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Embracing Risk Factors into Product Redesign Model based on DFMA and Concurrent Engineering: A Review for Research Opportunities

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ABSTRACT

Product redesign strategies can reduce production costs and shorten design lead times in developing new variants. In the manufacturing design model, identifying the function of components based on customer demand and quality standards becomes vital information for enhancing product reliability, even though design reliability analysis needs to be more frequently addressed. The Design for Manufacturing & Assembly (DFMA) model has been implemented to simplify product structure, reduce risk and manufacturing and assembly costs, and analyze and identify improvement targets. DFMA has evolved into a philosophy for optimizing total production costs from the perspective of assembly, part design, and total life cycle costs. In many studies, the design and development of remanufactured products have been conducted with quality and compliant initiatives. The form and behavior of failure and repair activities obtained during the conceptual design phase have yet to be systematically considered as the basis for product design enhancements. Risk considerations and failure analysis have yet to be utilized as an integrated model during the product redesign phase. This study aims to evaluate the existing DFMA model and develop a new product redesign model and repurposed product with the integration of the Concurrent Engineering (CE)-based Redesign for the Manufacturing & Assembly model by considering reliability and risk factors. Incorporating the model concept is anticipated to contribute to a dependable, efficient design and reduce manufacturing expenses.

Keywords: *Design for Manufacturing & Assembly (DFMA), Reliability, Concurrent Engineering (CE), risk factor, failure, manufacturing cost*

Introduction

Today's increasingly fierce market competition makes companies strive to be superior to others. Production costs are one of many factors that can make a company superior to others. Several aspects form the basis of a manufacturing company's competitive strategy to win a dynamic global competition: cost, quality, and timely delivery of orders. Product quality can be influenced by raw materials, component quality, and the quality of the product's production process [1]. The quality of the production process will be significantly influenced by the machine used. Machines with a high level of precision can produce tighter tolerances to produce products of higher quality. It is necessary to select an alternative process to determine the process to be used. However, this selection is increasingly complex as manufacturing processes with cost characteristics, and tolerances differ from process to process and machine to machine.

Research [2] examines the rules and guidelines for using DfMA and the design's ability to be manufactured and disassembled. Both of these studies have the orientation of implementing the DfMA model in new product development, but they still need to review the application of reused products.

A company's competitiveness can be increased by optimizing the production process or developing products and components to suit existing production processes better. Various Design for Manufacturing & Assembly (DfMA) concepts are developed in methods for designing better and more accessible to manufacture manufactured products. The DFMA method simplifies product structure, reduces manufacturing and assembly costs, and analyzes and identifies improvement targets. DFMA has evolved to become a philosophy of optimizing total production costs from the point of view of the assembly, part design, and total life cycle cost. DFMA is used to identify, measure, and eliminate waste or inefficiencies in product design. Early consideration of manufacturing issues shortens overall product development time, minimizes manufacturing costs, and ensures a smooth transition to the production process.

Design for Manufacturing and Assembly (DfMA) analysis is a study conducted at the early design stage. This study or analysis must be carried out very early before a product prototype is made. The design is reduced to a mass-produced product. In other words, the calculation of the analysis of a product using the DfMA method is performed early on to ensure that the designed product can be manufactured and assembled with minimal effort, time, and expense. Where the product to be produced is still in the design phase.

Research [3] designed the development of the Design for Production (DfP) model by considering the economic impact of decreasing manufacturing cycle time. The implementation of the DfP model is used to see the effect of the economic impact on improving product development.

In the study of efficiency literature on the Design for X (DfX) concept, there are three groupings of perceptions, namely from the aspect of product scope, system scope, and eco-system scope. DfMA method, design for variety, design for quality, design for obsolescence, design for maintainability, design for disassembly, and design for reliability (DFR) are the design methods studied from the perspective of product scope. DfR is a method to examine a product reliability design process, where the DfR method is not just a philosophy of testing, analysis, and improvement. However, in the implementation of the manufacturing process, this philosophy is still present in the design process today [4][5].

