DTU Library

Integration of Product and Manufacturing Design: A Systematic Literature Review

Shafiee, Sara

Published in:
Procedia CIRP

Link to article, DOI:
10.1016/j.procir.2023.09.224

Publication date:
2024

Document Version
Publisher's PDF, also known as Version of record

Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 121 (2024) 19–24

www.elsevier.com/locate/procedia

11th CIRP Global Web Conference (CIRPe 2023)

Integration of Product and Manufacturing Design: A Systematic Literature Review

Sara Shafiee[a,*]

[a]Technical University of Denmark, Department of Mechanical and Civil Engineering, 2800 Kgs. Lyngby, Denmark

* Corresponding author. Tel.: +45 50304495. *E-mail address:* sashaf@dtu.dk

Abstract

The integrated product life cycle encompasses key stages in product development, production, and maintenance. Effective management of these stages is vital for operational efficiency and competitiveness. However, the impact of design, product configuration, and operational changes on manufacturing performance requires further investigation. This systematic literature review examines the interplay between the manufacturing systems' life cycle, design, configuration, and operations. Literature emphasizes the integration of software and digital tools to achieve operational excellence and competitiveness. The findings offer valuable insights for future research and aid decision-making for practitioners seeking to enhance manufacturing processes through effective integration of product, manufacturing, and digital technologies.

Keywords: Integrated product and manufacturing; Product lifecycle; Design; Configuration; Manufacturing systems; Operation excellence

1. Introduction

Despite the long-standing emphasis in literature, the "integrated product and manufacturing" field still lacks comprehensive research. Our review search has revealed this gap in the literature, indicating that some studies that should have explored this interface have not fully addressed it. To avoid any confusion, we define 'integrated product and manufacturing' as the holistic approach that encompasses the alignment and coordination of product design activities with manufacturing processes, which involves the integration of various software/hardware tools to facilitate product configuration and optimize production plant operations. [1]. While a significant amount of research has focused on individual aspects of product design and manufacturing [2,3], there remains an insufficient link between product design and engineering and manufacturing strategy in the existing literature [4,5]. This shortage of proposed solutions has had a direct impact on industries. For instance, if a design engineer provides a product specification that does not consider manufacturability, it can lead to product failures [6].

1.1. Need for Integrated Product and Manufacturing Systems

In the current competitive market, customers' demands for personalized products have grown because they are looking for products that meet their unique needs [7,8]. As a result, the manufacturing industry faces the challenge of producing higher-quality customized products, with reduced lead-time, and costs. To remain competitive, manufacturing companies must adopt digital products and manufacturing systems. Managing product variety across the entire supply chain is a critical challenge in meeting personalized product demands [8]. While the space for personalized solutions may appear vast, configuration systems and product lifecycle management systems are implemented to handle the complexity. The number of possibilities within a given product category is finite

10.1016/j.procir.2023.09.224

due to constraints related to control, usage, and safety that are considered during the product configuration process [9,10]. However, the personalization strategy extends beyond meeting customer requirements; it is also a business consideration that can influence the market and drive increased sales [8,9].

The manufacturing industry, therefore, confronts the complex task of producing products that align with personalized requirements while achieving higher quality, shorter lead times, and cost-effectiveness. Manufacturing serves as a crucial foundation of the global economy [10]. In the face of a shrinking product life cycle, advanced manufacturing competes fiercely on a global scale [11]. Achieving economies of scope and scale by producing innovative product variants through customization is imperative. However, small and medium-sized companies encounter challenges in designing and developing new products, implementing new technologies, and optimizing production scope and manufacturing processes [10]. While existing approaches in literature and practice, such as concurrent engineering (CE) and design for manufacturing (DFM), integrate production aspects into product engineering [12], there is a need for a formalized method of storing and reusing knowledge from past and future generations of products, production systems, and business models. With the increasing complexity of product design and manufacturing processes, the ability to capture, retain, and leverage knowledge becomes crucial. By establishing a formalized knowledge management approach, companies can avoid reinventing the wheel, benefit from lessons learned, and capitalize on previous successes, leading to more effective decision-making, accelerated innovation, and enhanced competitiveness.

