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Cost Reduction of Table Fan Design using Design for Manufacture and Assembly (DFMA)

Wee Soon Chai[1], **Azli Nawawi**[1]*

[1]Department of Mechanical Engineering Technology, Faculty of Engineering Technology,
Universiti Tun Hussein Onn Malaysia, 86400 Pagoh, Johor, MALAYSIA

*Corresponding Author Designation

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Abstract: Design for Manufacture and Assembly (DFMA) is an integration of Design for Manufacturing (DFM) and Design for Assembly (DFA). Most mechanical engineers or design engineers in engineering studies take DFMA as their guidelines when developing a newly redesigned product. The main objective of this research is to focus on reducing part count and minimizing the cost of the product chosen which is the table fan by redesigning and analyzing it using the DFMA method. The product would have fewer parts after it has been redesigned, therefore the costs will be minimized and the process of manufacturing and assembly time for the operation will also be affected. The analysis was conducted according to Boothroyd Dewhurst's method using the DFA worksheet. The results revealed that the efficiency design is improved and a greater decrease in the assembly operational time and cost between original and new modified design table fan. The significant results indicate that the new modified table fan is accomplished with the lower parts count from 31 to 19 parts with the assembly operational time minimized from 238.7 seconds to 128.97 seconds and decreased from 95.348 cents to 51.588 cents for the assembly operational cost. The design efficiency of the modified design is 44.20 % and the original design is 31.46 % which indicates that the greater design efficiency has fewer parts and provides better operational time and cost.

Keywords: DFMA, DFM, DFA, DFA Worksheet, Boothroyd Dewhurst, Table Fan

1. Introduction

Design for manufacturing and Assembly (DFMA) is one of the engineering methodologies that mainly focus on product design for minimizing production costs and manufacturing time. DFMA is a practical design approach 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]. In the early 1970s, Geoffrey Boothroyd and Peter Dewhurst, who founded Boothroyd Dewhurst, Inc. were the first to research new technologies. Currently, the Boothroyd-

*Corresponding author: azle@uthm.edu.my

Dewhurst methodology is used to assist design in almost every industry, including circuit boards with manual mounting, automatic mounting, and machining.

The goal of DFMA is to optimize the use of manufacturing processes and reduce the number of components in the assembly or product. The procedure shall be applied as early as possible in the design process in order to gain full value from DFMA. As a result, it can be achieved in less time if a design is simpler to manufacture and install, so it is less expensive. 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 table fan as a product to be studied. Table fan is one of the conventional electric appliances utilized in houses, workplaces, shops, and business foundations to give air dissemination. The variety of table fan design depends on the manufacturing cost, the material used, and the complexity of its functions. As we can see in history, the early fan was made mainly of brass. Over the following decades, fans were developed out of many materials, including steel, copper, and aluminium. In the 21st century, most domestic fans are made out of plastic as it is cheaper with a simple design and at the same time maintains its quality [2]. In this research, it is fundamentally focused on analyzing the table fan for redesign and cost reduction by implementing Design for Manufacturing and Assembly (DFMA).

2. Literature Review and Methodology

2.1 Literature review

Design for assembly (DFA) is a systematic analysis process primarily intended to minimize the assembly cost of the product and making assembly easy by improving product design [3]. DFA is an industry tool for reducing the costs of the assembly by optimizing the assembly process and reducing the number of parts [4]. This process will ensure that the part is assembled at low cost, high speed, and efficiency levels. consideration should be given at all stages of the design process, in particular at the early stages, which offer many benefits:

- Reduce the amount of assembly needed for a product
- Minimizing manufacturing operation costs
- Improve productivity and quality

The objective of the DFA approach for these sections of the design is to direct the designer to simplify the structure. DFA also provides tools for the designer team to help decide the most effective fastening methods for the appropriate interfaces between the individual design items. These objectives contribute to the key anticipated DFA outcomes for the assembly, including lower material costs, reduce workload or automated assembly costs, decreased assembly cycle times, and improved product quality and reliability [5].

