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Journal of Advanced Research Design
ISSN (online): 2462-1943 | Vol. 25, No. 1. Pages 11-19, 2016

The Significant Improvement on The Design of Pedestrian Traffic Light Using Boothroyd Dewhurst Design for Assembly (DFA) Method: A Case Study

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Abstract – *Design for Assembly (DFA) is a tool for the industry to minimize the assembly cost by optimizing the assembly process and reducing the number of parts. In this paper, the pedestrian traffic lights from PPK Technology Sdn Bhd are selected as the case study sample. The Boothroyd Dewhurst DFA method is used to improve the design and reduce the cost of the pedestrian traffic lights. The Solidworks software is used to generate the CAD models, which are further analyzed using the Boothroyd Dewhurst DFA software tool. The result from this study shows that the assembly time decreased from 758.45 seconds to 318.80 seconds per product. The significant result shows that the assembly cost reduction is from RM1175.60 to RM207.20. From the result, it has been proven that this Boothroyd Dewhurst DFA method was able to improve the design in terms of design efficiency, product assembly time, and cost reduction. This method can be applied in the manufacturing industry in order to improve their design effectiveness.*

Keywords: Design for Assembly (DFA), cost reduction, Boothroyd Dewhurst, assembly time

1.0 INTRODUCTION

The goal of DFA is to ease the assembly of products and for the DFA tools to help ease the designers towards the assembly issue. The original and the redesigned products are compared to show that the new design will contain fewer parts, hence reducing cost, assembly time, and operation. The Boothroyd Dewhurst system benefits in the reduction of part count. Reducing part count does not only save assembly and manufacturing costs, but it can also save labor, inventory, floor space, documentation, and administration. In addition, a product that has fewer parts will have increased quality because mistakes can be avoided. A recent study by Masin [1] reported that the DFA methods are essential tools in providing feedback to the designers about the design's efficiency from the assembly viewpoint. Several DFA methods are available for the determination of product complexity and ease of assembly. The Design for Manufacture and Assembly (DFMA) principles for established frameworks are used to design products in the modern developed world [2]. Schonberger [3] discussed how the DFMA principles can help manufacturers become inclined with its emphasis on simplifying designs and standardizing parts. Conventionally, designed products call for extensive quick-changeover efforts, as they typically contain an outsized array of parts. By decreasing part count, the design

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for manufacture (DFM) eliminates the need for many setups, whereas the design for assembly (DFA) eliminates the need for many changeovers. One of the earliest and most successful adopters of lean manufacturing was Bruce Hamilton, a former general manager of United Electric Controls Co. and the current president of Greater Boston Manufacturing Partnership. In previous years, Hohnsbeen [4] and Anil et al. [5] studied the impact using the DFMA design process, which can shorten or reduce of the production time rather than using the traditional construction as illustrated in Fig. 1. Adopting early conceptual-stage design collaboration reduces time, effort, and risk for clients and designers. Furthermore, the quality, accuracy, and completeness of the information produced by the design collaborators are better coordinated, more complete, less error prone, and formatted for efficient dissemination into the material and component supply chain.