Concurrent Engineering (CE), also known as Simultaneous Engineering (SE), is defined as "a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support" [13]. Adopting a concurrent perspective in engineering implies that the engineers responsible for product and production system design activities are interdependent, with each party's decisions and actions influencing the other [14]. To enhance quality and reduce costs, the design and manufacturing processes must be organized in parallel. Furthermore, integrating methods and processes can lead to improved environmental outcomes. DfM and Design for Assembly (DfA) are approaches that integrate manufacturing aspects into product design, such as designing parts to be multi-functional [15]. In addition, set-based CE proposes working with solution sets rather than a single solution to identify overlaps between different domains [16].

1.2. Definition of Product Lifecycle Management (PLM) and its Significance

On the product side, effective management of requirements from legislation, customers, and other stakeholders necessitates the integrated development of both the product and production systems. Utilizing a product platform involves developing modules that can be combined to create predefined product variants or customized through module configuration [17]. However, significant challenges persist in terms of the time and effort required for initial development and the difficulties associated with maintaining these platforms. Moreover, the link between product platform development and the development of the production system, and the consideration of manufacturing constraints is often lacking [18]. PLM (Product Lifecycle Management) systems are centered around coordinating Information and Communication Technologies (ICTs), processes, and methodologies throughout the entire life cycle of products. In the past decade, this complexity has increased significantly due to the emergence of Industry 4.0 technologies [18]. Industry 4.0 is built upon pillars such as the Internet of Things (IoT), cloud services, big data, and analytics [19].

1.3. Overview of Various Systems in Manufacturing

The interaction between product and manufacturing involves utilizing various steps and systems. These include personalized and customized order placement facilitated by configuration systems [5]. Product (re)design and rapid prototyping are achieved through tools like Computer-Aided Design (CAD), Computer-Aided Systems (CAS), 3D printing, Augmented Reality (AR), and Virtual Reality (VR). Order processing and scheduling are managed using Enterprise Resource Planning (ERP) systems, while product assembly and inspection rely on PLM or Product Data Management (PDM) systems. Additionally, manufacturing design and synthesis for changeable requirements are supported by various types of plant simulation systems. Figure 1 demonstrates the interrelationships of product, configuration, and manufacturing.

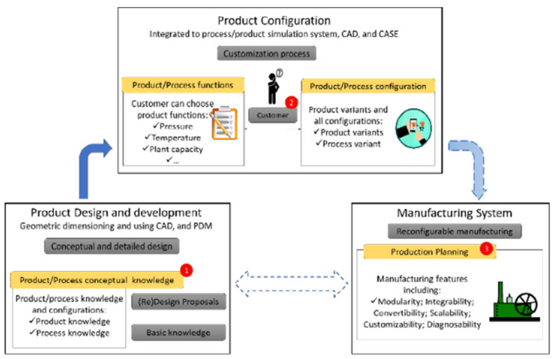

Fig. 1. The interfaces between product design, configuration and manufacturing.

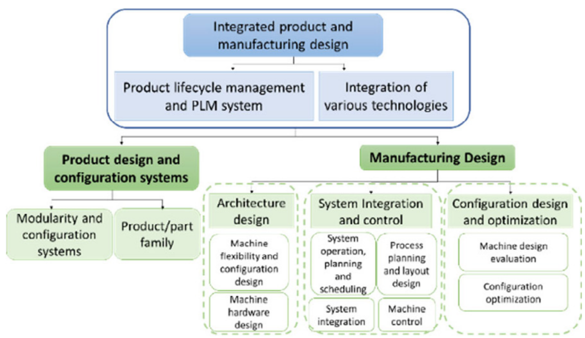

Fig. 2. a) the main scope of this study (integrated product and manufacturing design); b) the product design and configuration as a subcategory; c) manufacturing design as a subcategory

This paper presents a comprehensive review of the existing literature, aiming to examine the key knowledge elements related to the integrated product/system life cycle and the implications of design, control, and operational modifications on manufacturing systems. Through a systematic literature review, even though few papers focus on integrating product and manufacturing, this study reveals that significant attention has been given to integrating software and digital tools throughout the supply chain, highlighting their indispensability in modern manufacturing practices.

