Design for Manufacturing, Assembly, and Reliability on Product Redesign: Literature Review and Research Direction

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Abstract

Changes in lifestyles and consumer need the manufacturing industry to offer new products to stay competitive. A new product could be developed by improving the current product design (redesign) and aiming at cost reduction, higher customer satisfaction, and product reliability. Design for Manufacturing and Assembly (DFMA) is a concurrent product and process development approach that focuses on cost reduction by considering ease to manufacture and assembly. Besides manufacturability, product reliability is also an essential factor in the early design phase. The consequences of unreliable products could be very costly and even lead to market share loss. The primary purpose of this study is to provide insight based on current literature and propose future research opportunities on product redesign based on the integration of DFMA and Design for Reliability (DFR). Scopus database is used to obtain relevant articles, and bibliometric analysis is applied to a literature review to gratify the objective. This paper results in a systematic review of the past five years by investigating and discussing past and current DFMA and DFR for product redesign. The further research direction of product redesign framework based on DFMA approach and reliability prediction in the early design phase of product development.

Keywords
Design for Manufacturing and Assembly (DFMA), Design for Reliability, product redesign, review

1. Introduction
The manufacturing industry is faced with rapid technological changes, an increase in product complexity, and a relatively short time to market. Therefore, new product development is needed to stay in the competition. One way to introduce a new product is by redesigning the existing product when a product has been on the market for some time. (Smith, Smith and Shen, 2012). Changes in consumer needs or desires are also the main drivers for product redesign. Product redesign aims to answer any problems that occur in existing products capabilities and manufacturing processes and the development of elements of product redesign (Li, Zhou and Wu, 2020).

Designing a new product generally come from similar ones. Better product quality refers to improved ability to perform its function, such as durability, reliability, and outcome accuracy. Therefore, a new product design is generally a derivative design, which consists of changing the previous method to suit current needs (Harlalka *et al.*, 2016a; Prabowo *et al.*, 2020). It is found that more than 75% of all engineering design activities involve reusing previous design knowledge to solve new product design problems (Smith, Smith and Shen, 2012). A product can be redesigned for quality improvement, cost reduction, product life extension, environmental impact reduction, and even product reliability improvement (El-Nounu, Popov and Ratchev, 2018a; Chowdary, Richards and Gokool, 2019a). Product improvement is a critical factor affecting manufacturing costs. As a result, product designers adopt methods and techniques to improve their ability to evaluate costs and product development criteria, one of which is manufacturability. IBM, Ford, Toyota, and General Motors implemented a product redesign to reduce manufacturing costs (Geoffrey Boothroyd, Peter Dewhurst, 2010). Tesla, Apple, Honda, Boeing, and Hewlett-

Packard implemented product redesign to increase product reliability (Raheja and Gullo, 2012; Geiger and Motors, 2016).

The development of technology, especially in information technology which is very fast and the product life cycle is getting shorter, necessitates a more straightforward product development process while maintaining good product quality and competitive product prices. Concurrent Engineering (CE) is a method for integrating the design of goods and processes and their manufacturing and maintenance. Because of its promised benefits, CE has been seen as a better strategy for designing a new product (i.e., shorter time to market while maintaining the highest quality at the lowest cost) (Karningsih, Anggrahini, and Syafi'i, 2015). Determining product specifications and manufacturing processes carried out in parallel or together can minimize the high cost of rework and the risk of failure (Bowonder and Sharma, 2004). The main focus of CE is a holistic approach that considers all aspects of a product (throughout its lifetime) from the very beginning of the design process. Boothroyd (1994a) also emphasizes that the design process affects (determines) about 70% of the total cost, even though the cost required for the design process is only 5%. Therefore, the design process will have a significant effect on reducing the total cost.

The X (DFX) approach supports C.E. implementation and is used for product and process design improvements from any X perspective. The X's letter in DFX refers to a stage in the life phase of development (e.g., manufacture, assembly) or describes the characteristics the product must have (e.g., quality, reliability, environment impact) (Holt and Barnes, 2010). DFX benefits competitiveness measurement, improvement decisions in designing products and processes, lead time reduction, and material cost reduction. One of DFX's techniques is Design for Manufacture and Assembly (DFMA). DFMA focuses on identifying an inappropriate design with high manufacturing costs as early as possible and minimizing the total cost to produce a product. El-Nounu (2018) developed a DFA model for product redesign considering costs, failure analysis, obsolescence and the level of operational difficulty of components. By considering the form of failure from the existing product, it contributes to improving product design.

According to Paganin (2017), the possibility that a component, device, system, or process will run without failure for a set amount of time if used correctly in a previously stated environment is defined as reliability. Another of DFX's approaches is Design for Reliability (DFR), which strives to assure product component or system reliability at all phases of the product cycle. Product design to improve product reliability is a concept of DFR (Mayda and Choi, 2017; Pourgol-Mohammad *et al.*, 2017; Borchani *et al.*, 2019). Increasing reliability is one of the considerations for product redesign while ensuring that customer requirements are met.