There are two ways DFA can be considered, which are general DFA heuristics and systematic methods for analyzing assemblies. DFA heuristics are simple to understand but challenging to use in a structured way, such as in the context of a design review while systematic methods for analyzing assemblies refer to the methods that allow designers to recognize and develop the design in a structured manner [3].

To implement DFA, the following DFA guidelines must be followed to achieve the goal as mention above [6]:

- Minimize part count
- Design parts that have reasonable weight and size
- Maximize part symmetry

- Provide chamber
- Standardize the part
- Avoid the part that has tangling
- Minimize or eliminate the use of fasteners in the design by using the snap-fit method

2.2 Methodology

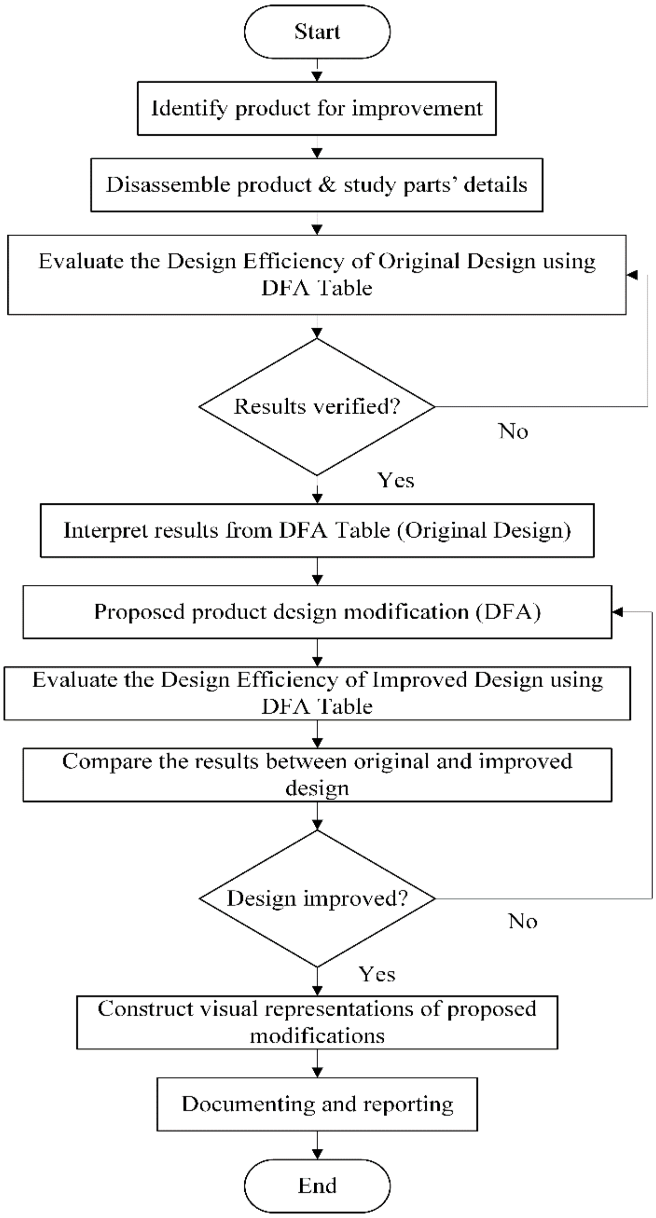

Figure 1: A flowchart of the DFA manual analysis methodology

The table fan consists of 31 parts including fasteners. The dimension for each part of the table fan is measured in millimeters. The manual DFA analysis is conducted on the table fan to obtain the results in terms of assembly operation time, assembly operation cost, and product design efficiency by using the DFA worksheet.

2.3 Table fan parts

The analysis can begin by listing the whole information and data for each table fan part and organize the parts according to the assembly sequence and the order of sub-assembly. The relevant data and value for the DFA worksheet are then respectively filled in Table 1.