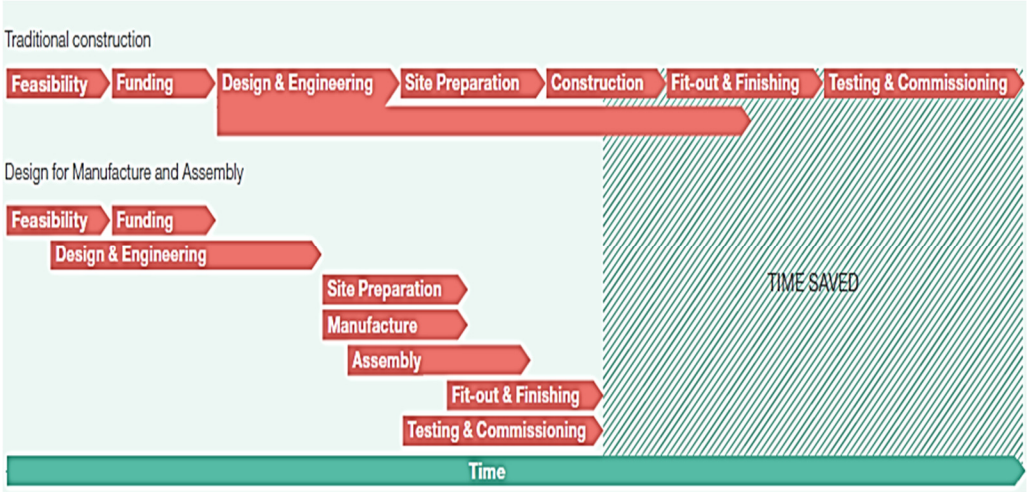

Figure 1: Impact of DFMA on design and construction program (Paul Hohnsbeen, 2013)

The application of the Design for Manufacturing (DFM) and Design for Assembly (DFA) methodologies can be beneficial to the industries involved in the design and development of products. Improper design decisions are responsible for the higher manufacturing cost for a product, according to Annamalai et al. [6]. However, Lu and Zhang's [7] study discovered that when oil fields become old, the proportion of water in the crude oil will become higher and higher. Using a traditional bulk separator to extract the water from the crude oil has many disadvantages: e.g. high pressure loss, low separation speed, heavy equipment, and sensitive to direction. Caltec Ltd. has developed Wx-12, an innovative separator for the oil and gas industry. The device has been tested on offshore platforms and has shown high performance. Currently, however, the manufacturing cost of the device is too high, making it unlikely to be accepted by the market. Subsequently, the DFA and DFM methods were applied to Wx-12 in order to make it compact and reduce the manufacturing cost.

Chang and Peterson [8] discussed various aspects and models of how the Boothroyd Dewhurst's Design-For-Assembly (DFA) methodology can be integrated into product development and design curriculum. The DFA methodology involves a team that includes all the concurrent engineering disciplines and the stakeholders in the success of the product design phase. Manufacturing engineers usually play a vital role in the conceptual design phase. Todić et al. [9] explained how the Boothroyd Dewhurst DFMA method evaluates the product based on design efficiency. The higher the design efficiency, the better the product. The number of parts of the product has significant effects to the design efficiency value. If the

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product has many parts, the assembly time will be higher. Higher assembly time means lower design of efficiency. Moreover, higher assembly time directly means that the assembly cost is higher. Therefore, the BoothroydDewhurst DFMA method recommends the elimination of unnecessary parts and the combination of many parts into fewer components to reduce the number of parts in a product. In the previous year, Sarmetnto et al. [10] studied the application of the DFA technique on an automotive fuel intake cover of a currently produced vehicle in order to simplify the current product design. The results from this comparison can be used to benchmark the DFA methods so that their weaknesses can be identified and improved [11].

In addition, Defosse [12], in his studies, reported that the Design for Assembly (DFA) module leads an engineer down a quantifiable path of parts consolidation and assembly simplification. The software methodically guides toward designs that have fewer parts and lower costs. For instance, the complex design such as the generator and gearbox of these turbines are to be placed over the tower which makes its design more expensive [23]. DFA is used as a method to improve the product and will result in cost reduction [13–15]. Based on the DFA analysis, the minimum number of workstations is needed to balance the line that will maintain the production rate (takt time) and determine the precedence constraints. Afterwards, the precedence constraints are systematically relaxed in order to generate measures on a component-by-component basis, as it could reduce the cycle time and improve the line balancing performance. These measures, coupled with an understanding of precedence types, are used to identify the design improvements of a product [16]. Hardee [17] studied that several software programs have been introduced for the analysis of design concepts that leads to the reduction in manufacturing and parts costs in the aeronautical engineering industry. Design for Manufacturing and Assembly (DFMA) is an integrated software suite from Boothroyd Dewhurst, Incorporation, and Wakefield, R.I., that helps engineers ask critical questions about their product designs early in the development process. The Design for Assembly (DFA) software guides engineers to simplify a design using questions such as the parts move with respect to one another, or they can be made of the same materials.