In product design, the initial conceptual design stage is progressively improved as it significantly influences the successive stages of product development and production. However, it is difficult to solve problems in product redesign accurately at the initial conceptual design stage, especially in reducing DFMA-based manufacturing time and costs and improved reliability. Several integrated design models have been proposed to overcome this problem, but efforts to predict the reliability of product redesign in the early conceptual stages have not been achieved. The following is a breakdown of how this article is organized. The research technique is described in part two. We give the results of the bibliometric study, the VOS analysis, and a structured review of existing DFMA and DFR approaches. The following sections propose the opportunities for future research, while the last section concludes the article.

2. Research Methodology

This literature review conducts an initial goal of exploring the body of literature and following the related articles in a combination of DFMA, product redesign, and DFR. It uses a systematic literature review (SLR) and bibliometric analysis (B.A.) to organize the data in a more reader-friendly form. SLR explicitly contains information needed to be tailored into some helpful information. This method has been widely used across multiple study fields and representing high volumes of bibliographic (Sulistio, 2015; Paganin and Borsato, 2017; Benabdellah *et al.*, 2019). To achieve the goal of this research, the general data of the articles available in the databases Scopus was considered by using the keyword "design for manufacturing and assembly" and "design for reliability." A method for selection and analysis of the articles is shown in Figure 1.

Next, search for these keywords in the Scopus database with the format: ((TITLE-ABS-KEY ("design for" manufacturing and assembly and product redesign) OR TITLE-ABS-KEY ("design for" X and product improvement) OR TITLE-ABS-KEY ("design for" reliability and product redesign or product improvement)) AND

(LIMIT-TO (LANGUAGE, “English”))). Search results are 212 final papers and 1 article in press in the year 2000-2021. The documents have 136 conference papers, 50 articles, three reviews, others in book chapters, and lecture notes. In line with the purpose of our study, we only considered 53 articles and reviews. The articles were scrutinized to see if they should be included in the sample. Only publications with a consistent title in relation to the research's goals and axes were chosen. As a result, 52 items were left for additional investigation. The purpose of reading the abstracts was to determine the major conclusions, goals, applications, and methodology used in each article in order to find the most relevant publications for this research. During the screening process, 36 papers were chosen, with the remaining articles being put on hold for further examination and possible selection. The remaining 14 articles were then chosen and added to the list, resulting in a total of 50 articles for final analysis.

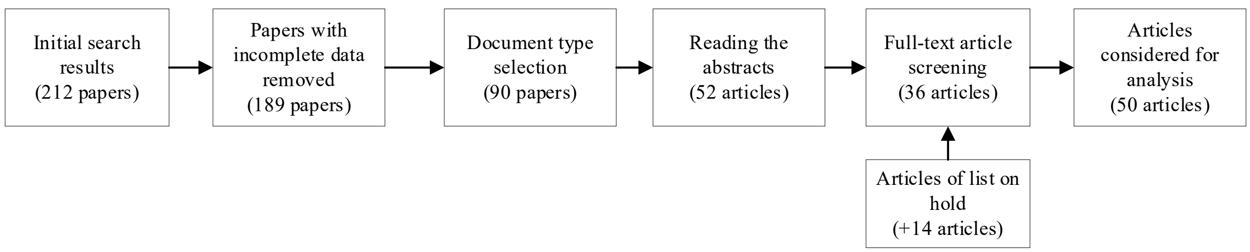

Figure 1. The screening process to select the article sample

This study uses the VOS viewer 1.6.13 edition to provide a graphical depiction of the bibliographic information as a supplement to the analysis. The software creates a visual representation of the network and cluster of documents. The type of analysis employed was co-occurrence, and the unit of analysis was keywords. That is, associations are established based on the quantity of documents that include the keywords in question. The method of counting utilized is full counting. That is to say, each association is equally weighted. Bibliometric analysis is a tool for determining the structure of a network that answers issues like what are the key themes in an area of study, how they relate to one another, and how a given topic evolves over time (Amin, Khan and Zuo, 2019). Bibliometrics can deliver more objective and thorough results, as well as handle massive data sets swiftly and clearly. If items in Figure 2 that the VOS algorithm generates have more references in common, they are closer to one another. It indicates that they share a theoretical standpoint or approach (Marzi *et al.*, 2020). Also, the VOS with network visualization gives 5 clusters. Articles are clustered in the same group are strongly linked as a group, indicating a possible area of research. It highlights the presence of five well-polarized clusters characterized by the following themes:

1) Red cluster: DFA, DFM, DFMA, DFX
2) Green cluster: DFM and mathematical model, CAD/CAE
3) Blue cluster: Cost-effectiveness, reliability, genetic algorithm, quality assurance
4) Yellow cluster: a design for reliability, reliability improvement, risk assessment
5) Purple cluster: concurrent engineering, cost reduction, machine design, manufacturing process, and optimal design

As emphasized by Benabdellah (2019) and Paganin (2017), visualization techniques can be used to simplify research mapping. These techniques have become one of the most reliable approaches in bibliometric network analysis, particularly in mapping and classifying the relationship between journals, co-authoring, researchers, and keyword emergence. When two papers cite the same third work in their references, this is known as bibliographic coupling. The degree of co-authorship among the most productive authors is measured by co-authorship. The degree of citations between two variables is the topic of citation analysis. The most common keywords used by different articles, as well as which terms usually appear below the abstract, are displayed in the co-occurrence of keywords. The terms that appear more frequently in the same papers are visualized using a network connection (Marzi et al., 2020).