Table 1: Data and part features for each part of the table fan

Part Number	Part Name	Part Quantity	Part Feature	α	β	α+β
1	Front guard	1	To avoid blades damage from any outside objects coming in contact with the blades	360	0	360
2	Blade cap	1	To avoid the oscillating fan blade from coming out	360	0	360
3	Fan blade	1	To provide proper and smooth air	360	0	360
4	Rear guard nut	1	Tighten the rear guard to the motor housing	360	0	360
5	Rear guard	1	To avoid blades damage from any outside objects coming in contact with the blades	360	360	720
6	Motor housing screw	4	Attach the motor housing cover with the motor housing	360	0	360
7	Motor housing cover	1	Cover for motor housing	360	360	720
8	Oscillating knob screw	1	To attach the oscillating knob with the fan motor	360	0	360
9	Oscillating knob	1	To adjust the direction of the oscillating fan head	360	0	360
10	Motor housing	1	Housing for the fan motor	360	360	720
11	Motor screw	2	Attach the motor to the fan body	360	0	360
12	Motor	1	To make the fan blade oscillate	360	360	720
13	Rubber feet	4	Provide friction to prevent the table fan from sliding	360	0	360
14	Base screw	5	Attach the base to the stand	360	0	360
15	Base	1	Act as a base for the table fan	360	360	720
16	Wire holder screw	2	Attach the wire holder to the stand	360	0	360
17	Wire holder	1	To hold the wire to prevent the wire from coming out	180	180	360
18	Regulator screw	2	Attach the regulator with the stand	360	0	360
19	Regulator	1	To control the speed of the motor at various levels and also control ON/OFF of the table fan	360	180	540
20	Stand	1	Keep the table fan body remains fixed without moving while the head of the fan oscillates	360	360	720

3. Results and Data Analysis

3.1 DFA worksheet assessment

The DFA worksheet assessment was conducted on the current design of the table fan to obtain its total assembly operational time, total assembly operational cost, and design efficiency as shown in Table 2

Table 2: DFA worksheet analysis for current design

0	1	2	3	4	5	6	7	8	9
Name of part	Part ID number	Number of times the operation is carried out consecutively	Two-digit manual handling code	Manual handling time per part	Two-digit manual insertion code	Manual insertion per time per part	Operation time, sec, (2) × [(4) + (6)]	Operation cost, cents, 0.4 × (7)	Estimation of the theoretical minimum
Front guard	1	1	83	5.6	30	2	7.6	3.04	1
Blade cap	2	1	10	1.5	30	2	3.5	1.4	1
Fan blade	3	1	10	1.5	00	1.5	3	1.2	1
Rear guard nut	4	1	10	1.5	30	2	3.5	1.4	1
Rear guard	5	1	83	5.6	00	1.5	7.1	2.84	1
Motor housing screw	6	4	11	1.8	39	8	39.2	15.68	0
Motor housing cover	7	1	30	1.95	01	2.5	4.45	1.78	1
Oscillating knob screw	8	1	11	1.8	39	8	9.8	3.92	1
Oscillating knob	9	1	13	2.06	10	4	6.06	2.424	1
Motor housing	10	1	33	2.51	10	4	6.51	2.604	1
Motor screw	11	2	11	1.8	49	10.5	24.6	9.84	2
Motor	12	1	30	1.95	00	1.5	3.45	1.38	1
Rubber feet	13	4	11	1.8	00	1.5	13.2	5.28	4
Base screw	14	5	11	1.8	39	8	49	19.6	4
Base	15	1	30	1.95	00	1.5	3.45	1.38	1
Wire holder screw	16	2	11	1.8	39	8	19.6	7.84	0
Wire holder	17	1	10	1.5	08	6.5	8	3.2	0
Regulator screw	18	2	11	1.8	39	8	19.6	7.84	2
Regulator	19	1	20	1.8	00	1.5	3.3	1.32	1
Stand	20	1	30	1.95	00	1.5	3.45	1.38	1
						Total	238.37	95.348	25
							TM	CM	NM

Eliminate (red)
Merge (yellow)
Minimize (blue)
Resize (green)

TM = Total manual assembly operation time
CM = Total manual assembly operation cost
NM = Total theoretical minimum number of parts

Design Efficiency
= (3*NM)/TM
= (3*25) / 238.37
= 0.3146 @ 31.46%

Based on Table 2, indicates that the total assembly operational time for the original design of the table fan is 238.37 seconds or approximately 4 minutes. In addition, the calculation of the overall assembly operation cost for one table fan is approximately 95.348 cents. The total theoretical minimum parts number for the original table fan design is determined at 25 with a design efficiency of 0.3146 or 31.46 %.