2. Methods

To address the conceptual lack of clarity in the field of integrated and aligned product and manufacturing design literature, we conducted a systematic literature review following a three-step protocol: data search, data analysis, and report generation [20]. The data search encompassed two steps. First, the search string TITLE-ABS-KEY ("integrated product and manufacturing" OR "integrated product and production" OR "interface product and manufacturing" AND "manufacturing" OR "production") was applied to search for journal and conference articles and reviews in English on the Elsevier Scopus database from 2000. A total of 43 publications were initially identified, and their abstracts were scanned to determine the sample of relevant literature. Based on specific selection criteria, including explicit focus on integrated product and manufacturing design and contributions that aligned with the scope of our research (e.g., reviews, definitions, frameworks), we selected a subset of 12 articles for full-text reading. This systematic approach ensured a comprehensive review of the literature on integrated product and manufacturing design, enhancing the reliability and validity of our findings. The researchers also utilized the backward snowballing approach [21] to capture additional established and conceptual knowledge beyond the initial data search. This involved screening and reviewing the references of the initially selected articles, assessing their relevance based on title and content. The snowballing procedure was then applied to the newly added publications, and this iterative process continued until no further relevant publications were identified. Through this snowballing approach, 24 additional publications were identified, expanding the pool of relevant literature to a total of 36. This comprehensive approach ensured the incorporation of insights gained from both the initial search and the exploration of references, capturing a broader range of relevant knowledge. During the data reporting phase, the author integrated, synthesized, and compiled their analyses, which are presented in Section 3 of the paper. After selecting relevant studies, the researchers defined the relevant topics, as depicted in Figure 2 as the main categories (represented by blue blocks) and subcategories (green blocks).

3. Literature review results

3.1. Product lifecycle management and PLM system

This section presents the available literature linking product design and manufacturing process ontology that can lead to greater industry adoption and knowledge reuse for manufacturing systems. Most papers address only the alignment of process plan generation with product modularization considering the machine configuration level [22,23]. In this sub-section, we provide an overview of PLM to gain insights into the factors contributing to effective product and manufacturing design integration through PLM systems.

The integrated design and manufacturing methodology encompasses various techniques such as product design, configuration, engineering, and process simulation modeling. This approach is instrumental in facilitating the (re)design and (re)engineering of products and processes, providing valuable insights into cost indications, determining suitable manufacturing paradigms, and conducting virtual experiments to assess the impact of production volume changes on designs and flexibility requirements in production systems [24]. PLM plays a pivotal role in this integrated approach, as it revolves around coordinating technologies, processes, and methodologies throughout the entire lifecycle of the products. PLM systems enable effective product information management, documentation, and collaboration, ensuring seamless integration between product design and manufacturing activities. The advent of emerging technologies associated with Industry 4.0 has further contributed to the complexity of this landscape [14]. Säfsten et al. [14] conducted a literature review and interviews with over 50 professionals from five manufacturing companies. Their findings highlighted the importance of integrated product and production platforms in supporting manufacturing companies' competitiveness in dynamic markets characterized by high diversity and rapid change [14]. Vogel-Heuser et al. [25] proposed a concept called co-evolution or co-platforming, which facilitates the simultaneous development of product and production platforms. They suggested combining an engineering approach for automated production, based on systems modeling language and cyber-physical system architectures, with models and techniques for software and hardware deployment. This interdisciplinary approach has the potential to enhance the integration between product and manufacturing domains [25].

Siiskonenet al. [26] presented a novel methodology for establishing integrated product and manufacturing system platform designs in the context of mass customization, specifically focusing on pharmaceutical products. Their approach aimed to assess the performance of these platform designs and enable the customization of products within the established platform framework. Levandowski et al. [16] applied set-based concurrent engineering to develop derivative products and extend the platform's capabilities to connect products and manufacturing systems. They proposed two modes of operation: Mode I, where products are configured within the existing platform's capabilities, and Mode II, which involves expanding the platform's functionality when required. This approach facilitates informed design decisions that span across the entire lifecycle of the products.