3. Metadata Statistical Analysis

The statistical metadata analysis in this study is limited to simple descriptive statistical analysis. Figure 3 exhibits the quantity of annually published papers and the number of citations from 2000 to 2021. It can be observed that research on DFMA and DFR continues to increase. Moreover, the number of papers published in the last five years are 30 papers. In terms of the year of publication, 2019 was the year in which the most articles on those topics were published in the previous five years. Figure 4 shows publication distribution to journals while the number of papers published on this research topic is less than ten papers of each journal. It is still relatively insufficient. Science Journal has the highest citations for leading publication (see Figure 5), while IEEE Trans Reliab has the leading publication by total papers.

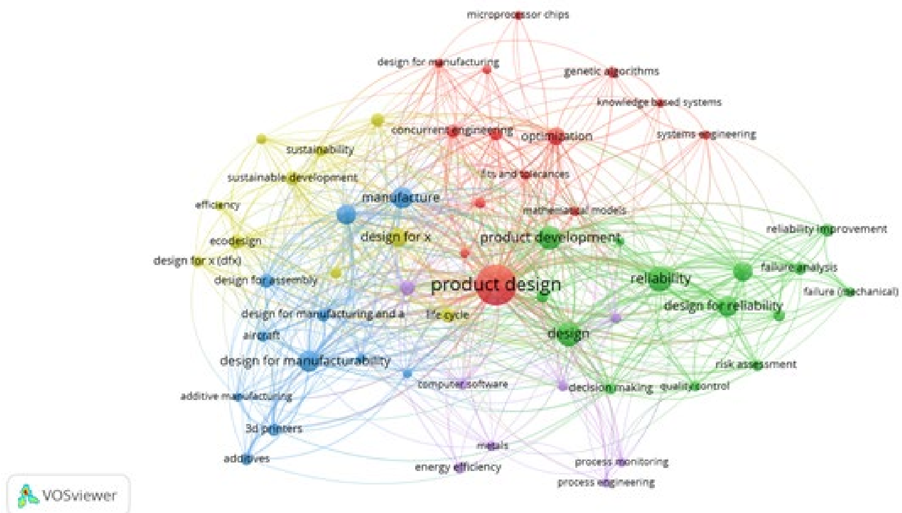

Figure 2. VOS Network Visualization for Bibliometric

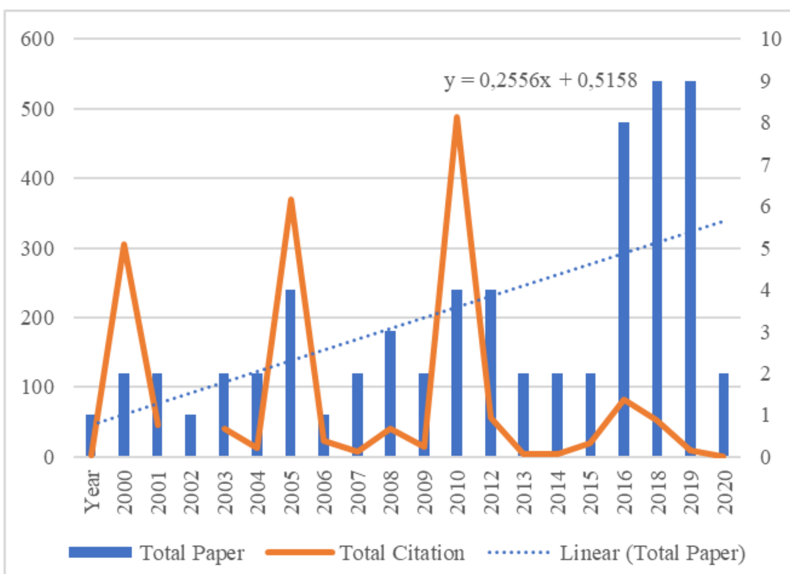

Figure 3. Distribution of papers and citations by year

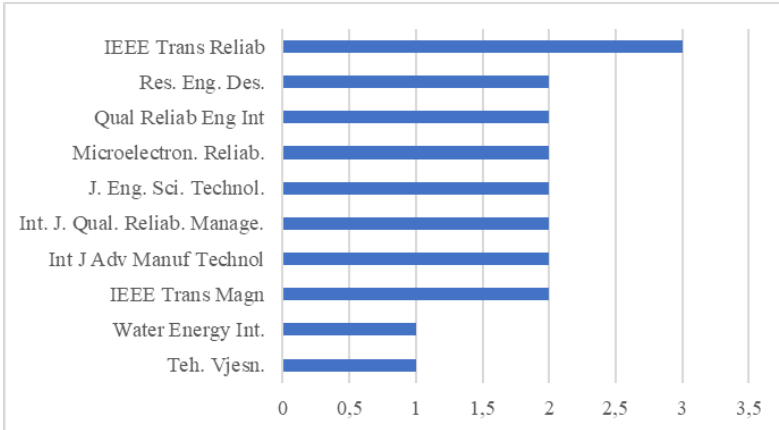

Figure 4. Publication distribution according to the total paper of journals

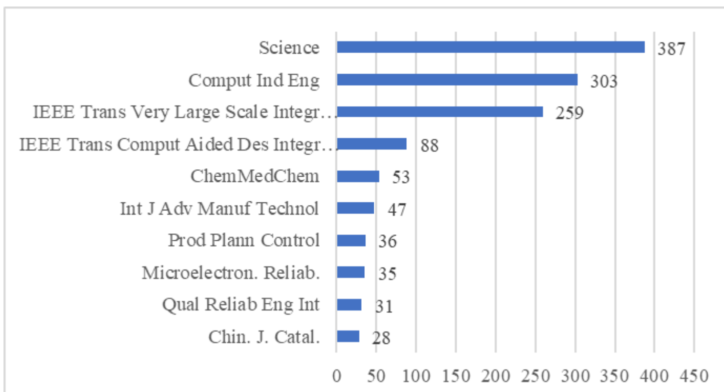

Figure 5. Publication distribution according to total citation of journals

4. Review of Main Concept and Foundations

This section addressed at the conceptual foundations of the DFMA and DFR, as well as how they may be merged into a new product redesign conceptual framework. A methodology for the use of DFMA and DFR in the early stages of product design and its benefits should be adopted in addition to the evaluation scope of conceptual definitions. Demonstrations of certain applications that have already been published in the literature, as well as their major findings, are also provided.

4.1 Design for Manufacturing and Assembly (DFMA)

DFMA is a combination of Design for Assembly (DFA) and Design for Manufacture (DFM). DFMA is used for three main activities (Boothroyd, 1994):

a) As a foundation for concurrent engineering research on structural simplification to save manufacturing and assembly costs.
b) As a tool for analyzing rivals' products and quantifying production and assembly challenges.
c) As a should-cost tool to assist control expenses and negotiate contracts with suppliers.

DFMA provides a more straightforward design structure without leaving customer needs nor compromising the product quality. A simple form of design also balances a shorter assembly time and reduces manufacturing costs. There are many DFA methodologies, but the most widespread are Boothroyd-Dewhurst (B&D) methodology, Lucas methodology, Hitachi-AEM methodology, and Westinghouse methodology. B&D methodology gives four indicators for its implementation: assembly time, assembly cost, the minimum number of component, and design efficiency (Ezpeleta *et al.*, 2019). As for the critical assumptions used in B&D methodology:

