The role of AI in Product Design: A Systematic Literature Review

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ARTICLE INFO	ABSTRACT
Keywords: Artificial Intelligence Role; Product Design; Ethics; Human-AI Collaboration *Article history:* Received 2025-04-12 Revised 2025-05-05 Accepted 2025-05-08	Applying Artificial Intelligence (AI) in product design offers opportunities to enhance efficiency, idea exploration, and personalization. However, its impact on human creativity and related ethical concerns remains unclear. This study aims to explore the role of AI in product design and highlight challenges in human-AI collaboration. Using an exploratory approach and a Systematic Literature Review with the PRISMA protocol, findings show that while AI accelerates the design process, human involvement remains crucial for creativity. Ethical issues such as intellectual property and workforce displacement also require attention. The study underscores the need for collaborative approaches and further research across diverse industries. *This is an open access article under the CC BY license.*

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1. INTRODUCTION

Product design is a discipline in engineering and art that focuses on creating and developing products that have aesthetic value and meet functionality, ergonomics, and production efficiency. Product design encompasses various aspects, including material selection, manufacturing processes, user needs analysis, and technology integration to create innovative and market-relevant solutions (Ulrich, Eppinger, & Yang, 2020). In the modern industry, product design plays a strategic role because it determines how a product can meet user needs while also providing a competitive advantage for the company. The product design process involves various stages, from user research, concept development, prototype creation, and mass production. However, the product design process often faces multiple challenges, such as high development costs, technical complexity, and the limitations of human creativity in exploring more optimal design possibilities. To address these issues, artificial intelligence (AI) technology is increasingly being adopted to support and enhance the product design process.

Product design is a complex yet crucial field in the modern industry. With the right approach, including the utilization of AI technology, companies can create more innovative, efficient, and competitive products in the global market. Therefore, further research on the integration of AI in product design is becoming increasingly relevant, both for the academic world and the industry.

Artificial Intelligence (AI) is a technology that enables machines to mimic human intelligence in various tasks, including learning, problem-solving, and data-driven decision-making (Russell & Norvig, 2021).In recent years, AI has shown a significant impact across various sectors, including product design. The application of AI in product design and development enables organizations to manage product complexity and the ever-evolving needs of customers within a shorter product lifecycle helps companies manage complex information more efficiently, accelerate time-to-market, and enhance the effectiveness of product maintenance and recovery through real-time monitoring (Sharma, 2023). Additionally, AI has been integrated into Computer-Aided Design (CAD) systems, enabling automation in design creation, reducing human errors, and increasing the speed of design iterations (Makridakis, 2017).

Furthermore, AI also plays a role in user data analysis, where AI-based systems can collect and analyze data from customers to identify their preferences based on historical data and market trends. Thus, AI enables the creation of more personalized designs that meet the specific needs of customers (Shneiderman, 2020). Additionally, AI plays a crucial role in design simulation and optimization, allowing companies to test various scenarios before mass production of the product. With this technology, companies can save on production costs and reduce the risk of product failure, as various potential errors have been identified from the early stages of design development (Camburn et al., 2015).

In facing various challenges in product design, artificial intelligence (AI) has become one of the solutions that can enhance efficiency and innovation in product design.AI enables the automation of the design process, predictive modeling, and more accurate customer data analysis to create products that better meet market needs (Sharma, 2023).AI also enables the use of generative design technology, where algorithms can generate various design alternatives based on parameters set by the designer. Thus, AI helps companies explore a wider range of design solutions and reduces the iteration time required in the product development process.

Additionally, AI can be used in design simulation and optimization, where computer models can test various scenarios before the product is produced. This technology allows companies to reduce prototype costs, improve design accuracy, and accelerate product time-to-market (Camburn et al., 2015). On the other hand, AI also plays a role in enhancing product personalization, where the system can analyze individual preferences and recommend designs that better meet customer needs.