Michaelis et al. [27] introduced a model for the conceptual design phase, focusing on reusing and redesigning components, machinery, manufacturing processes, and design solutions. They proposed a component structure that encompassed both product and manufacturing systems, including features, parts, and assemblies. This component structure was then linked to the manufacturing process through the Function-Means framework, enabling a seamless connection between product design and manufacturing considerations. [27]. Albers et al. [12] presented the concept of Product-Production-CoDesign, which considers six aspects to capture the interdependencies between products, production systems, and business models. Their approach aims to visualize these interdependencies and provide a comprehensive understanding of the relationships among these elements. Stürmlinger et al. [28] propose a method that combines a representative model for a holistic overview of interdependencies with a tool-based model utilizing Model-Based Systems Engineering (MBSE). This approach enables the automatic connection and evaluation of data, facilitating a more efficient analysis of the interdependencies between products and production systems. [13]Bruch and Bellgran [29] suggested an innovative structure for production system development, aiming to enable manufacturing companies to introduce new products quickly and cost-effectively. Their approach emphasizes the need for an interactive relationship between product innovation and the innovation of the company's production system. Regarding integrating communication and process management, some researchers have highlighted the importance of the communication layer. Limited research has focused on effective process management in the analysis/business layer [30]. Other solutions involve the development of architecture models that consider both the physical structure of the production system and the corresponding services [31].

3.2. Integration of various technologies

In this sub-section, we delve into integrating various crucial technologies in product and manufacturing design integration. We examine how technologies contribute to the seamless integration of product and manufacturing processes highlighting the opportunities and future directions for integrating these technologies into the product lifecycle and manufacturing processes.

Digitalization plays a crucial role in establishing a connection between product and production platforms. Digitalization encompasses the adoption and utilization of digital tools, data repositories, and advanced technologies that enable enhanced coordination and integration across the entire product lifecycle and manufacturing processes. A platform can encompass various digital tools, data repositories, and data management systems, all of which need to be integrated effectively [14]. Quin and Cheng [32] have highlighted several digital design and manufacturing technologies that support the entire product realization process, starting from design conception and engineering to manufacturing. These technologies include additive manufacturing, Cyber-Physical Systems (CPS), Big Data, the Internet of Things (IoT), Computer-Aided Manufacturing (CAM), Digital Twin, and SMAC (Social, Mobile, Analytics, Cloud). Additionally, product and design technologies such as Smart Products, Finite Element Analysis (FEA), User Experience (UX), and Human-Centered Design (HCD) play a significant role in the integration of product and manufacturing processes. Moreover, manufacturers face economic, organizational, and environmental challenges, including competitive pressure, the demand for personalized products and services, shrinking product lifecycles, and rapidly changing technologies [32]. These challenges necessitate the integration of product and manufacturing value chains to ensure agility and competitiveness. The state-of-the-art research suggests that integrating the various systems into a more cohesive approach can help address these challenges effectively [14]. Stoffels et al. [13] introduced a standalone software tool based on a set-based method to support the screening of potential combinations of functional principles, manufacturing processes, and materials. The tool considers multidimensional data, including ecological, economic, and technical aspects, to assist in decision-making processes related to product and production design. Researchers have been actively investigating product design and configuration, which is crucial in meeting market demands. However, product configuration faces challenges related to manufacturing processes due to the increasing demand for personalized products [1]. Fortunately, the technologies introduced by Industry 4.0, such as the IoT, CASE, CAD, Cyber-Physical Systems (CPS), and reconfigurable machines, have provided solutions to address the requirements of personalized products [33,34]. To effectively produce highly customized or personalized products, it is crucial to integrate the configurations of products and processes [35]. In modern manufacturing, flexibility, reliability, and availability are important, and real production costs also play a critical role [36]. Companies or individuals must access traditional manufacturing approaches' necessary design and manufacturing infrastructure. This includes acquiring expensive workstations for efficient 3D modeling, specialized software, suitable hardware, adequate resources, and a team of specialists to ensure high-performance components are produced. Yigit et al. [37] have been pioneers in proposing a systematic methodology for producing modular products within a reconfigurable manufacturing system (RMS). They address the trade-off between the quality loss resulting from modularization and the cost of reconfiguration by formulating it as an integer nonlinear programming problem, Feng et al. [38] propose a conceptual design model that leverages intelligent algorithms and data warehouse technologies for function reasoning and scheme decision-making. This model facilitates the iterative mapping from customer requirements to the solution space. Salonitis [39] has developed an integrated framework for the simultaneous design of modular products and automated assembly systems. Their approach is based on the Design Structure Matrix and Modular Function Deployment, enabling efficient coordination between the two design processes. They introduce MPCC (Modular Product Platform Configuration and Co-planning of platforms), which combines assembly and disassembly with product configuration. This framework generates product platforms and family members, ensuring compatibility with mixed-model assembly lines [40]. In another study, researchers employed a co-platform strategy for machines and products. This demonstrates that the manufacturing system platform remains unchanged when introducing new product variants with additional features within the same product family. This approach supports the economic sustainability of manufacturing [41]. Open Architecture Controllers have become prevalent in manufacturing systems, emphasizing the importance of interfaces between software modules [42]. For example, Leng et al. [43] have introduced the concept of the Open-Architecture Machine Tool (OAMT), which represents a novel class of machine tools. These OAMTs are standardized platforms facilitating rapid reconfiguration driven by digital twins within reconfigurable manufacturing systems (RMS) [24,36,44]. In recent years, numerous research projects have focused on enabling collaborative platforms to effectively integrate digital collaboration among the manufacturing, design, and customer perspectives. However, establishing trustable collaboration and efficiently leveraging customer views still poses challenges. To address this, Barenji et al. [45] have proposed a blockchain-enabled fog computing-based collaborative design and manufacturing platform. This platform aims to foster triple communication and cooperation among manufacturing, design, and customers within a trustable environment. Leveraging blockchain technology and fog computing offers enhanced transparency, security, and efficiency in collaborative processes.