The DFMA procedure can typically be broken down into two stages. Design for Assembly is conducted, leading to a simplification of the product structure and economic selection of materials and processes. After iterating the process, the best design concept is taken forward to Design for Manufacture, leading to a detailed design of the components for minimum manufacturing costs [18–20]. Developments of the Boothroyd Dewhurst DFA method started in 1977 with funding from the U.S. National Science Foundation and were first introduced in a handbook form in 1980. Geoffrey Boothroyd and Peter Dewhurst, who founded the Boothroyd-Dewhurst, Inc. (BDI) in 1982, are the first persons performing the research in this new technology. The Boothroyd Dewhurst method can be used manually and in the software. The manual process can be done by referring to the tables, which are the manual handling and the manual insertion [21–22]. Surprisingly, no previous study has investigated the significance of DFA in improving the design of pedestrian traffic lights.

The main aim of this paper is to redesign and evaluate the pedestrian traffic lights by using the Boothroyd Dewhurst DFA methodology approach and estimate the assembly cost of the product. The contribution of this study is obvious as the resulting outcomes can be capitalized as guidelines to simplify the product so that the cost and time of assembly are reduced. Applying a design for analysis also improves quality and reliability, and leads to a reduction in production equipment and part inventory.

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2.0 RESEARCH METHODOLOGY

This research paper starts with a literature review towards the scope of study. The pedestrian traffic lights from PPK Technology Sdn Bhd are selected as the case study sample. The case study sample will go through the process of part disassemble and will be evaluated by using the Boothroyd Dewhurst method. The data is analyzed and the parts for modification are proposed. The redesigned parts are revaluated using the same method. The results between the original and the improved designs are compared. If the design results are improved, the next process will proceed to the sketch and produce the detail drawing. The overall process involved in this study may refer to Fig. 2.