a) Parts are added one at a time during assembly.
b) Components are present in bulk and randomly oriented.
c) The designer has complete information on part dimensions.

Lucas's methodology has a scale point related to measuring the difficulty level of assembly processes in their implementation. This method gives three indicators: design efficiency, feeding index, and fitting index (Dochibhatla, Bhattacharya and Morkos, 2017). Dochibhatla (2017) conquered the joint implementation of Lucas and B&D methodologies, as seen in Figure 7. It also underlined the use of the Lucas method in the early phase because this method does not require part dimensions data to result in design efficiency. B&G method is applied later to improve the design with accurate data of design parameters. The implementation resulted in an increase in processing time for designers. Only Lucas methodology fits to implement when details product data is incomplete. Lucas's methodology used to be considered in the conceptual design phase. While in the detailed engineering design phase, it would be considered to use B&D, Hitachi, or Westinghouse method.

Chowdary et al. (2019) discovered that DFMA tools can save time when evaluating designs and that they should be used early in the design selection process. As the original design is evaluated, revised, and redesigned work is conducted for the product evaluation, Ahmad et al. minimize the product cost water nozzle by implementing DFMA approach. Jaime Mesa et al. (2018) investigated sheet metal enclosure device design for assembly and manufacturing (DFMA). The methodology used in this study to determine the step of DFMA standards linked to sheet metal enclosures, as well as sustainability indicators that provide manufacturing and design advice, was integrated with this strategy to establish a sustainable approach.

The objective of DFMA is to reduce product structure to make assembly easier and to enhance components to make manufacturing easier. It also enables designers to reduce the number of components used, simplify and reduce the number of manufacturing procedures, use standard parts and materials, design for efficient joining, part production, and assembly, and use common parts across product lines, as well as eliminate or reduce the amount of adjustment required. Table 1 summarizes the influence of various researchers towards the DFMA framework based on integrated product design.