When exploring the integration of various technologies, it is important to highlight the contributions of CAM) and CAE. CAM plays a significant role in controlling manufacturing operations, while CAS supports decision-making and enhances the overall efficiency of manufacturing systems. In addition to the technologies discussed above, several other technologies have also emerged as significant contributors to the integration of product and manufacturing design. These include Cloud Computing, which enables collaborative access to shared resources and software tools; Artificial Intelligence (AI) and Machine Learning (ML), which provide capabilities for optimization, pattern recognition, and intelligent decision-making; Robotics and Automation, enhancing efficiency and productivity in manufacturing operations; Advanced Simulation and Virtual Reality (VR), facilitating immersive visualization and design validation; Supply Chain Integration Technologies, enabling seamless coordination and visibility across the supply chain; and Data Analytics and Business Intelligence (BI), supporting data-driven decision-making and process optimization.

4. Concluding remarks

This systematic literature review has shed light on various methodologies, frameworks, and technologies that facilitate the integration of these two domains, enabling manufacturers to adapt to market requirements and achieve competitive advantage [1]. The literature review presented in this paper highlights the significance of integrating product and manufacturing design within the context of modern manufacturing systems. Building upon the reviewed literature, it is crucial to look towards the future development directions in the Integration of Product and Manufacturing Design field to guide further research and innovation. In light of the reviewed literature, several future development directions emerge as crucial for advancing the field. Firstly, emerging technologies such as advanced automation, artificial intelligence, and data analytics hold great potential in transforming product design and manufacturing processes. Researchers can explore the integration of these technologies to enable more efficient and intelligent decision-making, optimization, and resource utilization.

Secondly, sustainability and environmental considerations are becoming increasingly important in manufacturing [37]. Future research should focus on developing sustainable manufacturing practices, including circular economy principles, energy-efficient processes, and eco-friendly materials. Thirdly, the integration of digital-physical systems and human-robot collaboration [42] presents exciting opportunities for improving productivity, flexibility, and worker safety. Future studies can investigate novel approaches for seamless interaction between humans and machines, enhancing collaboration and efficiency on the shop floor. Additionally, interdisciplinary collaborations and knowledge sharing between engineers, designers, data scientists, social scientists, and domain experts are essential for tackling the complex challenges in integrated product and manufacturing design. The introduction of blockchain-enabled fog computing-based platforms has addressed the challenges of trustable collaboration and efficient utilization of customer views, providing a secure and transparent environment for information exchange [44,45]. Collaborative research efforts can address issues related to data interoperability, privacy concerns, ethical implications, and the integration of supply chain partners.

