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Integration of Value Engineering for Design for Assembly in Product Design: A Comprehensive of Literature Review

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ABSTRACT

This study explains the benefits obtained from the integration of Design for Assembly (DFA) and Value Engineering (VE) methods in the product design process. DFA is proven to provide benefits such as product simplification, reduced assembly costs, and improved quality by creating product structures that are simpler and easier to install. While VE adds value by taking into account the replacement of expensive or difficult-to-assemble components, speeding up overall assembly time. Although specific research on the integration of these two methods may be limited, studies show that the combination of DFA and VE produces design alternatives that consider various aspects of the product life cycle. The result is reduced costs, faster development times, and a reduced need for rework. The concepts and benefits of integrative DFA and VE approach can be an effective strategy for enhancing assembly efficiency and reducing production costs in product design.
Keyword: Design for Assembly, Literature Review, Product Design, Value Engineering

ABSTRAK

Studi ini menjelaskan manfaat yang diperoleh dari integrasi metode *Design for Assembly* (DFA) dan *Value Engineering* (VE) dalam proses desain produk. DFA terbukti memberikan manfaat seperti penyederhanaan produk, pengurangan biaya perakitan, dan peningkatan kualitas dengan menciptakan struktur produk yang lebih sederhana dan lebih mudah dipasang. Sementara VE menambah nilai dengan mempertimbangkan penggantian komponen yang mahal atau sulit dirakit, mempercepat waktu perakitan secara keseluruhan. Meskipun penelitian spesifik tentang integrasi kedua metode ini mungkin terbatas, studi menunjukkan bahwa kombinasi DFA dan VE menghasilkan alternatif desain yang mempertimbangkan berbagai aspek dari siklus hidup produk. Hasilnya adalah pengurangan biaya, percepatan waktu pengembangan, dan kebutuhan akan perbaikan yang lebih sedikit. Konsep dan manfaat pendekatan DFA dan VE yang integratif dapat menjadi strategi efektif untuk meningkatkan efisiensi perakitan dan mengurangi biaya produksi dalam desain produk.
Kata Kunci: *Design for Assembly, Literature Review, Product Design, Value Engineering*

1. Introduction

Product design is a complex process involving various elements including function, aesthetics, reliability, and production processes [1]. Among the diverse approaches used in designing products, Design for Assembly (DfA) stands out as a crucial methodology in optimizing assembly processes [2].

DFA is a product engineering approach that aims to design products by minimizing the number of components and assembly steps so as to reduce costs and assembly time [3]. Several studies have shown that implementing DFA can lower production costs and provide far greater benefits than just reducing assembly time [4]. DfA is not just a concept, but a systematic approach that considers ease of assembly at every stage of design. Its main focus is on simplicity of structure, reduction in the number of components, and ability to assemble products efficiently [5]. DfA has become a key focus in the industry to reduce production costs, speed up assembly time, and improve operational efficiency [6]. As technology advances and market dynamics, these approaches continue to evolve to meet increasingly complex demands.

DFA has several weaknesses in capturing qualitative aspects that are important at the development stage [7]. This can be overcome by value engineering methods that provide a more thorough quantification of component functions, alternative generation of components, and economic factors that are not fully covered by DFA [8].

In this context, a literature review becomes important to consider the integration of DfA with other methodologies, such as Value Engineering (VE), to produce designs that are not only easy to assemble but also provide maximum value at minimal cost. On the other hand, VE is a process of evaluation and optimization of designs to achieve better or equivalent results at a lower cost [9]. The main objective of VE is to increase the value of products received by consumers while considering the cost, quality, and functional aspects of the product [10].

This study aims to examine the concepts of DFA and VE, through a systematic literature review. The study focused on showing how the integration of the two concepts was able to produce an optimal product design in terms of value and cost. The results of the research are expected to provide theoretical and practical implications for efficient and effective product development in the future.

2. Method

The literature search method used refers to databases of leading international journals such as Scopus and Web of Science with the keywords "Design for assembly" or DFA and "Value engineering" or VE. Inclusion criteria include articles discussing actual implementation of DFA and VE and offering impact measurement through empirical studies in the manufacturing industry. Conceptual studies or those that address only one aspect of DFA or VE, as well as those that do not present quantitative data on implementation, are excluded from selection. The selection process involves a brief review of articles that fit the inclusion and exclusion criteria, with an emphasis on quantitative data on implementation impact, especially in the context of case studies in the manufacturing industry. At is expected to achieve a comprehensive literature review on the integration of DFA and VE and identify gaps that can be the basis for further research on the topic.