3.2 The first product modification

The manual DFA analysis was carried out on the first product modification of the table fan by using the DFA worksheet as seen in Table 3 to acquire the design efficiency, total assembly operational time, and total assembly operational cost

Table 3: DFA worksheet analysis for first product modification

0	1	2	3	4	5	6	7	8	9
Name of part	Part ID number	Number of times the operation is carried out consecutively	Two-digit manual handling code	Manual handling time per part	Two-digit manual insertion code	Manual insertion per time per part	Operation time, sec, (2) × [(4) + (6)]	Operation cost, cents, 0.4 × (7)	Estimation of the theoretical minimum
Front guard	1	1	83	5.6	30	2	7.6	3.04	1
Blade cap	2	1	10	1.5	30	2	3.5	1.4	1
Fan blade	3	1	10	1.5	00	1.5	3	1.2	1
Rear guard nut	4	1	10	1.5	30	2	3.5	1.4	1
Rear guard	5	1	83	5.6	00	1.5	7.1	2.84	1
Motor housing cover	7	1	30	1.95	01	2.5	4.45	1.78	1
Oscillating knob screw	8	1	11	1.8	39	8	9.8	3.92	1
Oscillating knob	9	1	13	2.06	10	4	6.06	2.424	1
Motor housing	10	1	33	2.51	10	4	6.51	2.604	1
Motor screw	11	2	11	1.8	49	10.5	24.6	9.84	2
Motor	12	1	30	1.95	00	1.5	3.45	1.38	1
Rubber feet	13	4	11	1.8	00	1.5	13.2	5.28	0
Base screw	14	4	11	1.8	39	8	39.2	15.68	2
Base	15	1	30	1.95	00	1.5	3.45	1.38	1
Regulator screw	18	2	11	1.8	39	8	19.6	7.84	2
Regulator	19	1	20	1.8	00	1.5	3.3	1.32	1
Stand	20	1	30	1.95	00	1.5	3.45	1.38	1
						Total	161.77	64.708	19
							TM	CM	NM

Eliminate (red)
Merge (yellow)
Minimize (blue)
Resize (green)

TM = Total manual assembly operation time
CM = Total manual assembly operation cost
NM = Total theoretical minimum number of parts

Design Efficiency
= (3*NM)/TM
= (3*19) / 161.77
= 0.3524 @ 35.24%

For the first product modification, several screws in some table fan regions are suggested to be minimized or eliminated. As the screws are diminished or eliminated in some areas, the screws attaching the motor housing cover to the motor housing is eliminated and recommend substituted with the snap-fit mechanism as an instant secure fitting for mounting. Regarding the screws at the table fan base, the number of the screws can be decreased from five to four. The screws that join the wire holder to the table fan's main body are eliminated and suggested to merge the wire holder within the main body of the table fan. Besides, it is suggested that the base and stand be resized to a smaller size, although resizing a part in the DFA worksheet assessment did not make any difference.

The outcome of the first product modification in Table 3 indicates that the total assembly operational time for the first product modification is 161.77 seconds or approximately 3 minutes. Furthermore, the calculation of overall assembly operation cost for the first product modification is approximately 64.708 cents with the design efficiency estimation of 0.3524 or 35.24 %. This indicates that the total assembly operational time and overall assembly operation cost are lowered by 76.6 seconds and 30.64 cents from the current design respectively. However, in contrast to the current design, the efficiency of the design in the first product modification indicates a slight improvement from 31.46 % to 35.24 %.

3.3 The second product modification

The DFA worksheet was continued to apply for analyzing the second product modification of the table fan to obtain the total assembly operational time, total assembly operational cost, and design efficiency as shown in Table 4.