This paper has some limitations. First, this literature review focused primarily on English-language publications from specific databases, potentially excluding relevant research from other sources or languages. Second, the review mainly centered on studies published since 2000 and overlooking earlier contributions. Third, the scope of the review was focused on the integration of product and manufacturing design, and other aspects such as supply chain management or sustainability were not addressed. Further investigation can focus on the implementation challenges and barriers to seamless integration between product and manufacturing design. Moreover, future research can explore innovative technologies and methodologies, such as artificial intelligence, machine learning, and advanced data analytics, to enhance the integration process. There is need for future research to investigate the impacts of integrated product and manufacturing design on sustainability, including resource efficiency, waste reduction, and environmental performance, also the role of human factors.

References

[1] Shafiee S, Zhang L, Mortensen NH, Hansen HN. Integrating product configuration systems with manufacturing system reconfiguration. Procedia CIRP 2022;107:999–1004. https://doi.org/10.1016/j.procir.2022.05.098.

[2] Wang Y, Wu J, Lin L, Shafiee S. An online community-based dynamic customisation model: the trade-off between customer satisfaction and enterprise profit. Int J Prod Res 2021;59:1–29. https://doi.org/10.1080/00207543.2019.1693649.

[3] Lianos AK, Koutsoukos S, Bikas H, Stavropoulos P. Manufacturability Assessment and Design for AM. Procedia CIRP, vol. 91, Elsevier B.V.; 2020, p. 290–4. https://doi.org/10.1016/j.procir.2020.02.178.

[4] Dekkers R, Chang CM, Kreutzfeldt J. The interface between product design and engineering and manufacturing: A review of the literature and empirical evidence. Int J Prod Econ 2013;144:316–33. https://doi.org/10.1016/j.ijpe.2013.02.020.

[5] Yoon S. Building digital twinning: Data, information, and models. Journal of Building Engineering 2023;76:107021. https://doi.org/10.1016/J.JOBE.2023.107021.

[6] Chhim P, Chinnam RB, Sadawi N. Product design and manufacturing process based ontology for manufacturing knowledge reuse. J Intell Manuf 2019;30:905–16. https://doi.org/10.1007/S10845-016-1290-2/FIGURES/10.

[7] Dekkers R, Chang CM, Kreutzfeldt J. The interface between product design and engineering and manufacturing: A review of the literature and empirical evidence. Int J Prod Econ 2013;144:316–33. https://doi.org/10.1016/j.ijpe.2013.02.020.

[8] Shafiee S, Kristjansdottir K, Hvam L, Forza C. How to scope configuration projects and manage the knowledge they require. J Knowl Manag 2018;22:982–1014. https://doi.org/10.1108/JKM-01-2017-0017.

[9] Shafiee S, Sandrin E, Forza C, Kristjansdottir K, Haug A, Hvam L. Framing business cases for the success of product configuration system projects. Comput Ind 2023;146:103839. https://doi.org/10.1016/J.COMPIND.2022.103839.

[10] ElMaraghy H, ElMaraghy W. Learning integrated product and manufacturing systems. Procedia CIRP, vol. 32, Elsevier B.V.; 2015, p. 19–24. https://doi.org/10.1016/j.procir.2015.02.222.

[11] Piroozfar P, Farr ERP, Hvam L, Robinson D, Shafiee S. Configuration platform for customisation of design, manufacturing and assembly processes of building façade systems: A building information modelling perspective. Autom Constr 2019;106. https://doi.org/10.1016/j.autcon.2019.102914.

[12] Albers A, Lanza G, Klippert M, Schäfer L, Frey A, Hellweg F, et al. Product-Production-CoDesign: An Approach on Integrated Product and Production Engineering Across Generations and Life Cycles. Procedia CIRP, vol. 109, Elsevier B.V.; 2022, p. 167–72. https://doi.org/10.1016/j.procir.2022.05.231.

[13] Stoffels P, Kaspar J, Bähre D, Vielhaber M. Integrated Product and Production Engineering Approach - A Tool-Based Method for a Holistic Sustainable Design, Process and Material Selection. Procedia Manuf, vol. 21, Elsevier B.V.; 2018, p. 790–7. https://doi.org/10.1016/j.promfg.2018.02.185.