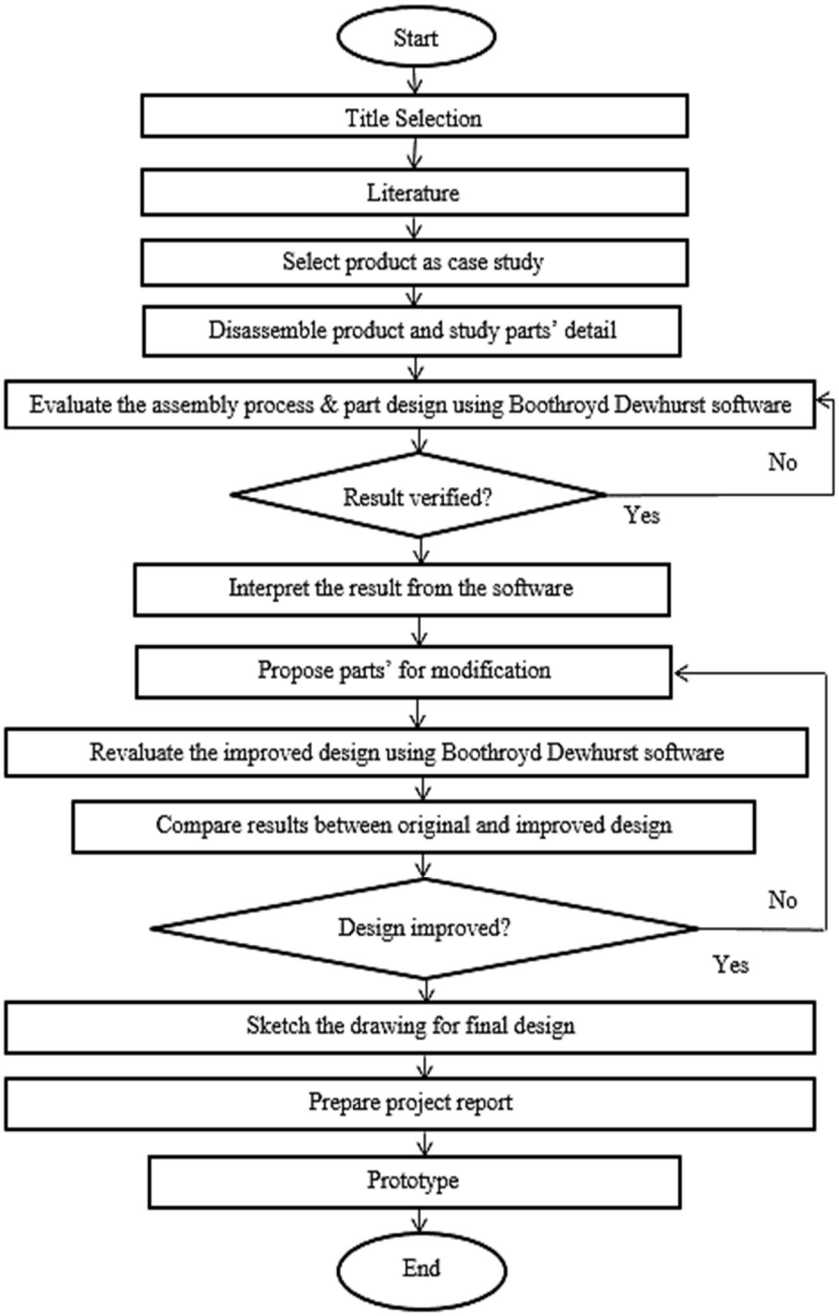

Figure 2: Flow chart of methodology

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ISSN (online): 2462-1943 | Vol. 25, No. 1. Pages 11-19, 2016

3.0 RESULT AND DISCUSSION

The pedestrian traffic light was the selected product for this research. A pedestrian traffic light is a set of automated operated colored lights, typically red and green for controlling traffic at crosswalks, which give safety to the pedestrians to cross the road. This product consists of 16 main parts. Fig. 3 shows the tree structure of the original part that will show the structure and number of parts.

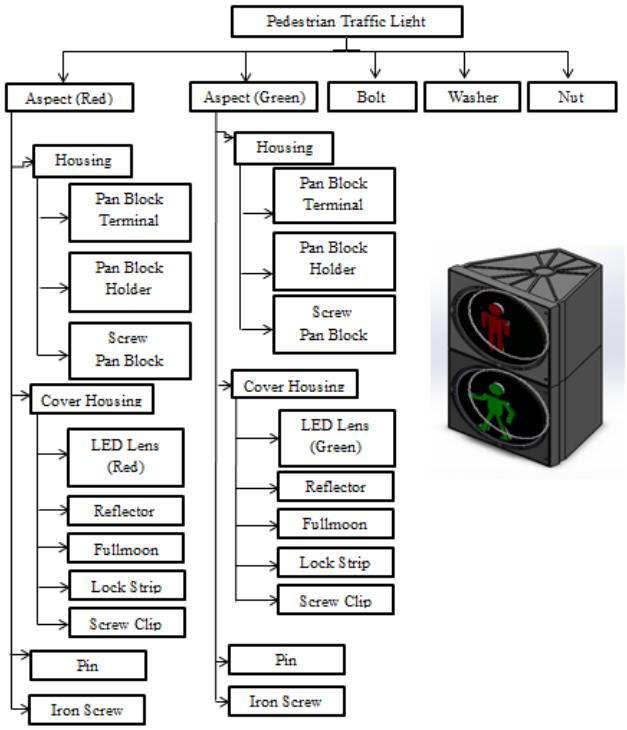

Figure 3: Tree Structure (original)

The suggestion to redesign, in which the pin is combined with the cover housing to be eliminated, is shown in Fig. 4. This can help in reducing the assembly time of the cover to the housing. By following the British International Standards Organization (ISO) Standard, the shaft is the interference fit with H6/P7, while the hole is H7/p6.

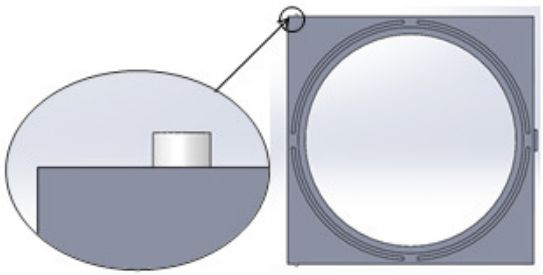

Figure 4: New design of the cover housing after combining the pin to the cover

The bolt, washer, and nut are also eliminated based on guideline number six in the guidelines of insertion and handling, which can help in lowering the assembly cost. It also follows

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guideline number four in the guidelines for fixed or hard automation to avoide screws. The new design has been produced, which is the interference fit. Interference fit, also known as press fit or friction fit, is a fastening between two parts, which is achieved by friction after the parts are pushed together, rather than by any other means of fastening. The new design of housing is shown in Fig. 5.