Table 1. Contribution researchers to DFMA area and its integration design approach

Research Study	Contribution to the field
(Cakir and Cilsal, 2008)	To assist designers in refining their designs according to DFM principles, a DFM matrix-based access tool was developed using the theory of innovative problem solving (TRIZ).
(Emmatty and Sarmah, 2012)	DFMA and platform-based design provide an integrated conceptual product development framework. For a specific application in aircraft design and production, the DFMA approach was used.
(Barbosa and Carvalho, 2013)	The DFMA approach was used to develop a food processor in order to reduce manufacturing costs.
(Harlalka *et al.*, 2016a)	Developing a model of manufacturing cost reduction through DFMA methodology to redesign a food processor
(Thompson, Juel Jespersen and Kjærgaard, 2018)	In high-speed product development contexts, DFMA can be beneficial in reducing late engineering changes (E.C.s), according to an industrial case study.
(Volotinen and Lohtander, 2018)	DFMA concepts were used to redesign a ventilation unit in this case study.
(Pinzon, Lascano and Maury-Ramirez, 2012)	Integration of DFMA with CAE programs to decrease manufacturing costs, shorten time to market, and enhance the quality of mechanical system design deliverables
(Tasalloti *et al.*, 2016)	Weld design and analysis using an integrated DFMA–PDM (product data management) model that can be utilized with CAD programs.
(Ginting and Ali, 2016)	Combining TRIZ, DFMA, and QFD, this examination gives an in-depth analysis of identifying and locating issues of strength, weakness, and results.

(Mesa *et al.*, 2018a)	For sheet metal enclosure devices, a unique way to incorporating sustainability ideas into traditional DFMA methodology has been developed in this article.
(Zhang, Chu and Xue, 2019)	Identification of product aspects that may be enhanced based on internet feedback for product redesign.
(Ezpeleta *et al.*, 2019)	During all phases of product development, a novel DFA approach to enhance assembly has been developed.
(Butt and Jedi, 2020)	Using the DFMA methodology, this research redesigns the TTC conveyor system for cost and design efficiency gains.

While the DFA approach is being used to redesign the product, another topic that needs to be addressed is the cost-effectiveness of materials and production processes. Cost estimation is the study of predicting expenses associated with a set of activities before they are carried out. Design for Manufacturing and Assembly (DFMA) is a cost-cutting approach presented by Harlalka et al. (2016) for designers to analyze manufacturing components of a product redesign. Various cost-cutting options are identified in the design of a food processor built by a reputable Indian business in this study. The researcher's suggestions are generated to lower the product's overall production cost. According to Favi et al. (2016), developing a multi-objective design method is done in the conceptual design phase of complex product development for a complete examination of the manufacturing factors (assembly, materials, processes, costs, and times). At a conceptual level, the integrated ideas of DFMA and Design to Cost (DtC) are used to select the ideal assembly concept (see Figure 6). The method would aid designers and engineers in determining the most cost-effective design option.

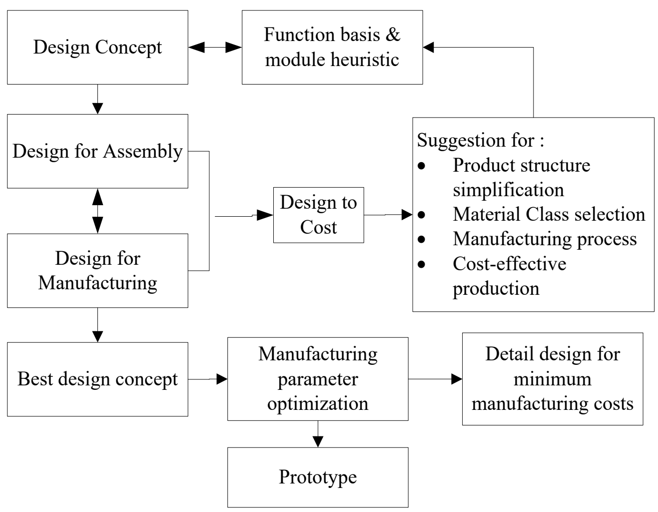

Figure 6. DFMA vs Design to Cost framework (Favi, Germani and Mandolini, 2016a)

