Jurnal Sistem Teknik Industri
Journal homepage: https://talenta.usu.ac.id/jsti

Combination Between Design for Assembly and Design for Serviceability Method in Concurrent Engineering: A Literature Review

Akbar Gading Alfadli Harahap*[1], Rosnani Ginting[1], Aulia Ishak[1]
[1]*Industrial Engineering Department, Universitas Sumatera Utara, Medan, 20155, Indonesia*
*Corresponding Author: akbargading2003@gmail.com

ARTICLE INFO

Article history:
Received 17 April 2025
Revised 9 October 2025
Accepted 6 January 2026
Available online 23 February 2026

E-ISSN: 2527-9408
P-ISSN: 1411-5247

How to cite:
A.G.A. Harahap, R. Ginting, and A. Ishak, "Combination between design for assembly and design for serviceability method in concurrent engineering: a literature review," *J. Sist. Tek. Ind.*, vol. 28, no. 1, pp. 1–10, Feb. 2026.

ABSTRACT

Increased competition in the industry encourages companies to focus on customer satisfaction to maintain competitiveness. The combination of Design for Assembly (DFA) and Design for Serviceability (DFS) methods is a common concern for researchers, especially in product development. This research describes the integration of DFA and DFS methods to solve product problems, starting from the method development stage, the interrelationship between the two methods, etc. The successful application of these methods is evident through high efficiency and improved product quality. Key factors involved management cooperation, use of quality tools, and teamwork. Leading journals highlight product cost reduction through Design for Serviceability and DFA techniques. Emphasis on sustainability, especially by integrating sustainability goals in product design, evidenced positive environmental impact and market response. Research also highlighted the need for identification and prioritisation of customer requirements and optimisation of production process parameters. The integration of modelling methods and design systems, such as in the development of a modelling system for metal casting processes, demonstrated success in achieving effective product development goals. Overall, this research provides an in-depth understanding of the potential and benefits of applying DFA and DFS in efficient, high-quality and sustainable product development, providing a foundation for further development and implementation by practitioners and researchers.

Keyword: Product Design, Concurrent Engineering, Design for Assembly, Design for Serviceability

ABSTRAK

Persaingan yang semakin ketat dalam industri mendorong perusahaan untuk fokus pada kepuasan pelanggan guna mempertahankan daya saing. Kombinasi metode DFA dan DFS menjadi perhatian umum bagi peneliti, khususnya dalam pengembangan produk. Penelitian ini menggambarkan integrasi terhadap metode DFA dan DFS untuk menyelesaikan masalah pada produk, mulai dari tahap pengembangan metode, keterkaitan antara kedua metode, dll. Keberhasilan penerapan metode ini terbukti melalui efisiensi tinggi dan peningkatan kualitas produk. Faktor kunci melibatkan kerjasama manajemen, penggunaan alat kualitas, dan kerja tim. Jurnal-jurnal terkemuka menyoroti pengurangan biaya produk melalui teknik Design for serviceability dan DFA. Penekanan pada keberlanjutan, terutama dengan mengintegrasikan tujuan keberlanjutan dalam desain produk, membuktikan dampak positif terhadap lingkungan dan respons pasar. Penelitian juga menyoroti perlunya identifikasi dan prioritisasi kebutuhan pelanggan serta optimalisasi parameter proses produksi. Integrasi metode pemodelan dan sistem desain, seperti dalam pengembangan sistem pemodelan untuk proses perancangan produk, menunjukkan keberhasilan dalam mencapai tujuan pengembangan produk yang efektif. Secara keseluruhan, penelitian ini memberikan pemahaman mendalam tentang potensi dan manfaat penerapan DFA dan DFS dalam pengembangan produk yang efisien, berkualitas tinggi, dan berkelanjutan, memberikan landasan bagi pengembangan dan implementasi lebih lanjut oleh praktisi dan peneliti.

