	35.62
	15. 0.85inch x 0.85inch x 12inch Square Hollow Tube	2	33.68
	16. 15inch x 21inch x 0.2inch Hollow Plate	1	27.32
	17. 15inch x 21inch x 0.2inch Plate	1	43.33
	18. 0.8inch x 0.8inch x 39inch Angle Bar	2	34.14
	19. 0.7inch Radius x 75inch Hollow Cylinder	2	57.52
	20. 8.57inch x 5inch x 0.5inch Plate	1	25.56

	21. 0.1inch Radius x 11inch Cylinder	1	16.56
	22. 2.10inch Radius of Cylinder	1	20.83
	23. 8.86inch Radius of Rim	2	33.96
	24. 14inch Radius of Rim	1	17.12
	25. Side Upper Cover	2	36.56
	26. Side Lower Cover	2	51.50
	27. Front Cover	1	19.34
	28. Upper Cover	1	20.04
	29. Big Rim Cover	1	22.96
	30. Rim Support	2	107.34
	31. Grip	2	35.82
	32. Screw Base Plate	8	131.76
	33. Half Rim	1	17.35
	34. Roller	1	17.03
	35. Castel Wheel	4	19.56
Total Direct Cost	-		1972.33
4. Calculate Indirect cost			
Fasteners	1. M10x40mm Hexagon Head Screw	77	123.20
	2. M10 Hexagon Nut	77	41.58
Utilities	5 kw × 8 × 21.8sen/kwh		8.72
Other	Filler Materials Cost		80
Total indirect cost	-		253.50
5. Calculate overhead cost	$\frac{\text{Total indirect cost}}{\text{Total Number of Units}}=?$		
Total overhead cost	$\frac{253.50}{231}$		1.10
6. Calculate the unit cost			
Total Cost	Unit cost of 3+4+5		2226.93

Based on the table 9, we can see that the total absorption cost of the original basketball training simulator machine is RM2226.93.

3.7 Absorption Cost Analysis of Proposed Basketball Training Simulator Machine

Table 10 below shows absorption costing analysis for the proposed design of the basketball training simulator machine. The cost is summed by determining the direct cost, indirect cost, and overhead cost of the original basketball training simulator machine.

Table 10 Absorption Cost Analysis of The Proposed Basketball Training Simulator Machine

Steps	Notes		Unit Cost, RM
1. Define unit	Proposed Basketball Training Simulator Machine		-
2. Determine no of units	95		-
3. Calculate the direct cost			
Material Cost	1. 7079 Aluminum Alloy	30kg	391.20
	2. HDPE	9kg	50.13
Other	1. 1.05inch x 1.05inch x 52inch Square Hollow Tube	2	42.78
	2. 1.05inch x 1.05inch x 26inch Square Hollow Tube	8	151.04
	3. 2.10inch x 1.05inch x 19inch Rectangular Hollow	1	20.09
	Tube	2	33.78
	4. 1.05inch x 1.05inch x 5inch Square Hollow Tube	2	47.78
	5. 1.05inch x 1.05inch x 78inch Square Hollow Tube	2	41.38
	6. 1.05inch x 1.05inch x 44.7inch Square Hollow Tube	4	103.92
	7. 1.05inch x 1.05inch x 100inch Square Hollow Tube	7	125.37
	8. 1.05inch x 1.05inch x 15.5inch Square Hollow Tube	2	34.98
	9. 1.05inch x 1.05inch x 23inch Angle Bar	2	34.88
	10. 1.05inch x 1.05inch x 21inch Angle Bar	2	36.00

	11. 1.05inch x 1.05inch x 35inch Angle Bar	1	17.03
	12. 0.85inch x 0.85inch x 17.5inch Square Hollow Tube	1	17.07
	13. 0.85inch x 0.85inch x 19inch Square Hollow Tube	2	35.62
	14. 0.85inch x 0.85inch x 40inch Square Hollow Tube	2	33.68
	15. 0.85inch x 0.85inch x 12inch Square Hollow Tube	1	27.32
	16. 15inch x 21inch x 0.2inch Hollow Plate	1	43.33
	17. 15inch x 21inch x 0.2inch Plate	2	34.14
	18. 0.8inch x 0.8inch x 39inch Angle Bar	2	57.52
	19. 0.7inch Radius x 75inch Hollow Cylinder	1	25.56
	20. 8.57inch x 5inch x 0.5inch Plate	1	16.56
	21. 0.1inch Radius x 11inch Cylinder	1	20.83
	22. 2.10inch Radius of Cylinder	2	33.96
	23. 8.86inch Radius of Rim	1	17.12
	24. 14inch Radius of Rim	2	43.7
	25. Side Cover	1	19.34
	26. Front Cover	1	20.04
	27. Upper Cover	1	22.96
	28. Big Rim Cover	2	107.34
	29. Rim Support	2	35.82
	30. Grip	8	131.76
	31. Screw Base Plate	1	17.35
	32. Half Rim	1	17.03
	33. Roller	4	27
	34. Caster Wheel		
Total Direct Cost	-		1935.41
4. Calculate Indirect cost			
Fasteners	1. M10x40mm Hexagon Head Screw	8	12.80
	2. M10 Hexagon Nut	8	4.32
	3. M20 Hexagon Nut	4	8.80
Utilities	5 kw × 8 × 21.8sen/kwh		8.72
Other	Filler Materials Cost		80
Total indirect cost	-		114.64
5. Calculate overhead cost	$\frac{\text{Total indirect cost}}{\text{Total Number of Units}}$=?		
Total overhead cost	$\frac{114.64}{95}$		1.21
6. Calculate the unit cost			
Total Cost	Unit cost of 3+4+5		2051.26

Based on the table 10, we can see that the total absorption cost of the proposed basketball training simulator machine is RM2051.26.

3.8 Comparison Between the Original Design and the Proposed Design

Table 11 Comparison Between Original Design and Proposed Design of Basketball Training Simulator Machine

	Original Design	Proposed Design
Total Manual Assembly Time, TM	1451.27s	699.35s
Theoretical number of parts, NM	69	67
Design Efficiency, DE	14.26%	28.74%
Total Manufacturing Cost	RM 2225.83	RM 2050.05
Total Absorption Cost	RM 2226.93	RM 2051.26

Based on table 11, indicates that the total manual assembly time and the total theoretical number of parts of the proposed design are less than the original design. After the improvement, the design efficiency of the basketball training simulator machine was increased from 14.26% to 28.74%. As Table 11 shows above, we can see that the total manufacturing cost and total absorption cost were reduced after the improvement.

4. CONCLUSIONS

This research is focused on evaluating an assessment of the current product and developing the design of the basketball training simulator machine using the manual DFA analysis, DFM analysis using Solidworks Costing and cost analysis through absorption cost analysis. In this research, the DFA worksheet assessment is used by evaluating the findings about design efficiency, theoretical number of parts, assembly and the total manual assembly time between the original design and the proposed design. The results show that the DFA method can minimize the complexity of the original design by decreasing the parts counts and eventually reducing the total manual assembly time and improving the design efficiency. From the result of the DFM analysis, we also can see that the manufacturing cost and the purchase cost of the machine are reduced after the improvement. The result of the absorption cost analysis also shows that the total absorption cost of the proposed basketball training simulator machine is less than the original design. To put it clearly, the improvement of the basketball training simulator machine through manual DFA analysis, DFM analysis and cost analysis has a greater design efficiency than the original design, while at the same time helping to minimize time, total manufacturing cost and the total absorption cost.

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