Johansson's research [6] evaluates the use of Reliability Block Diagram (RBD), Fault Tree Analysis (FTA), and dynamics methods in determining the best method for reliability studies in the early design stage. Among the three methods have yet to be able to provide the best results. FTA is structured to break down the causes of a system or product failure. Research [6] can model the condition of a system in functionality and failure state. However, it has yet to conduct a study with cost, risk, and optimization considerations. The cost model is one of the research opportunities that can be studied.

Product reliability in research [7] depends on successful operation or performance and the absence of failure. Poor reliability causes frequent product failures. It results in higher costs for manufacturers and buyers and customer dissatisfaction. Low reliability, according to [7], will affect manufacturers' sales and overall business performance. It can be concluded that reliability performance is significant for both manufacturers and buyers. This study takes product failure factors at the conceptual design stage and reliability analysis as considerations in developing the Re-DfMA model.

This research aims to produce a design model for manufacturing and assembly processes oriented towards design reliability and maintainability (DfMAR), taking into account economic factors and manufacturing cycle effectiveness in the development of new products and reused products through a series of studies of previous studies. Regarding the basic DfMA model from Boothroyd Dewhurst, Lucas-Hull, and AEM Hitachi, a DfMA model with a manufacturing and assembly process orientation that is reliable and efficient will be developed.

Materials and Method

Identification, screening, feasibility, and inclusion and relevance are the four steps that comprise the compilation of this literature review. The research area and data are gathered at the identification stage by searching reputable international scientific publications and reference books. The keywords used to locate previous studies will be cited in this study. Design for manufacturing & assembly, reliability, stress analysis, strength analysis, product improvement, risk assessment, probability, quality initiatives, and complaint failure management are the corridors constructed thus far in the literature information search process. In the filtering stage, the search results are a collection of relevant and accurate types of publications. http://scopus.com, http://sciencedirect.com, http://scholar.google.com, http://springer.com, http://emerald.com, and http://iopscience.com are examples of digital information media used to facilitate access to subscription library sources. Maintaining the credibility of the literature review and assessing the viability of publication with a quality publisher is the objective of the third stage, which is feasibility. Inclusion and relevance are the next steps. The inclusion phase will assess articles published within the past five years. This phase is done to ensure that the research topic remains unique.

A review of credible library sources is beneficial for enhancing the researchers' understanding of the current state of research in the area to be expanded. Design for Manufacturing & Assembly reference materials include the Journal of Engineering Design, Journal of Management for Sustainable Development, Assembly Automation, Mechanical Design, Journal of Cleaner Production, Journal of Architectural & Design Management, Computer & Industrial Engineering, and Journal of Cleaner Production. In contrast, the Journal of Quality & Reliability Management, the Journal of Quality & Services Sciences, the Journal of Cleaner Production, the Journal of Architectural & Design Management, and the TQM Journal were consulted for the quality initiatives literature review. In addition, failure and reliability keyword research was conducted in the Expert System Journal with Application, Engineering Design Journal, Management for Sustainable Development Journal, Advanced in Management Accounting, Maintenance & Reliability, and Product

Development Journal. The credibility of the DFMA research area is demonstrated by the large number of libraries that intersect with it (Table 1), as numerous aspects of knowledge and scholarship are pertinent to the DFMA area and topic.