Keyword: Perancangan Produk, Rekayasa Serempak, Design for Assembly, Design for Serviceability

http://doi.org/10.32734/register.v27i1.idarticle

1. Introduction

Understanding and fulfilling each individual's needs has been considered a challenge of every industry[1]. Industrial competition between companies is currently increasing. So that companies are increasingly competing to be able to provide satisfaction to customers by meeting customer needs according to customer expectations or expectations [2]. Today's average consumer has many options available to choose from similar products and services. Most consumers make choices based on a general perception of quality or value. For remain competitive, organizations must determine what drives consumer perceptions of value or quality in a product or service. These companies use a structured process to determine the wants and needs of their customers and turn them into specific product design and process plans to produce products that meet customer needs [3]. By successfully knowing customer needs, the process of improving the product can be carried out so that it becomes a product according to market desires [4].

In the process of producing products, companies often overlook certain aspects, particularly the ease of assembly and service, which may pose challenges for users in the event of product failure. Furthermore, a production process that does not prioritize customer needs may result in products that fail to remain competitive in the market over time.

Product design is an activity that begins with the analysis of perceptions and opportunities, and ends with the production, sale, and distribution of products [5]. Product design should involve the scientific application of organizing a particular component in order to achieve the purpose of the product, with several conditions: the principle of organizing the component must be established, accessibility to the device must be available, the cost of the result can be approved, the appearance of the component can be approved, etc. [6] [7].

There are 3 main studies to achieve these product goals, namely the relationship between people, products and the environment [8]:

1. Human studies [9]: Study to understand human needs such as physical needs, security, social needs, etc.

2. Product study [10]: Some elements will affect the user's needs. To make it specific, there are several aspects to the product, namely the product design must be consistent, in accordance with the user's psychological state, and in accordance with the user's safety and comfort.

3. Study of the environment [11]: Each type of environment will affect the user's needs. This means that people from different environments such as cities with high and low living costs will require different product performance.

In manufacturing activities, especially product design, the term concurrent engineering (CE) is known, which is a systematic approach to product design and manufacturing processes by integrating various types of disciplines in the product development life cycle. The main objective of CE is to make high quality products in a time and cost-efficient manner [12]. With CE workflow, parallel activities are simulated. The ease of information transfer means engineers can work in different phases with the final design evolving simultaneously [13]. The implementation of the CE concept involves all departments and functions, making it a crucial key in the early stages of product design. These departments are marketing, design, manufacturing, etc. [14].

The driver of the CE system from each study is the long-term benefits of life cycle cost, product quality and time to market, although each company expects different benefits Varying attribute designs have been introduced since the CE approach, including manufacturability, maintainability, upgradability, and reliability [15]. Therefore, CE is not only about inter-departmental integration, collaboration in decision-making, and parallel processes but also high-level technology by emphasizing effectiveness and efficiency in the product lifecycle [16].

Design for "X" (DFX) is a type of method in product development with objectives such as quality improvement, cost reduction, cycle time reduction, and increased product flexibility. The word "X" in Design for X can be associated with various forms of product development needs, such as assembly, maintenance, etc.[17]. DFX can also be defined as a knowledge-based approach to product maximization. There is a crossfunctional concept in DFX which relates to the functions of organization, marketing, engineering, and finance [18].

Design for Assembly is a method concerned with adding and combining parts to make a finished product. This means that assembly is not part of the manufacturing process. Therefore, DFA is a design method to simplify assembly [19].

Design for Assembly can be a method for improving assembly efficiency, saving costs, and increasing business competitiveness. In the assembly process, there is an important use of measuring the DFA index or assembly efficiency of the proposed design [20].

DFS is a development method in the production process of ready-to-use products with applications tailored to the needs of each problem. The integration process of the DFS method must be adapted to the problem solving, so that the objectives can be achieved and the problem can be solved [21]. In addition, DFS is a flexible method and can help practitioners and scientists to determine requirements based on problems [22].

The purpose of the DFS method is to develop products that can function further both through their attributes and functions. In addition, problem solving with the DFS method allows the product to be more easily repaired, tested, and managed when defects or technical problems occur. This approach continues to be developed in order to assist designers in improving quality, reducing the number of components and assembly costs, and quantifying design improvements of products. The principle of DFS is to minimize time by eliminating or eliminating and combining components in the product to be manufactured [23]. The machining process and the production process must be accompanied by maintenance, as a form of maintaining and maintaining the components in the machine so that it can last long so that it can achieve maximum production results [24].