[14] Säfsten K, Elgh F, Rösiö C, Stolt R. Integrated Product and Production Platforms: Towards a Research Agenda. Advances in Transdisciplinary Engineering, vol. 21, IOS Press BV; 2022, p. 829–41. https://doi.org/10.3233/ATDE220201.

[15] Chu WS, Kim MS, Jang KH, Song JH, Rodrigue H, Chun DM, et al. From design for manufacturing (DFM) to manufacturing for design (MFD) via hybrid manufacturing and smart factory: A review and perspective of paradigm shift. International Journal of Precision Engineering and Manufacturing - Green Technology 2016;3:209–22. https://doi.org/10.1007/s40684-016-0028-0.

[16] Levandowski C, Michaelis MT, Johannesson H. Set-based development using an integrated product and manufacturing system platform. Concurr Eng Res Appl 2014;22:234–52. https://doi.org/10.1177/1063293X14537654.

[17] Shafiee S, Haug A, Shafiee Kristensen S, Hvam L. Application of design thinking to product-configuration projects. Journal of Manufacturing Technology Management 2021;32:219–41. https://doi.org/10.1108/JMTM-04-2020-0137.

[18] Pirmoradi Z, Wang GG, Simpson TW. A review of recent literature in product family design and platform-based product development. Advances in Product Family and Product Platform Design: Methods and Applications, Springer New York; 2014, p. 1–46. https://doi.org/10.1007/978-1-4614-7937-6_1.

[19] Ghobakhloo M. The future of manufacturing industry: a strategic roadmap toward Industry 4.0. Journal of Manufacturing Technology Management 2018;29:910–36. https://doi.org/10.1108/JMTM-02-2018-0057.

[20] de Almeida Biolchini JC, Mian PG, Natali ACC, Conte TU, Travassos GH. Scientific research ontology to support systematic review in software engineering. Advanced Engineering Informatics 2007;21:133–51. https://doi.org/10.1016/J.AEI.2006.11.006.

[21] Wohlin C, Kalinowski M, Romero Felizardo K, Mendes E. Successful combination of database search and snowballing for identification of primary studies in systematic literature studies. Inf Softw Technol 2022;147. https://doi.org/10.1016/J.INFSOF.2022.106908.

[22] Benderbal HH, Dahane M, Benyoucef L. Modularity assessment in reconfigurable manufacturing system (RMS) design: an Archived Multi-Objective Simulated Annealing-based approach. Modularity Assessment in Reconfigurable Manufacturing System (RMS) Design: An Archived Multi-Objective Simulated Annealing-Based Approach 2018;94:729–49. https://doi.org/10.1007/s00170-017-0803-2.

[23] Massimi E, Khezri A, Benderbal HH, Benyoucef L. A heuristic-based non-linear mixed integer approach for optimizing modularity and integrability in a sustainable reconfigurable manufacturing environment. International Journal of Advanced Manufacturing Technology 2020;108:1997–2020. https://doi.org/10.1007/s00170-020-05366-y.

[24] Agyapong-Kodua K, Darlington R, Ratchev S. Towards the derivation of an integrated design and manufacturing methodology. Int J Comput Integr Manuf 2013;26:527–39. https://doi.org/10.1080/0951192X.2012.749528.

[25] Vogel-Heuser B, Wildermann S, Teich J. Towards the co-evolution of industrial products and its production systems by combining models from development and hardware/software deployment in cyber-physical systems. Production Engineering 2017;11:687–94. https://doi.org/10.1007/s11740-017-0765-0.

[26] Siiskonen M, Malmqvist J, Folestad S. Integrated product and manufacturing system platforms supporting the design of personalized medicines. J Manuf Syst 2020;56:281–95. https://doi.org/10.1016/j.jmsy.2020.06.016.

[27] Michaelis MT, Johannesson H, Elmaraghy HA. Function and process modeling for integrated product and manufacturing system platforms. J Manuf Syst 2015;36:203–15. https://doi.org/10.1016/j.jmsy.2014.06.012.

[28] Stürmlinger T, Jost D, Mandel C, Behrendt M, Albers A. Impact and risk analysis in the integrated development of product and production system. Procedia CIRP, vol. 91, Elsevier B.V.; 2020, p. 627–33. https://doi.org/10.1016/j.procir.2020.02.221.