Table 1. Literature Review for Finding Research Opportunities

Author	Year	Focus Area	Contributions	Methodology	Findings
Boothroyd and Dewhurst	1980	Foundational DFMA principles	Introduced systematic DFMA principles to reduce manufacturing costs and improve assembly efficiency.	Case studies and development of DFMA guidelines	Reduced manufacturing and assembly costs; improved product manufacturability.
Prasad B.	1996	Concurrent Engineering Frameworks	Proposed models integrating cross-functional collaboration for product development in concurrent engineering.	Theoretical modelling	Enhanced team collaboration led to reduced time-to-market and better design decisions.
Huang, G.Q., et al.	2002	Concurrent Engineering and DFMA Integration	Explored synergies between DFMA and concurrent engineering to improve product lifecycle performance.	Case studies and multi-objective optimization models	Demonstrated improved efficiency in design cycles and manufacturing processes.
Jiao, J., et al.	2007	Modular Design in DFMA	Proposed modular design strategies to enhance DFMA and concurrent engineering practices.	Empirical research and computational modelling	Improved design flexibility and adaptability for customization while maintaining manufacturability.
Whitney, D.E.	2012	Interdisciplinary Approaches in Concurrent Engineering	Discussed the integration of mechanical, electrical, and software design in concurrent engineering contexts.	Multi-disciplinary project analysis	Promoted seamless integration of design elements, reducing bottlenecks in product development.
Imrack et al.	2012	Design Optimization on Elevator Car for Double-Deck System	Focused on CE based design processes and design tools DFA and DFM	Design Optimization	Renewed designs were compared according to their part numbers, costs, efficiency and reliability
Khan, S., et al.	2015	Evolution of DFMA for Sustainability	Addressed environmental considerations in DFMA, emphasizing sustainable material choices and manufacturing methods.	Sustainability analysis and case studies	Highlighted the potential for reducing environmental impact while maintaining cost-effectiveness.
Fang et al.	2016	DFMA - Remanufacturing	Develops a framework of design for disassembly for remanufacturing based on product design information available in CAD models	Framework Development	Software tool development for the implementation of the proposed approach for product remanufacturing assessment, process planning, and disassembly route evaluation.
Juniani A. I., et al.	2023	DFMAR Models	Developed an integrated framework of DFMA and Design for Reliability.	Framework Development and case study	Design for Manufacturing, Assembly, and Reliability: An Integrated Framework for Product Redesign and Innovation

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Results and Discussion

Concurrent Engineering

The fact that some businesses continue to operate in a function-based, sequential manner, in which products such as the baton transition from design to manufacturing, has prompted the development of methods to improve enterprise collaboration by integrating corporate functions as a whole [8]. Concurrent Engineering (CE) is an approach that focuses on conducting engineering activities such as design and production planning concurrently within a company [9]. This integration and parallelization aim to establish a multidisciplinary team representing the entire product life cycle. Thus, engineering design concepts can be conceived considering the product's life cycle.

Research [10] discusses how companies struggle with CE adoption and suggest how CE should be implemented and maintained in companies using the proposed implementation framework of decision-support tools, techniques, and methodologies.

Design for Manufacturing and Assembly

DFMA is a set of guidelines designed to ensure that these products are designed so that they can be manufactured and assembled easily with minimal effort, time, and expense [11], [12]. DFMA is used for the following three primary activities:

[1] As a guide for the design team to simplify product structure, reduce assembly costs, and enhance quality.

[2] As a tool for studying competitors' products and quantifying the complexity of manufacturing and assembly processes.

Three DFMA models are frequently employed in scientific research: Boothroyd Dewhurst, Lucas-Hull, and AEM-Hitachi [13, 14]. Design for Assembly (DFA) and Design for Manufacturing (DFM) are the two primary phases of the DFMA process, which is supported by research [15]. (DFM). DFA optimizes component assembly during the design of a product, whereas DFM maximizes manufacturing process utilization during the design of a component or part family. [12, 16].

Design for Reliability

The probability or probability of a device malfunctioning can be reduced by using a reliability approach [17]. Failure is almost unacceptable in business and industry, which is critical to safety. The design process continues until the required level of reliability is achieved, even if additional or re-design costs are incurred. The importance of reliability is due to the consequences of failure. If high reliability is optional, it is almost always desirable and an essential part of the overall quality of the product. The reliability of currently available methods effectively reduces product failure, but there is still a need for methods adapted to the conceptual design stage [17], [18].

Product reliability in research [7] depends on successful operation or performance and the absence of failure. Poor reliability causes frequent product failures. This, in turn, results in higher costs for manufacturers and buyers and leads to customer dissatisfaction. Low reliability will affect sales and overall business performance for manufacturers. It can be concluded that reliability performance is significant for both manufacturers and buyers. Reliability performance depends on the decisions made by the manufacturer during the design and development stages and production [7], [19].

Conceptual reliability is related to the reduction of conceptual failures, i.e., failures that occur during conceptual design [17]. In his research, [17] identified two types of conceptual failures to illustrate the description, as mentioned earlier, of reliability presented in Figure 1.