The combination of Design for Manufacture and Assembly (DFA) with Design for Serviceability (DFS) is useful for achieving certain targets in research. If the product has problems in the assembly process and the production process is costly and time consuming, the production activities will be hampered. In addition, Design for serviceability allows other problems to be solved on the product, especially on maintenance issues [25].

The aim of this study is to examine the scholarly development surrounding product design, particularly in the integration between DFA and DFS methods. This integration enables companies to assess both the ease of assembly and the serviceability of a product.

2. Research Methodology

2.1. Design for Assembly (DFA)

DFA is a term for “to assemble” regarding the addition and joining of parts into a finished product. This means that assembly is not part of the manufacturing process. DFA is used for 3 things, namely [26]:

1. As a basis for concurrent engineering studies to guide the design team in simplifying the product structure, reducing manufacturing and assembly costs.

2. As a form of benchmarking to competitor's products and quantifying the difficulty of manufacturing and assembling the product

3. As a proposal tool for negotiating contracts with suppliers.

The steps of Design for Assembly are as follows [27]:

1. Drafting the design concept: The first step in DFA is the drafting of a design concept to identify product objectives and customer needs.

2. Carry out evaluation of product components of the initial design: Once the initial design concept has been developed, the design team should carry out an evaluation of the components in the product with the aim of identifying components with assembly problems, complexity, redundancy, or high cost and propose improvements to simplify the product.

3. Identify product development components: Design team identifies components for design simplification to meet efficient assembly requirements.

4. Calculating design efficiency, assembly time and assembly cost: Design efficiency is obtained by dividing the theoretical minimum assembly time by the actual assembly time.

5. Final product design: The design team designs the final product with improvements to make the product easy to assemble, more cost-efficient, and in line with the original design intent.

One of the problem-solving methods in DFA is the snap-fit approach, which is an integral locking mechanism to attach one part to another. Snap-fit is commonly associated with plastic parts. Snap-fit differs from loose or chemical mounting methods in that it does not require additional pieces, materials, tools to perform the mounting function [28].

The steps in Snap-fit are as follows [29]:

1. Defining the application: Explain in advance the use of the application to the problem.

2. Benchmark: Comparing one product to another to compare problems and solutions to be implemented.

3. Create multiple concepts: Form alternative concepts to distinguish the advantages and disadvantages of lockdowns.

4. Design of connection type: Use the best type of snap-fit connection

5. Customize the design with parts: The use of locks must be matched with the part to be combined

6. Refine the design

7. Snap-fit application completed

2.2. Design for Serviceability (DFS)

Design for Serviceability is a product design approach focused on maintainability The goal of DFS is to ensure that the product is easy to solve all its problems so that the product can work as much as possible, both in terms of attributes and functionality [30]:

The steps in DFS are as follows [31]:

1. Identify product development components: Design team identifies components for design simplification to meet efficient assembly requirements

2. Calculate the time and number of proposed components: The design team calculated the time and number of proposed components after identifying the product development components and proposed product simplification.

3. Calculate the design efficiency, assembly time, and assembly cost of components: Design efficiency with is the number obtained by dividing the theoretical minimum assembly time by the actual assembly time.

4. Final product improvement design: The design team designs the final product with improvements to make the product easy to assemble, more cost-efficient, and in line with the original design intent.

3. Method’s Integration

The research methodology “Combination of DFA and DFS Methods: Review of Literature” was conducted with a systematic approach to investigate and describe the integration between Design for Manufacturing and Assembly and Design for serviceability in product development. The research carefully selected and evaluated literature from reputable journals to gain a comprehensive understanding of the advantages, challenges, and potential synergies between DFA and DFS. Through the identification of research objectives, selection of information sources, and determination of inclusion-exclusion criteria, this research discusses recent advances in the merger of the two methods. The process of data collection and in-depth analysis of literature findings formed the basis for compiling a literature review that integrates key findings with cohesive arguments, ultimately providing an in-depth understanding of the role of DFA and DFS in product development and their potential impact on product efficiency and quality. Basically, in search of the literature sources on this literature review is using keywords, such as Design for Assembly and Design for Serviceability that represent the methods in this field of research [32].

The integration steps of the DFA and DFS methods are shown in the following figure.