Overall, research on the role of AI in product design is very important because it has broad implications for both industry and academia. From an industrial perspective, AI helps companies develop more innovative products, reduce production time, and increase cost efficiency. Meanwhile, from an academic perspective, this research can provide new insights into how AI technology can be effectively integrated into the product design process. Moreover, the application of AI in product design also has significant social and economic impacts. With AI, companies can respond more quickly to market trends and create products that better meet customer needs. This not only enhances the company's competitiveness but also drives economic growth through more sustainable innovation (Gero & Kannengiesser, 2014).

Modern product design has undergone significant evolution driven by technological advancements. The main characteristics of this era include compressed product life cycles, consumer demands for higher personalization, and a shift towards high-variation production on a small scale. To address this complexity, AI-based design models have been developed by adapting nonlinear programming techniques into linear programming, aiming to enhance efficiency in solving design problems. This approach indicates that the integration of contemporary information technology and design principles can optimize the implementation of new technologies while enriching the cultural and emotional dimensions for users (Ying et al., 2021).

The implementation of AI in the product design process has a substantial impact on enhancing quality and innovation. The capability of AI in deeply analyzing consumer data and market trends enables designers to produce artifacts that more accurately respond to user needs and preferences. Additionally, AI facilitates design simulation and validation efficiently, accelerates iterations, and enhances the precision of the final design. Thus, the adoption of AI in the realm of product design not

only enhances process efficiency but also promotes innovation through the exploration of more comprehensive and creative design solutions (Hong, 2023).

The emergence of the product innovation era facilitated by AI is reflected in various case studies, ranging from creativity augmentation to supply chain optimization and production acceleration. In this context, designers' understanding of AI fundamentals and relevant ethical principles, such as fairness, transparency, and accountability, becomes crucial. The implementation of these principles by leading technology entities such as Google, OpenAI, and Microsoft emphasizes that AI-based design goes beyond mere efficiency considerations and includes moral responsibility in innovation (Akhtar & Ramkumar, 2024).

In the context of marketing, the utilization of AI in generating automatically designed products is becoming increasingly prevalent. Research findings indicate a tendency among consumers to assign higher value to products generated by AI, especially utilitarian products. However, this phenomenon may decline as consumer understanding of technology increases, potentially reducing the novelty effect of AI products (Zhang et al., 2022).

Furthermore, various AI methodologies, including artificial neural networks, fuzzy logic, ontology, genetic algorithms, and k-nearest neighbors, have been applied to address various challenges in product design. The implementation of these methodologies allows the production process to become more flexible, responsive to market dynamics, and enhances interdisciplinary collaboration throughout the entire production chain (Bartolome et al., 2021).

In addition to operational efficiency, AI plays a significant role in accelerating the transition towards a circular economy. The application of AI in product design contributes to waste reduction through rapid prototyping, real-time material analysis, and remote maintenance, which reinforces the principles of reuse, remanufacturing, and repair in the production cycle (Ghoreishi & Happonen, 2020).

The transformative potential of big data and AI algorithms in modern product design is becoming increasingly realized, especially through the capability to efficiently access and process unstructured data such as text and images (Quan et al., 2023). The integration of AI is becoming increasingly essential in driving the automation of design processes, which is crucial for minimizing manual workload, accelerating product development cycles, and enhancing overall efficiency (Hodges, 2025). AI-based automation enables organizations to identify viable design concepts more quickly, reduce the potential for errors, and ensure consistency in quality and innovation (Hodges, 2025). This facilitates the creation of more complex, innovative, and market-responsive products efficiently and safely (Hodges, 2025).