Table 4: DFA worksheet analysis for second product modification

0	1	2	3	4	5	6	7	8	9
Name of part	Part ID number	Number of times the operation is carried out consecutively	Two-digit manual handling code	Manual handling time per part	Two-digit manual insertion code	Manual insertion per time per part	Operation time, sec, (2) × [(4) + (6)]	Operation cost, cents, 0.4 × (7)	Estimation of the theoretical minimum
Front guard	1	1	83	5.6	30	2	7.6	3.04	1
Blade cap	2	1	10	1.5	30	2	3.5	1.4	1
Fan blade	3	1	10	1.5	00	1.5	3	1.2	1
Rear guard nut	4	1	10	1.5	30	2	3.5	1.4	1
Rear guard	5	1	83	5.6	00	1.5	7.1	2.84	1
Motor housing cover	7	1	30	1.95	01	2.5	4.45	1.78	1
Oscillating knob screw	8	1	11	1.8	39	8	9.8	3.92	1
Oscillating knob	9	1	13	2.06	10	4	6.06	2.424	1
Motor housing	10	1	33	2.51	10	4	6.51	2.604	1
Motor screw	11	2	11	1.8	49	10.5	24.6	9.84	2
Motor	12	1	30	1.95	00	1.5	3.45	1.38	1
Base screw	14	2	11	1.8	39	8	19.6	7.84	2
Base	15	1	30	1.95	00	1.5	3.45	1.38	1
Regulator screw	18	2	11	1.8	39	8	19.6	7.84	2
Regulator	19	1	20	1.8	00	1.5	3.3	1.32	1
Stand	20	1	30	1.95	00	1.5	3.45	1.38	1
						Total	128.97	51.588	19
							TM	CM	NM

Eliminate Merge Minimize Resize	TM = Total manual assembly operation time CM = Total manual assembly operation cost NM = Total theoretical minimum number of parts	Design Efficiency = (3*NM)/TM = (3*19) / 128.97 = 0.442 @ 44.2%

As the product appears to be capable of being further improved, a further improvement to the second product modification was suggested for this research. The screws attaching the base to the stand are minimized from four to two and suggested to be replaced with the snap-fit mechanism as an instant secure fitting for the attachment between the base and the stand with the two number of screws as the supporters so that the cover would not come off easily from the table fan body. Meanwhile, the rubber feet at the table fan base are proposed to be eliminated due to its function is pointless as the table fan base surface texture is sufficient to prevent the table fan from sliding.

Table 4 indicates the total assembly operational time for the second product modification is 128.97 seconds or approximately 2 minutes which has a shorter time compared to the first product modification. This shows that the total assembly operational time for the second product modification can be saved up to 109.4 seconds from the current design compared to the first product modification which is 76.6 seconds. In contrast, the overall assembly operation cost achieved in the second product modification is 51.588 cents and this indicates that the overall assembly operation cost in the second product modification has been saved up to 43.76 cents compared to the first product modification which only can be saved up to 30.64 cents from the current design. However, compared to the design efficiency of the first product modification, the design efficiency for the second product modification has indicated an improvement from 35.24 % to 44.20 %.

3.4 Result analysis and interpretation

After some improvement and redesigning parts had been implemented to the current design of the table fan, the screws were removed and the snap-fit mechanism was applied as an instant secure fitting, and at the same time provided improved performance with less cost-efficiency. Table 5 provides a summary of the outcomes of the current design, the first product modification, and the second product modification.

Table 5: Outcomes summary for the current design, first product modification, and second product modification

Description	Current design	First product modification	Second product modification
Parts number	31	25	19
Assembly operation time, s	238.37	161.77	128.97
Assembly operation cost, cents	95.348	64.708	51.588
Design efficiency, %	31.46	35.24	44.2

Table 5 indicates a comparison of parts number, assembly operation time, assembly operation cost, and design efficiency between the current product, first product modification, and second product modification. The total parts number is decreased from 31 for the current product to 25 for the first product modification and continue decreased to 19 for the second product modification. This indicates a complete reduction relative to the current product of 12 parts for the second product modification with the reduction percentage of 38.71 %.

In the meantime, the assembly operation time is decreased from 238.37 seconds to 161.77 seconds in the first product modification while the second product modification is decreased to 128.97 seconds. That results shows the reduction percentage for the assembly operational time between the second product modification and the current product is 45.90 % compared to the first product modification which can only decrease by up to 32.13 %. This also means that the second product modification has a shortened installation operating time and will save more time compared to the first product modification due to the second product modification has fewer redundant parts and assembly difficulties during the assembly process.