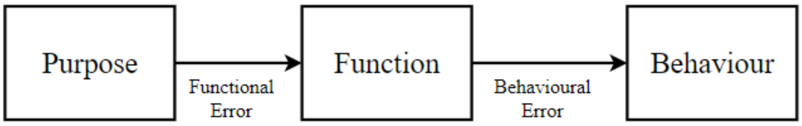

Figure 1. Functional and behavioral failure

Product failures occur due to functional and behavioural failures at the conceptual design stage under certain circumstances. The high probability of product failure causes a decrease in product reliability.

Design for Efficiency

According to research [2], the primary objective of designing for efficiency is to serve as a model for reducing costs and waiting times for a product while maintaining or enhancing its quality. Review [2] for concept effectiveness is divided into two perceptual ranges: product scope and system scope. The product scope focuses on the product aspect, which facilitates efficiencies on a company's manufacturing floor (e.g., changing the design of a product to reduce machining time). The scope of the system focuses on the integration and coordination of the value chain from the design phase to the delivery and maintenance system.

In the literature on DFM and DFA, the integration of the DFX concept, specific design for efficiency, has yet to be discussed. It is possible to anticipate the compilation and exchange of impacts between these concepts in field applications. In contrast, most research on grouping DFX concepts employs two dimensions (product-scope space, systems, eco-systems, focus efficiency, and green design). It is understood that such a structure must be supported by research and real-world industry examples. An integrative framework is expected to incorporate product design, operation, and disposal, encompassing the entire spectrum of product life cycles. Recent studies support this conclusion. In order to achieve efficiency, it is imperative to research to reduce product life cycle costs at the conceptual design stage [20].

Risk Factors

Risk is the probability of occurrence of an undesirable event and all of its possible outcomes [21]. As depicted in Figure 1, the initial phases of a project represent the window of opportunity to minimize impacts and mitigate potential risks. Since opportunities to reduce project risk occur during the conceptual design phase, a tool that uses failure analysis to estimate project risk during the design phase is useful. This newly proposed method is intended to aid designers by providing an initial risk assessment for products based on the failure history of the component or product. This relationship enables designers to predict failures associated with their product's function as early as possible in the conceptual design phase before the product's physical form is determined [22].

Gap Analysis

Numerous researchers have developed the DFMA framework and model, which includes optimization of DFMA, a review of design verification and validation, case studies of the model in the context of new products and remanufacturing, and tolerance models in DFMA [23, 26]. Some studies include reliability considerations, such as [27]–[29], and risk studies in DFMA, such as [30, 31, 34], but these have not been conducted in an integrated framework.

The majority of applications of the DFMA model, both Boothroyd's model and Lucas' model, are used independently with relatively similar goals, namely reducing manufacturing costs and boosting efficiency. However, based on the current DFMA model, it is common for design enhancements to discuss the onset of failure behaviour or repair activities. If failure analysis, reliability, and risk factors are factored into the design enhancement, will this significantly impact the DFMA conceptual framework? With a mini literature review, the initial gaps in this research can be addressed by proposing a design model for manufacturing and assembly processes oriented toward design reliability and maintenance capability, embracing risk and economic factors. This research opportunity would improve the manufacturing cycle effectiveness in new product development and product redesign.

To align with the global shift towards sustainable design and production, it is strongly recommended to integrate eco-design principles into the creation of models or ideas for further study. Eco-design places a high priority on reducing environmental impacts throughout a product's lifecycle, from material selection to end-of-life disposal. By embedding sustainability into the design process, academics and practitioners play a crucial role in developing innovative solutions that address both economic and ecological challenges. This approach not only amplifies the relevance of the work in the face of mounting environmental issues but also positions it as a significant contribution to global sustainable development goals and the circular economy, ensuring long-term viability and international relevance.

Conclusion

This research establishes a conceptual design framework for a Redesign of the Manufacturing Assembly model. The development of the Re-DFMA model is an integrated product development concept that emphasizes the principles of manufacturing, assembly, product specifications, product quality, and product reliability. DFMA begins during concept development when product specifications and functions are defined. Cost is a deciding factor when selecting a concept, despite the subjectivity of cost estimates. During the systems-level design phase, the team determines how to deconstruct the product into its parts based on anticipated costs and the manufacturing process's complexity. A precise cost estimate can be obtained at the detailed engineering design stage. Researchers should be able to validate the initiation of product failure factors, product specifications, consumer voices, and user complaints as information for manufacturing design enhancements. High product quality assurance, optimal machining time, and low manufacturing costs are essential to the economic success of design improvement.