[29] Bruch J, Bellgran M. Integrated portfolio planning of products and production systems. Journal of Manufacturing Technology Management 2014;25:155–74. https://doi.org/10.1108/JMTM-09-2013-0126.

[30] Rusev SJ, Salonitis K. Operational Excellence Assessment Framework for Manufacturing Companies. Procedia CIRP, vol. 55, Elsevier B.V.; 2016, p. 272–7. https://doi.org/10.1016/j.procir.2016.08.026.

[31] Benkamoun N, ElMaraghy W, Huyet AL, Kouiss K. Architecture framework for manufacturing system design. Procedia CIRP, vol. 17, Elsevier B.V.; 2014, p. 88–93. https://doi.org/10.1016/j.procir.2014.01.101.

[32] Qin SF, Cheng K. Future Digital Design and Manufacturing: Embracing Industry 4.0 and Beyond. Chinese Journal of Mechanical Engineering 2017;30:1047–9. https://doi.org/10.1007/S10033-017-0176-3.

[33] Shafiee S, Wautelet Y, Friis SC, Lis L, Harlou U, Hvam L. Evaluating the benefits of a computer-aided software engineering tool to develop and document product configuration systems. Comput Ind 2021;128:103432. https://doi.org/10.1016/j.compind.2021.103432.

[34] Shafiee S, Hvam L, Haug A, Dam M, Kristjansdottir K. The documentation of product configuration systems: A framework and an IT solution. Advanced Engineering Informatics 2017;32:163–75. https://doi.org/10.1016/j.aei.2017.02.004.

[35] Zheng P, wang H, Sang Z, Zhong RY, Liu Y, Liu C, et al. Smart manufacturing systems for Industry 4.0: Conceptual framework, scenarios, and future perspectives. Frontiers of Mechanical Engineering 2018;13:137–50. https://doi.org/10.1007/s11465-018-0499-5.

[36] Paszkiewicz A, Bolanowski M, Budzik G, Przeszłowski Ł, Oleksy M. Process of creating an integrated design and manufacturing environment as part of the structure of industry 4.0. Processes 2020;8. https://doi.org/10.3390/PR8091019.

[37] Yigit AS, Ulsoy AG, Allahverdi A. Optimizing modular product design for reconfigurable manufacturing. J Intell Manuf 2002;13:309–16.

[38] Feng Y, Zhao Y, Zheng H, Li Z, Tan J. Data-driven product design toward intelligent manufacturing: A review: Int J Adv Robot Syst 2020;17. https://doi.org/10.1177/1729881420911257.

[39] Salonitis K. Modular design for increasing assembly automation. CIRP Annals 2014;63:189–92. https://doi.org/10.1016/J.CIRP.2014.03.100.

[40] Hanafy M, ElMaraghy H. Modular product platform configuration and co-planning of assembly lines using assembly and disassembly. J Manuf Syst 2017;42:289–305. https://doi.org/10.1016/J.JMSY.2016.12.002.

[41] Abbas M, ElMaraghy H. Synthesis and optimization of manufacturing systems configuration using co-platforming. CIRP J Manuf Sci Technol 2018;20:51–65. https://doi.org/10.1016/J.CIRPJ.2017.09.006.

[42] Gadalla M, Xue D. Recent advances in research on reconfigurable machine tools: a literature review. Int J Prod Res 2017;55:1440–54. https://doi.org/10.1080/00207543.2016.1237795.

[43] Leng J, Liu Q, Ye S, Jing J, Wang Y, Zhang C, et al. Digital twin-driven rapid reconfiguration of the automated manufacturing system via an open architecture model. Robot Comput Integr Manuf 2020;63. https://doi.org/10.1016/j.rcim.2019.101895.

[44] Zhao YF, Habeeb S, Xu X. Research into integrated design and manufacturing based on STEP. International Journal of Advanced Manufacturing Technology 2009;44:606–24. https://doi.org/10.1007/s00170-008-1841-6.

[45] Barenji AV, Guo H, Wang Y, Li Z, Rong Y. Toward blockchain and fog computing collaborative design and manufacturing platform: Support customer view. Robot Comput Integr Manuf 2021;67:102043. https://doi.org/10.1016/J.RCIM.2020.102043.