3. Design for Assembly

Design for and Assembly (DfA) seeks to simplify products so that assembly costs are reduced [11]. The application of DfA principles to product design usually results in improved quality and reliability as well as a reduction in production equipment and inventory parts [12]. It has been repeatedly observed that these secondary benefits often outweigh the reduction in assembly costs. In principle, the need to analyze the design and the entire product for any assembly problems early in the process to cut costs during the product cycle process and also aim to improve the design product for easy and inexpensive assembly, which is achieved in a concurrent way [13].

3.1. DfA Steps

The steps to improve product design are carried out using the DfA (Design for Assembly) method according to Boothroyd et al (2011) as follows [14].

1. Drawing up a design concept. The first step in DFA is the drafting of a design concept for the identification of product objectives [15].

2. Carry out the evaluation of product components from the initial design. After the initial design concept is developed, the design team must evaluate the components in the product to identify components with assembly problems, excessive complexity, or high cost and propose improvements to product simplification [16].

3. Identify components of product development. The design team identified the components by design simplification to improve assembly efficiency [4].

4. Calculates design efficiency, assembly time, and assembly cost. Boothroyd & Dewhurst argue Design efficiency is a measure of the DFA index or "assembly efficiency" of a proposed design. The DFA index is

a number obtained by dividing the theoretical minimum assembly time by the actual assembly time through the following equation [17].

$$Ema = \frac{(Nmin \times Ta)}{Tma} \quad (1)$$

where Nmin is the theoretical minimum, Ta is the base assembly time for one part, and Tma is the estimated time to complete product assembly. Base assembly time (Ta) = 3 seconds, which is the average time for parts that have no difficulty handling, inserting, or binding.

5. Final product improvement design. The design team designed the final product with product improvements that are easy to assemble, efficient in terms of cost, and in accordance with the original purpose of the design [18].

4. Value Engineering

Value engineering is a design engineering technique that involves a critical examination and analysis of the design of a component with reference to its functional value to obtain equal or better performance at a lower cost, so as to increase the value of goods, or products and services by optimizing value for money in the project and emphasizing analyzing the functional values of all component design features [19].

4.1. Value Definition

Value is perception, therefore, each customer will have his or her own perception of how they define value [20]. However, we can relate value to quality, performance, style, and design as opposed to product cost. Value is a measure of the performance of a product in relation to the function of the product or service in relation to the costs and expenses to make it [21]. Products can be engineered to increase value by either improving quality, reliability, availability, maintenance, serviceability, etc., at the same cost or by reducing costs to degree factors of quality, reliability and others [22]. In short, value analysis produces more functions at a fixed cost or fixed functions at a lower cost.

4.2. Stages of Value Engineering

Creative thinking is needed in completing value analysis [23]. The application of the value engineering method consists of 4 phases:

1. Drawing up a design concept. The first step in DFA is the drafting of a design concept for the identification of product objectives [24].

2. The creative phase develops alternative product/process designs based on the creative ideas generated. Focus on increasing value through unnecessary elimination, simplification, and replacement of materials/components [25].

3. The evaluation phase identifies and evaluates and selects which creative ideas are most likely to be implemented. Consider technical factors, cost, and value to customers [26].

4. The recommendation phase plays the key role that the value analyst team prepares a report detailing several factors that are considered to have been detailed earlier, emphasizing net cost savings to management as their recommendations. Once recommendations are received, operators and relevant personnel should be trained and follow up periodically to maintain established implementation [27].

5. Integration

The use of DFA methods has been shown to improve product design as well as reduce assembly time and costs [28]. Some of the benefits obtained include product simplification, reduction of assembly and overhead costs, quality improvement, and acceleration of time to market [29]. In addition, the integration of Design for Assembly (DFA) with Value Engineering (VE) also brings a number of advantages to the product design process. Product development can be done by improving existing product attributes or designs to improve product quality [30]. To reduce design time and costs and improve product quality, new products are generally produced by improving functionality and design by changing components and requirements which are important keys in simplification of product structure with cost benefits resulting from Design for Assembly (DfA) methods [31].

According to George Q. Huang [32], DFA helped design products with simpler and easier to install structures. While taking into account VE, the assembly process can be further improved by substituting components that have high cost and complexity or are difficult to assemble. This can ultimately speed up the overall assembly time.