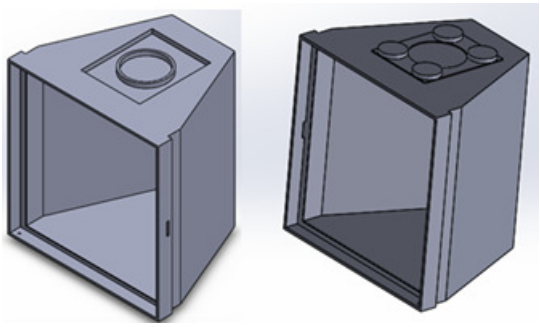

Figure 5: The new design for housing

The last redesign process is by eliminating the iron screw as in Fig. 6. This follows guideline number four in the guidelines for fixed or hard automation to avoide screws. Fig. 7 shows the modeling of the pedestrian traffic light between the original and the redesigned models.

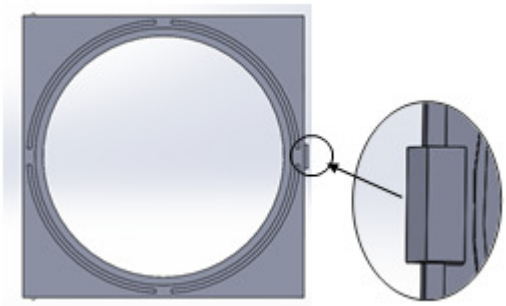

Figure 6: New design of the cover housing after eliminating the iron screw

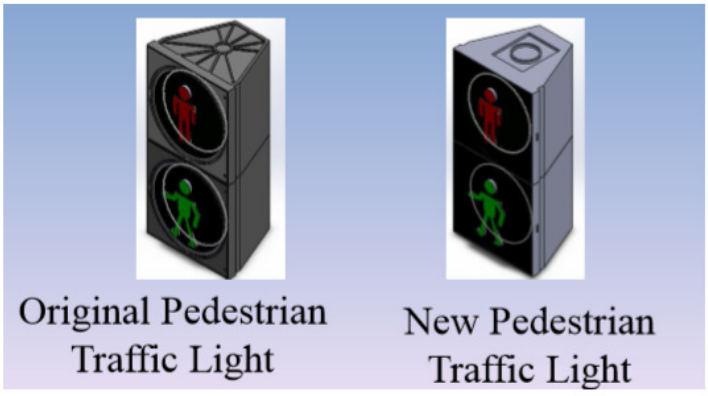

Figure 7: The comparison between original and redesigned models

In addition, the application of the Boothroyd Dewhurst DFA method was able to improve the design of the pedestrian traffic light, which will then reduce the product assembly time and cost as in Table 1. The reduction percentage of assembly time and assembly cost are 58% and 82%, respectively.

Table 1: Reduction percentage for the DFA analysis

Criteria	Original Result	New Result	Reduction percentage, %
No. of part	64	36	44
Total labor cost, RM	1.55	0.65	58
Total assembly time, s	758.45	318.80	58
Total assembly cost, RM	1175.60	207.22	82

4.0 CONCLUSION

The improvement of product design by using the Boothroyd Dewhurst DFA method is able to produce significant results upon product assembly time and assembly cost. The assembly cost of pedestrian traffic lights is reduced from RM1175.60 to RM207.22. This will give significant effects to companies, whereby reducing the production cost will increase the profit margin. Important conclusions have been obtained and are summarized as follows:

i. The Boothroyd Dewhurst DFA method is a powerful tool to reduce the cost of assembly.
ii. The DFA method is able to reduce the number of parts and assembly time.
iii. The DFA method is available for the determination of product complexity and ease of assembly.

ACKNOWLEDGMENT

The authors wish to thank Universiti Teknikal Malaysia Melaka (UTeM) for supporting this research.

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