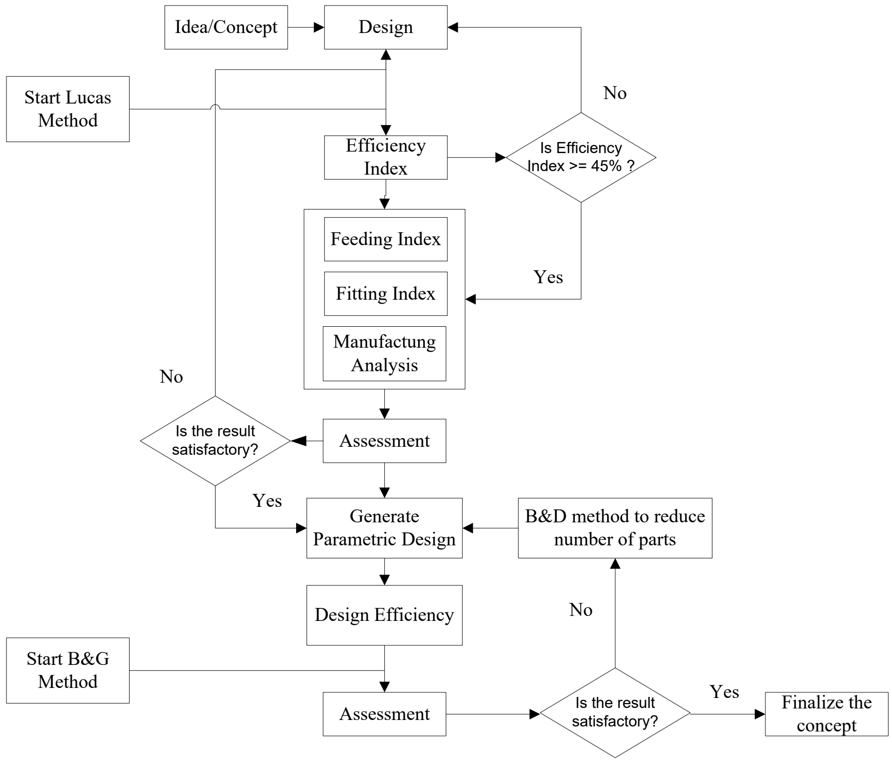

Figure 7. An Integrated of Lucas-B&G method of DFA (Dochibhatla, Bhattacharya and Morkos, 2017)

4.2 Design for Reliability (DFR)

The possibility that a component, tool, machine, system, or process will perform a specific function without failure within a given time period is defined as reliability. The goal of Design for Reliability (DFR) is to design key system functions out of a system (Raheja and Gullo, 2012; Prabowo et al., 2018). The DFR process begins with the development of all products and processes at an early level. It assesses whether any of the idea designs can achieve the derived reliability requirement, as well as uncovering probable failure modes and making design recommendations to mitigate them. DFR will aid in the identification of prototype issues, lowering life cycle costs and field failure rates. The importance of the DFR technique throughout the new product development stage has the advantage of ensuring a product's reliability throughout its life cycle.

From inception until obsolescence, design for reliability is a method that describes a full collection of techniques that aid efforts to improve a product's reliability. The choice of the suitable reliability tool at each stage of product development and implementation is closely related to the success of the DFR application. Because reliability is defined as the probability of failure, the designer must have data on loads and strengths as well as a proper stochastic model in order to evaluate it. If the obtained reliability values are for each usage, then the input data (load and strength) must be precise, which necessitates a careful design (Mayda and Choi, 2017). Reliability becomes a design parameter, and it must be considered early in the product development process. Using a probabilistic approach in product design is a step toward considering reliability and DFR. The strength factor and stress factor are the fundamental assumptions of reliability analysis in probabilistic design methodology (Kapur and Pecht, 2014). Table 2 summarizes different scholars' contributions to the DFR framework based on integrated product design.

Table 2. Contribution researchers to DFR area and its integration design approach

Research Study	Contribution to the field
(Sharp, Andrade and Ruffini, 2019)	Determining since none of the concept designs are capable of satisfying the derived reliability requirement, as well as identifying possible failure causes and making design recommendations to mitigate them. Probabilistic Design and Physics of Failure Analysis are two DFRL approaches used in this article.

(Araujo, 2017)	Presenting the implementation of a failure mode-based product design and manufacturing process review, as well as reducing reliability concerns owing to design flaws, lowering quality costs, and launching a successful new product and process.
(Pourgol-Mohammad *et al.*, 2017)	Based on the DFRL of an automobile system and taking into account its safety-critical component, an integrated approach has been developed. The dependability block diagram approach is used to represent the system, which is then simulated using the Monte Carlo methodology.
(Mayda and Choi, 2017)	This research developed a framework of reliability-based design for early stages of the design process. Proposed framework is effective to achieve reliable design solutions that have uncertain quantitative characteristics to be used further in probabilistic structural analysis
(Khodaygan and Ghaderi, 2019)	For the early phases of the design process, a reliability-based design framework is provided. The proposed framework is useful for achieving trustworthy design solutions with unknown quantitative features, which can then be employed in probabilistic structural analysis.
(Ma, Chu and Li, 2019)	An integrated approach to identify function components for product redesign based on analysis of customer requirements and failure risk
(Borchani *et al.*, 2019)	An integrating model-based system engineering with set-based concurrent engineering principles was developed in this research. This model is developed for reliability and manufacturability analysis of mechatronic products
(Paganin and Borsato, 2017)	Collecting and performing an analysis of the most recent literature of Design for Reliability