The results of the study of Paulo et al. [33] show that the integration of the VE method and the DFA concept in product development results in design alternatives that already consider the requirements of various areas involved in the product life cycle. This in turn results in reduced costs, development time, and rework needs. In addition, the implementation of this structured process is able to significantly improve the balance of value and cost in the Company

Studies that support the integration of DFA (Design for Assembly) and VE (Value Engineering) methods can be found in a variety of contexts. For example, a study on "Development of Anti-Rain Portable Clothes Drying Products with Design For Assembly (DFA) Method" shows the application of DFA in product development to meet the needs of the Community [34]. In addition, an article explains that the application of DFA and DFMA (Design for Manufacture and Assembly) principles is necessary to reduce the time and cost of producing a product [35]. Although not directly related to the integration of DFA and VE, the results of this study show the benefits of applying the DFA method in reducing production costs. Although research results specifically addressing the integration of DFA and VE methods may be limited, the concepts and benefits of each method have been extensively documented in the engineering and management literature. DFA and VE integration can provide benefits in terms of product simplification, reduction in assembly costs, quality improvement, and acceleration of time to market [36]. In addition, DFA helps design products with simpler and easier to install structures, while VE can improve the assembly process by substituting components that have high cost and complexity or are difficult to assemble. The study results also show that the integration of the VE method and DFA concept in product development can result in design alternatives that consider the requirements of various areas involved in the product life cycle, resulting in reduced costs, development time, and rework needs [37].

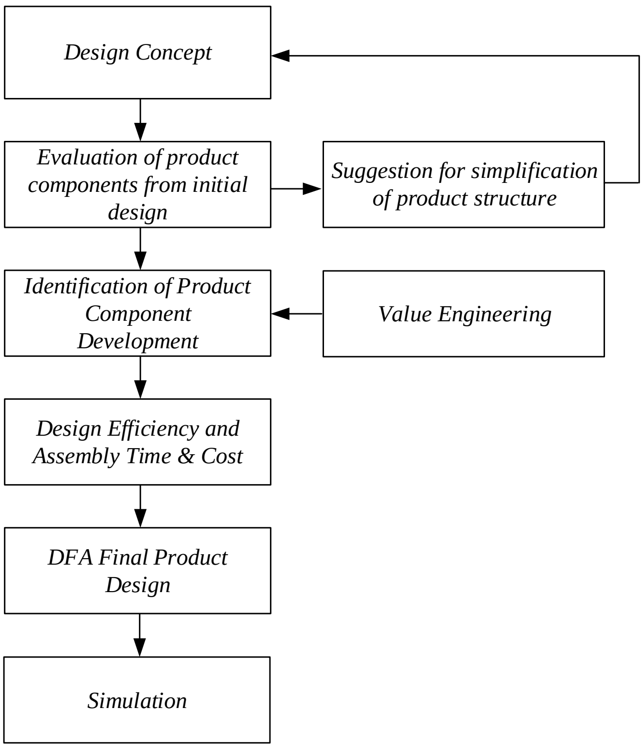

Figure 1. Block Diagram of DFA and VE Method Integration

Design for Assembly (DfA) integration with other design methodologies such as Value Engineering (VE) offers synergistic benefits that enhance product design and manufacturing efficiency. When combined with DfA, VE allows for a comprehensive evaluation of product components to optimize value without sacrificing functionality [33]. By identifying and replacing expensive or complex components with more cost-effective alternatives, VE enhances the overall cost-effectiveness of the product while DfA ensures that these replacements do not sacrifice assembly ease. Integrating DfA with VE facilitates a more efficient and effective product development process, resulting in products that are not only easier to assemble but also more cost-effective to produce [38].

DfA and VE have complementary roles in an efficient and effective product design process. DFA is closely related to product simplification and reduction of assembly costs with a focus on product design that is easy to assemble [39]. This method focuses on simple structure and ease of assembly. In contrast, VE is concerned with evaluating the value of components or processes in a product to maximize value by considering function, cost, and performance [38].

The integration of DfA and VE methods brings a number of benefits in the product design and development process. DfA helps simplify the product structure so that it is easier to assemble, while VE complements by evaluating the value of each component and process in the product structure to maximize cost efficiency. These two methods complement each other in optimizing product functions while considering costs. If DfA focuses on improving ease of assembly, VE ensures that the selected components have optimal value and cost for a particular function.

6. Conclusion

In the product design process, the Design for Assembly (DFA) method has been proven to provide great benefits such as product simplification, reduction of assembly costs, and quality improvement. Meanwhile, the integration of DFA with Value Engineering (VE) adds value to this process. DFA helps in creating a simpler and easier to install product structure, while VE considers the replacement of expensive or difficult-to-assemble components, ultimately speeding up overall assembly time. This integrative approach can be an effective strategy for enhancing assembly efficiency and reducing production costs in product design. Studies have also shown that the integration of these two methods results in design alternatives that consider various aspects of the product life cycle, reducing costs, development time, and the need for rework. Thus, although there may not be specific studies that explicitly address the integration of DFA and VE, the concepts and benefits of these two methods have been proven in a variety of contexts, and their application can provide significant benefits in product development and assembly processes.

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