After the Re-DFMA conceptual model has been compiled, the following research step is to develop a mathematical model of the manufacturing and assembly processes' cost and time. The resulting mathematical model will be implemented in a case study of experimental design for the railroad and shipbuilding industries. The scope of the case study used in this study is an industry with a closed-loop manufacturing business framework, in which several companies are integrated into the roles of conceptual product designers, manufacturing, and assembly industries. Furthermore, it is strongly advised to incorporate eco-design concepts into the construction of models or ideas for more study. Eco-design prioritizes minimizing environmental consequences over a product's lifecycle, encompassing material selection to end-of-life disposal. Integrating sustainability into the design process enables academics and practitioners to develop novel solutions that tackle both economic and ecological issues.

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References

[1] S. Sivaloganathan and P. Hills, "Design for excellence," *J. Eng. Des.*, vol. 12, no. 1, pp. 1–2, 2002.
[2] M. C. Chiu and G. E. O. Kremer, "Investigation of the applicability of Design for X tools during design concept evolution: a literature review," *Int. J. Prod. Dev.*, vol. 13, no. 2, p. 132, 2011.
[3] T. C. Kuo, S. H. Huang, and H. C. Zhang, "Design for manufacture and design for 'X': Concepts, applications, and perspectives," *Comput. Ind. Eng.*, vol. 41, no. 3, pp. 241–260, 2001.
[4] M. Chiu, C. Lin, and G. Okudan, "An Investigation of the Applicability of DfX Tools during Design Concept Evolution Design for X Design for Efficiency Eco-system," *Network*, no. 1, pp. 1–10.
[5] M. Silverman and A. Kleyner, "What is design for reliability and what is not?," *Proc. - Annu. Reliab. Maintainab. Symp.*, no. November, 2012.
[6] C. Johansson, *On system safety and reliability methods in early design phases*. 2013.
[7] D. N. P. Murthy, M. Rausand, and S. Virtanen, "Investment in new product reliability," *Reliab. Eng. Syst. Saf.*, vol. 94, no. 10, pp. 1593–1600, 2009.
[8] G. Boothroyd, *Product design for manufacture and assembly*, vol. 26, no. 7. 1994.
[9] B. Prasad and W. Bloomfield, "A Concurrent Function Deployment Process for Product Life-cycle Management Introduction Limitations in Deploying QFD in a Concurent Design Process," no. Vcm.
[10] I. Gerdemeli, C. Fetvaci, and E. Kayaoglu, "Design for assembly in concurrent engineering a case study on its application: Glass block holder and glass mold," *Key Eng. Mater.*, vol. 450, pp. 141–144, 2011.
[11] B. D. Methods, "Detc2017-68126 Evaluating Assembly Design Efficiency : a Comparison Between," pp. 1–20, 2017.
[12] Y. He, C. Gu, Z. He, and J. Cui, "Reliability-oriented quality control approach for production process based on RQR chain," *Total Qual. Manag. Bus. Excell.*, vol. 29, no. 5–6, pp. 652–672, 2018.
[13] R. Bogue, "Design for manufacture and assembly: Background, capabilities and applications," *Assem. Autom.*, vol. 32, no. 2, pp. 112–118, 2012.
[14] S. V. S. Dochibhatla, M. Bhattacharya, and B. Morkos, "Evaluating assembly design efficiency: A comparison between lucas and boothroyd-dewhurst methods," in *Proceedings of the ASME Design Engineering Technical Conference*, 2017, vol. 4.
[15] B. V. Chowdary, M. A. Richards, and T. Gokool, "An integrated approach for sustainable product

design: concurrent application of DFMA, DFE and CAD/CAE principles and tools," *Lat. Am. J. Manag. Sustain. Dev.*, vol. 4, no. 4, p. 259, 2019.

[16] B. V. Chowdary, R. L. Bhagan, and K. Ojha, "Improvement of operational efficiency in a jobshop using lean manufacturing principles: a case study," *Int. J. Collab. Enterp.*, vol. 5, no. 3/4, p. 125, 2016.