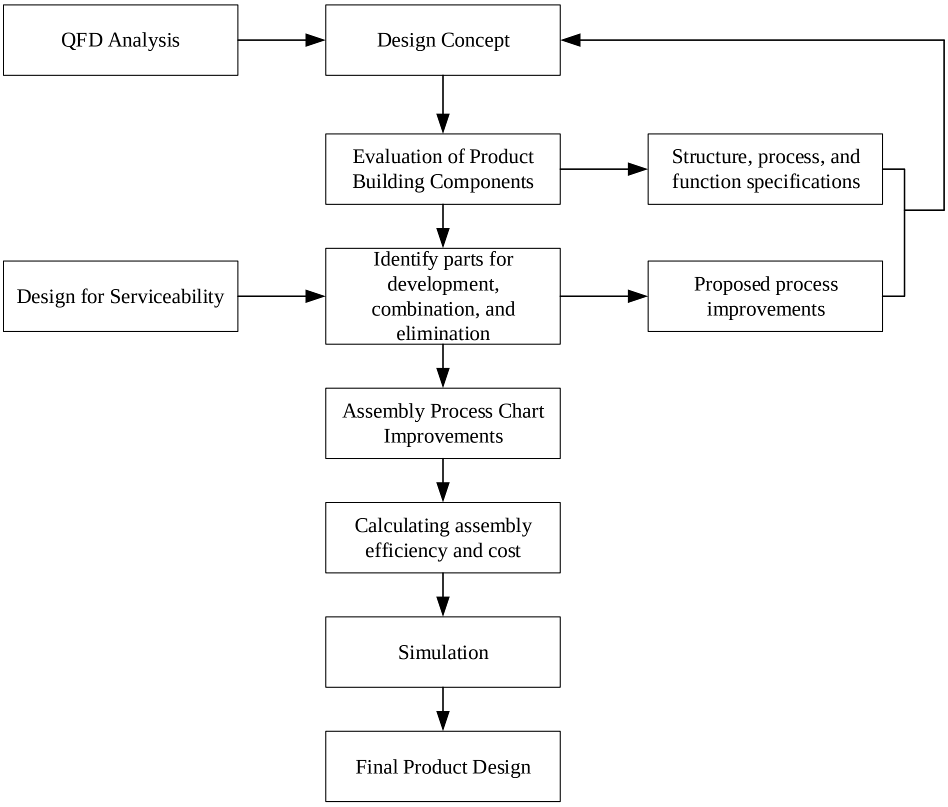

Figure 1. DFA-DFS Integration

Based on Figure 1, the steps of DFA-DFS integration as follows:

1. QFD Analysis: A two-phase Quality Function Deployment (QFD) analysis was conducted. Phase I of the QFD analysis was to determine the technical characteristics of the product, i.e. the characteristics and advantages of the product [33]. QFD Phase II analysis was conducted to determine the critical part of the product, i.e. the part of the product to be improved immediately [34].

2. Design Concept: The design concept is applied to define the initial structure of the product based on materials, production steps, and product assembly activities to identify the initial symptoms of problems in the product [35].

3. Evaluation of product components: An evaluation of the product was conducted. The evaluation was conducted using a questionnaire instrument to determine the cause of the problem [36].

4. Identify parts for development, combination, and elimination: To carry out product redesign, some parts will be modified for easy combination, assembly, and even elimination using engineering tools. At this stage, integration with DFS is also carried out to enable engineering of the product to make it easier to assemble and maintain [37].

5. Assembly Process Chart Improvements: The Assembly Process Chart will be improved based on the combination and elimination of certain parts in the product. This will have implications for the improvement of the assembly process on the product [38].

6. Calculating Assembly Efficiency and Cost

The efficiency calculation will use the following formula [39]:

$$EM = \frac{(3 \times NM)}{TM} \quad (1)$$

Description:
EM = Product Design Efficiency
NM = Number of Components
TM = Assembly Time

Assembly Cost can be measured by the following formula [40]:

$$\text{Assembly Cost} = (\text{Cost/Second}) \times \text{Assembly Time} \quad (2)$$

7. Simulation: Simulation with stress analysis is a method to understand how a material or structure will respond to various loads or stresses. It is carried out to simulate real conditions on a machine model using software [41].