Next, the approximation reduction for the assembly operation cost from 95.348 cents to 64.708 cents in the first product modification and 51.588 cents for the second product modification. This leads to a decrease of 45.90 % between the second product modification and the current product. Based on the results assessment, it can be seen that the assembly operation cost for the second product modification is cheaper than the first product modification and current product.

However, unlike assembly operational time and cost, the design efficiency indicates an improvement for the first and the second product modification. According to Table 5, the efficiency of the design is improved from 31.46 % to 35.24 % for the first product modification and 44.20 % for the second product modification. From the results, the efficiency of the design for the second product modification is better than the first product modification and the current product, which indicates that the second product modification has fewer redundant parts and complications than the first product modification and the current product during the assembly operation.

In the first product modification, a decrease in the assembly operational time and cost is accomplished by removing the four screws that attached the motor housing cover to the motor housing as seen in Figure 2 and replaced with the snap-fit locking technique. In addition, the screws joining the wire holder to the table fan's main body is also eliminated. The two screws in the red circle were eliminated and as seen in Figure 3, the wire holder illustrated by the yellow circle was suggested to merge within the table fan's main body. Lastly, the screws at the base of the table fan were diminished from five to four as illustrated in Figure 4.

While for the second product modification, Figure 5 reveals that the rubber feet at the table fan base in the red circle were eliminated due to its pointless function. Additionally, Figure 6 shows the screws attaching the base to the table fan's main body are minimized from four to two and suggested to be replaced with the snap-fit mechanism as an instant secure fitting for the attachment between the base and the table fan's main body with the two number of screws as the supporters to avoid the cover base come off easily from the table fan's main body.

Figure 2: Elimination of motor housing screws

Figure 3: Elimination of wire holder screws and the wire holder is suggested to merge within the table fan's main body

Figure 4: Reducing screws number from five to four

Figure 5: Elimination of rubber feet

Figure 6: Reducing screws number from four to two as the supporters to support the snap-fit secure fitting

4. Conclusion

This research is focused on evaluating an assessment of the current product and developing the table fan design using the manual DFA methodology. In this research, the DFA worksheet assessment is used by evaluating the findings with regard to design efficiency, parts number, assembly operational time, and assembly operation cost between the current design and the modified design. Throughout the results, it shows that the DFA method can minimize the complexity of the current design by decreasing the parts counts and eventually reduced the assembly operational time, assembly operational cost, and improved the design efficiency. To put it clearly, the modification of the table fan through manual DFA analysis has a greater design efficiency than the original design, while at the same time helping to minimize time and costs for the production and assembly of products.

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References

[1] M. N. Sudin, N. S. Chin, S. A. Shamsudin, and M. A. Yusuff, “Design Efficiency Analysis Towards Product Improvement for Eco-Friendly Using DFMA Method,” *Open Mech. Eng. J.*, vol. 10, no. 1, pp. 173–181, 2016, doi: 10.2174/1874155x01610010173

[2] K. F. Hasan, “TERM PAPER ON ELECTRIC FAN,” 2012

[3] Filippa von Yxkull, “Implementing Design For Automatic Assembly,” KTH ROYAL INSTITUTE OF TECHNOLOGY, 2018

[4] M. N. Ahmad, M. H. Osman, N. A. Maidin, and M. K. Wahid, “Reducing Product Cost By Implementing Dfma Methodology – Lucas Hull : a Case Reducing Product Cost By Implementing Dfma,” no. November, pp. 6–8, 2016, doi: 10.13140/RG.2.2.32881.17763

[5] M. V. Tatikonda, “Design for assembly: a critical methodology for product reengineering and new product development,” *Prod. Invent. Manag. J.*, vol. 35, no. 1, pp. 31–38, 1994

[6] M. F. Alias, “Redesign Of Rice Cooker Component By Using An Integrated Boothroyd Dewhurst Dfa And Axiomatic Design,” Universiti Malaysia Pahang, 2007