5. Discussion

Most company redesign to create new product. The new product design with improvement from the existing product means redesign product. Redesign improves the quality and efficiency of the product development. Researchers have developed the Boothroyd and Lucas-Hull DFMA models by considering several factors, such as improved reliability (Smith and Clarkson, 2005; He et al., 2018), performance improvement (Smith and Clarkson, 2005; Gu, Cheng and Qiu, 2019; He *et al.*, 2019; Yin and Hou, 2019), reuse-ability or remanufacture-ability of products (Anguswamy *et al.*, 2013; Chhim, Babu and Sadawi, 2019), increased efficiency (Li, Reimann and Zhang, 2018), improved tolerance (Khan *et al.*, 2018; Wagner, Haefner and Lanza, 2018), increased reliability (Farooq *et al.*, 2017; John, Balachandra Shetty and Mishra, 2018; Lu *et al.*, 2018), ease of maintenance and repair (Desai and Mital, 2006), leanness (Gupta and Kundra, 2012), and design optimization (Al-Shayea *et al.*, 2011; Cheng, Conrad and Du, 2017; El-Nounu, Popov and Ratchev, 2018b).

A systematic literature review has been conducted (Benabdellah et al., 2019; Chowdary, Richards and Gokool, 2019a) that 83% of potential loss or failure in product planning and development occurs at the early design stage to conceptual design. Product redesign that satisfies consumer demand are often unable to be implemented on the production floor, because aspects of manufacturing, material selection, cost considerations and reliability planning are not considered in the assembly planning process in product design development or improvement. Therefore, research opportunities focusing on developing a failure risk-based product redesign need to be realized.

In improving product design, it is increasingly emphasized that it is carried out at the initial design stage because it significantly affects the product development stage and the production process. However, it is challenging for larger and more complex product scales to predict product reliability at the initial design stage accurately. Various design methodologies have been proposed to solve this problem, but efforts to predict reliability in each design alternative have not been achieved. Therefore, research proposals in the development of the DFMA model at the conceptual stage must consider the predictions of reliability that might occur at the successive detailed design stages.