4. Results and Discussion

Halttula (2017) states that DFS is a method with the function of reducing waste in production. In addition, DFS shows that improvements are repetitive [42]. Peruzzini (2018) mentions that research on DFS can be integrated with other kinds of digital research. DFS can serve to simplify calibration activities and tailor its needs to the user [43]. Research by Favi (2021) shows that solving and planning in product design engineering can be integrated with DFS, one of which is by using CAD [44].

Junior & Borsato (2020) state that there is a relationship between DFA and DFS, namely DFS is a further development of the DFA method. With the Design for Serviceability method, the product does not need to be deformed every time maintenance is carried out, but will carry out simplification of the parts in the product [45]. Pudi's research (2023) emphasizes the importance of recognizing customer needs in product development and cost reduction, using concurrent engineering techniques such as DFS, DFA, and DFM. The implementation of these techniques can significantly reduce product costs and improve the development process, and have a positive impact on the company's success and production chain efficiency [46].

Alric's research (2022) emphasizes that in product development, the integration of the snapfit method with the solidworks method can find difficulties when carrying out assembly. Then, the assembly can be completed with snap-fit [47]. In addition, assembly efficiency in the product assembly process can be improved by the integration of DFS and DFA [48]. Ginting and Fattah (2019) mentioned that the product assembly process greatly impacts the reduction in the amount of costs and also assembly efficiency. This causes the production process with DFA to minimize waste and assembly time [49]. Guo & Sun's research (2022) states that one approach to implementing DFA is to snap-fit so that the product will be easier to remove based on the geometry, friction, and interaction between parts [50]. Arifiansah (2022) emphasized that the DFA method can reduce the number of parts which can lead to increased assembly effectiveness, decreased work time, and reduced mass of the object [51].

Based on Table 1, integration between DFS and DFA yields several benefits, including, enhanced design efficiency, reduced assembly costs and assembly time, as well as improved ease of product maintenance. Based on previous studies, there has been limited integration between Design for Serviceability (DFS) and Design for Assembly (DFA). The integration of these two methods can be implemented as illustrated in Figure 1. To identify customer needs. Quality Function Deployment's analysis can be utilized to derive technical characteristics and critical parts that require improvement. By identifying these critical parts, the integration of the DFA and DFS methods is carried out in the third stage, which involves identifying parts for development, combination, and elimination. This process ensures that components that complicate assembly and maintenance can be modified, leading to a product design that is more assembly and maintenance-friendly.

Table 1. Tabulation of Research Methods

Reference	Combination of Methods in Concurrent Engineering		Conclusion
	Design for Serviceability	Design for Assembly	
Haltula (2017)	✓		Accessibility is the urgency to have an easy service for the product itself.
Peruzzini (2018)	✓		Serviceability has its own performance index to measure the ease of product service.
Favi (2021)	✓	✓	DFS basically is part of DFA. Having a simple design help product to be maintained and serviced
Junior & Borsato (2020)	✓	✓	The ease of assembly can affect the ease of serviceability.
Pudi (2023)	✓	✓	Accessibility on product is the main point in serviceability. It can be obtained by having ease on product assembly.
Ginting & Fattah (2019)		✓	Eliminating components on product design can increase the design efficiency on assembly
Guo & Sun (2022)		✓	Material selection and geometrical shape play a big part on product assembly
Alric (2022)		✓	Snap-fit is one way to increase the ease of assembly of product.
Arifiansah (2022)		✓	Eliminating certain element on the product can help to reduce assembly time

5. Conclusions

The application of DFA and DFS in product development, it can be concluded that the integration of these methods has a significant positive impact. Management cooperation, the use of quality tools, and teamwork proved to be key factors in the successful application of these methods. In addition, several journals emphasize the product cost reduction that can be achieved through DFA techniques and other methods such as DFS, DFA, and DFM.

The studies also highlighted the need to identify and prioritize customer requirements and optimize production process parameters. The integration of modeling methods and design systems, such as in the development of a modeling system for metal casting processes, demonstrated success in achieving effective product development goals. Furthermore, the integration between DFA and DFS resulted in the design of products that matched technical characteristics and consumer preferences.

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