[17] J. Smith and P. J. Clarkson, "Design concept modelling to improve reliability," *J. Eng. Des.*, vol. 16, no. 5, pp. 473–492, 2005.

[18] J. M. Cui, Y. H. He, C. L. Zhu, and F. D. Liu, "Reliability-oriented quality risk modeling and monitoring approach in manufacturing process," *IEEE Int. Conf. Ind. Eng. Eng. Manag.*, vol. 2017-Decem, pp. 2093–2097, 2018.

[19] T. Osteras, M. Rausand, and D. N. P. Murthy, "Reliability specification in new product development," *Int. J. Prod. Dev.*, vol. 5, no. 1/2, p. 17, 2007.

[20] G. Li, M. Reimann, and W. Zhang, "When remanufacturing meets product quality improvement: The impact of production cost," *Eur. J. Oper. Res.*, vol. 271, no. 3, pp. 913–925, 2018.

[21] K. G. Lough, R. Stone, and I. Y. Tumer, "The risk in early design method," *J. Eng. Des.*, vol. 20, no. 2, pp. 155–173, 2009.

[22] H. C. Liu, X. Q. Chen, C. Y. Duan, and Y. M. Wang, "Failure mode and effect analysis using multi-criteria decision making methods: A systematic literature review," *Comput. Ind. Eng.*, vol. 135, no. June, pp. 881–897, 2019.

[23] C. Imrak and M. Kocaman, "Design Optimization on Evelator Car for Double-Deck System," pp. 37–40, 2012.

[24] M. Kalyun and T. Wodajo, "Application of a Design Method for Manufacture and Assembly -Flexible Assembly Methods and their Evaluaiton for the Construction of Bridges," pp. 17–19, 2012.

[25] M. Mobin and Z. Li, "An Integrated Approach to Plan the Design Verification and Validation Activities for the New Product Reliability Improvement," *Proc. - Annu. Reliab. Maintainab. Symp.*, vol. 2018-Janua, pp. 1–7, 2018.

[26] H. C. Fang, S. K. Ong, and A. Y. C. Nee, "An Integrated Approach for Product Remanufacturing Assessment and Planning," *Procedia CIRP*, vol. 40, pp. 262–267, 2016.

[27] Y. H. He, L. B. Wang, Z. Z. He, and M. Xie, "A fuzzy TOPSIS and Rough Set based approach for mechanism analysis of product infant failure," *Eng. Appl. Artif. Intell.*, vol. 47, pp. 25–37, 2016.

[28] K. D. Sharma and S. Srivastava, "Failure Mode and Effect Analysis (FMEA) Implementation: A Literature Review," *Copyr. J. Adv. Res. Aeronaut. Sp. Sci. J Adv Res Aero SpaceSci*, vol. 5, no. 2, pp. 2454–8669, 2018.

[29] L. Wang, C. Xiong, and Y. Yang, "A novel methodology of reliability-based multidisciplinary design optimization under hybrid interval and fuzzy uncertainties," *Comput. Methods Appl. Mech. Eng.*, vol. 337, pp. 439–457, 2018.

[30] P. N. Bajeel and M. Kumar, "Reliability test plan for a series system with variable failure rates," *Int. J. Qual. Reliab. Manag.*, vol. 34, no. 6, pp. 849–861, 2017.

[31] F. Shaker, A. Shahin, and S. Jahanyan, "Developing a two-phase QFD for improving FMEA: an integrative approach," *Int. J. Qual. Reliab. Manag.*, no. D, 2019.

[32] H. Yu, G. Zhang, Y. Ran, M. Li, and Y. Wang, "A comprehensive and practical reliability allocation method considering failure effects and reliability costs," *Eksploat. i Niezawodn. - Maint. Reliab.*, vol. 20, no. 2, pp. 244–251, 2018.

[33] M. Wouters, S. Morales, S. Grollmuss, and M. Scheer, "Methods for cost management during product development: A review and comparison of different literatures," *Adv. Manag. Account.*, vol. 26, pp. 139–274, 2016.

[34] Juniani, A.I.; Singgih, M.L.; Karningsih, P.D. Design for Manufacturing, Assembly, and Reliability: An Integrated Framework for Product Redesign and Innovation. *Designs* 2022, *6*, 88. https://doi.org/10.3390/designs6050088