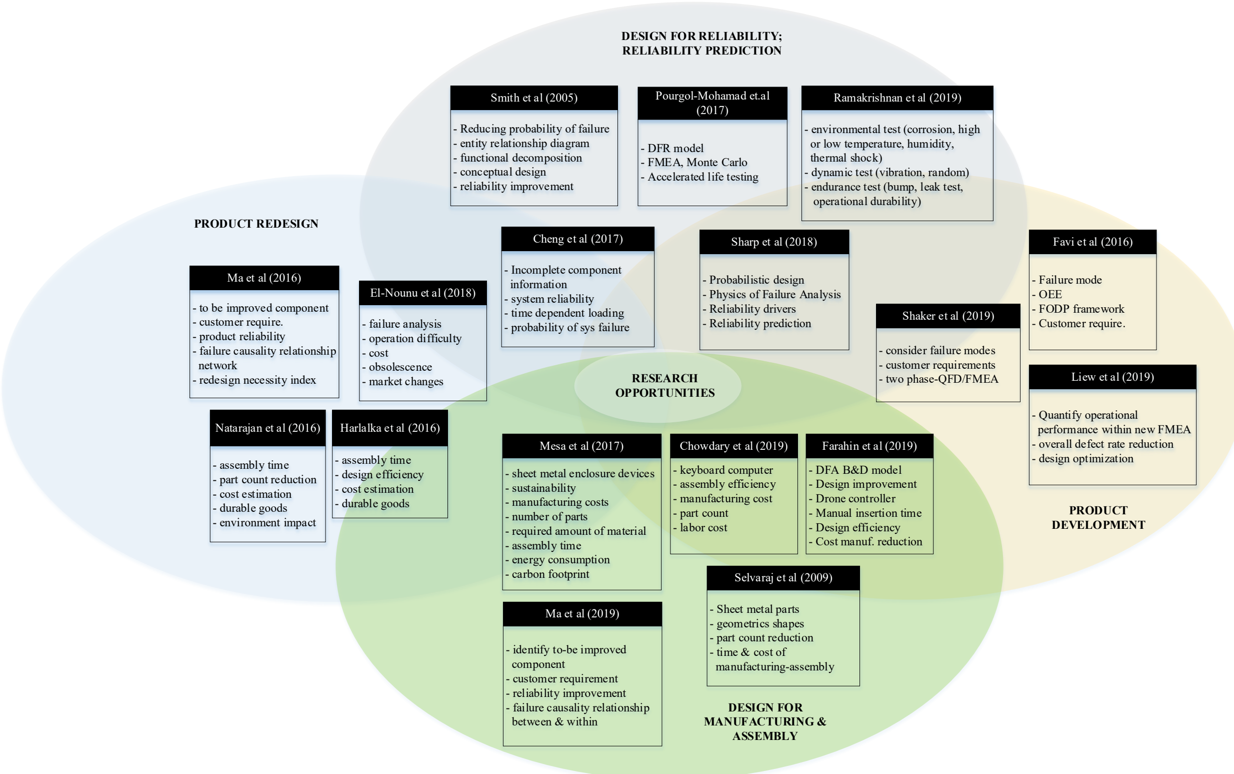

Figure 8. Research Opportunities Map

Ma (2016) developed an integrated QFD-FMEA framework to identify components to be redesigned by considering consumer needs and product reliability. This QFD-FMEA integration can solve deficiencies in the FMEA method so that in determining the priority of critical components to be redesigned, it involves customer needs and technical characteristics supported by the QFD method (Gu, Cheng and Qiu, 2019; Shaker, Shahin and Jahanyan, 2019). Behnke (2018), in his research in the area of failure data and warranty, found cases of how the failure analysis process was carried out with the condition that most of the failure modes had unknown information. Shahin (2004), Madzik (2020), and Tang (2021) developed the Kano-FMEA integration in determining the risk priority of components of a product. Suef et al. (2014) proposed a new way for identifying the VOC using complaints and claims in a product design with QFD-Kano approach. The integration of Kano-FMEA and QFD/FMEA shows that a history of product failure is also considered in product development. The contribution of the two integration models is the determination of the ranking or priority of components and features of the product to be developed by meeting consumer needs and improving reliability. In relatively similar research in product and system reliability predictions, the dependent component in the product structure becomes a priority for obtaining information about environmental conditions and operational conditions. No research discusses the priority use of the components and product features developed at the early design stage. As studied by Ma (2016, 2019), his contribution to the integration of QFD / FMEA in product redesign. In contrast, the development of the Liew et al. (2019) model utilizes the component priority ranking results from the failure analysis in assembly and manufacturing process improvements (DFMA).

Simplification of the structure of assembly and manufacturing products through DFMA aims to reduce manufacturing costs and times (Harlalka *et al.*, 2016; Mesa *et al.*, 2018; Butt and Jedi, 2020; Mandolini *et al.*, 2020). The considerations used in simplifying the structure of the product components in the assembly process are also supported by the ease of manufacture and accommodating the needs and wants of consumers with the support of the Kano-QFD method (Ginting, Ishak and Malik, 2020). Improvement of assembly method is one product redesign benefits (El-Nounu, Popov and Ratchev, 2018). The ease of assembling and manufacturing from the product redesign is expected to increase product reliability. Research by Pourgol (2017) and Mayda (2017) outlines a reliability design framework (DFR) in the product improvement process, especially in the early design stage. The FMEA method takes a significant position in determining the critical components that are decisive in a redesign.

Research gaps are open to considerations of reliability in the DFMA framework. Both Pourgol and Mayda have not reviewed the predictions of product reliability when faced with the challenge of downsizing the product component structure. Future research opportunity needs to be completed in the following research as seen in Figure 8.

The DFMA model that considers manufacturing costs at the material planning stage is a significant decision in the Design to Cost framework (Favi, Germani and Mandolini, 2016). It is not up for debate to consider manufacturing costs in assembly design and ease of manufacture. Mandolini (2019) emphasizes that the combination should include a costing model, which is generally applied in the procurement phase, with a design-to-cost model usually implemented at the early design stage. Therefore, proposed research focusing on framework development of design for manufacturing, assembly, and reliability consideration needs to be realized by taking into account manufacturing costs. In improving product design, it is emphasized that it is carried out at the early stage because it significantly affects the product development stage and the production process. However, it is tough for larger and more complex product scales to predict product reliability at the initial design stage accurately. Various design methodologies have been proposed to solve this problem, but efforts to maintain reliability in exploring design alternatives have not been achieved (Goo et al., 2019). Therefore, this study proposes a DFMA development model for conceptual design considering the reliability problems and failure modes that may arise at the successive detailed design stages. This model intends to integrate axiomatic design independence and hierarchical structure from failure modes, effects, and criticality priorities, which are widely used techniques for analyzing product reliability.

6. Conclusions

Companies have been more focused with product redesign to stay competitive as their drive of attracting more consumers and increasing product complexity has grown. The initial conceptual design stage of product design is gradually improved since it has a substantial impact on the product's development and manufacturing stages. DFMA detects ineffective designs with high production costs as soon as possible and reduces the total cost of improvement. DFR will assist in identifying prototype issues, lowering life cycle costs and failure rates in the field. From 2000 through 2021, this research provides a bibliometric summary of literature on DFMA and DFR. The study analyzes publications from the time period in question using the Scopus database. The findings indicate that distribution publications are still inadequate, indicating that more research in this field is needed. However, it is challenging to solve problems in accurately redesigning products at the initial conceptual design stage, especially in meeting customer requirements, reducing manufacturing time and costs, and increasing reliability in an integrated manner. In addition, to fit customer requirements, considerations that can be involved in determining critical components of product redesign are product obsolescence, warranty data analysis, user claims, online review, and consumer acceptance. Moreover, research development using the DFMA method is still quite extensive. A reverse engineering approach would strengthen DFMA and DFR integrated model as a consequence of product redesign. Further challenging considerations that can be used are the sustainability aspect, minimum investment, and risk. Future research should also establish a trade-off analysis among multiple product redesign objectives.

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