AI fundamentally transforms the design process from conventional methodologies that tend to be slow and rely on subjective expertise to a faster, automated, and data-driven workflow (Hodges, 2025). The generative design system, supported by historical data and prior knowledge, enables AI to generate and refine designs iteratively, accelerating the acquisition of the final design (Hodges, 2025). The implementation of AI-based "copilot" systems empowers users with varying levels of expertise to access specific knowledge and execute complex workflows through natural language commands, enhancing efficiency and focusing on the creative aspects (Hodges, 2025). The development of Reduced Order Models (ROMs) by AI enables real-time prediction of design outcomes, reducing the need for intensive computational simulations and accelerating validation (Hodges, 2025). Consequently, AI facilitates faster simulations and validations with more efficient resource allocation, enabling the evaluation of various design scenarios without expensive physical prototypes (Hodges, 2025). The future vision of generative and autonomous design indicates the potential of AI to perform automatic design from conception to final optimization independently (Hodges, 2025). Additionally, AI plays a role in the acquisition and utilization of previous design knowledge to accelerate future processes (Hodges, 2025). The synergy between AI and big data becomes a crucial foundation, where AI's ability to intelligently analyze large volumes of data allows for the extraction of deep insights regarding user preferences and market trends, which in turn guides a more innovative and efficient design process (Quan et al., 2023). The integration of big data and AI becomes a fundamental pillar in designing products that are more adaptive, intelligent, and aligned with market demands more quickly and accurately (Quan et al., 2023).

Although the application of AI in product design has shown various benefits, there are still several research gaps that need to be explored further. One aspect that is still limited in discussion is how AI affects designers' creativity. Several studies have highlighted the role of AI as an aid in design exploration, but it is still unclear whether AI can effectively collaborate with human designers to produce higher innovation or if it limits their creative space (Zhu, 2021).

Moreover, the ethical and social implications of applying AI in product design have not been extensively discussed. For example, the increasing use of AI has the potential to reduce the need for human designers in several stages of the design process, which could impact jobs in the creative industry. Moreover, the aspect of intellectual property rights over designs generated by AI remains a topic of debate, particularly regarding copyright and design originality (Smith, 2022). Furthermore, the effectiveness of AI implementation in product design across various industries is still in question. Most current research focuses on the high-tech and manufacturing sectors, while other industries such as fashion, furniture, and consumer products still receive less attention in academic studies. Understanding the factors that influence the successful implementation of AI in various industrial contexts is crucial so that this technology can be widely and sustainably optimized (Kim, 2023). By identifying and exploring the gaps in this research, it is hoped that a more comprehensive understanding of the role of AI in product design can be achieved, thereby maximizing the potential of this technology in the design industry.

2.   METHODS

This research uses a Systematic Literature Review (SLR), which involves the collection and evaluation of data from research results deemed This study employs a Systematic Literature Review (SLR) approach to comprehensively examine literature relevant to the research topic. SLR was selected due to its ability to provide systematic and in-depth evaluation of related research developments. To ensure transparency and accuracy in the review process, this study adopts the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, which offers clear guidelines for conducting systematic literature reviews.

Table 1. SLR Phase

Phase 1: Planning	Phase 2: Search Process	Phase 3: Document Review
Determining the direction of research	Literature Search: 18	Data extraction and synthesis: 12
Determining source criteria	Sourcing and selection: 17	Writing findings: 12

As illustrated in Table 1, the research process begins with the planning phase, where the research direction is established and literature selection criteria are formulated. This phase serves as the foundation for subsequent steps, ensuring that literature searches are conducted in a focused manner. Subsequently, in the search process phase, an initial identification of 18 articles from various credible sources is performed. These articles are then screened based on predetermined criteria, resulting in 17 articles that qualify for further review. The final phase involves document review, where data extraction and synthesis are conducted on 12 selected articles. The synthesis results form the basis for research findings, ensuring comprehensive and relevant analysis.

Table 2 presents the literature selection criteria for this study, which include the types of articles reviewed, namely research articles, review articles, and conceptual articles. The literature sources are obtained from indexed databases such as Google Scholar and ResearchGate, with a publication timeframe spanning from 2018 to 2025. This temporal limitation aims to ensure that the literature used reflects current developments in the research field under investigation.

Table 2. Article Criteria

Criteria	Description
Type of Article	Research articles, review articles, and conceptual articles
Source	Google Scholar, Research Gate
Publication Time Frame	2018-2025

For the research design itself, it is not specified whether it should be qualitative or quantitative because it remains open to other SLRs and conceptual articles that can support the chosen topic, while still optimizing the results of empirical research as a reference. Articles that have the highest relevance to the existing criteria as the main articles for conducting the SLR will be listed in Table 3.

Table 3. Journal sources of articles included in the final sample

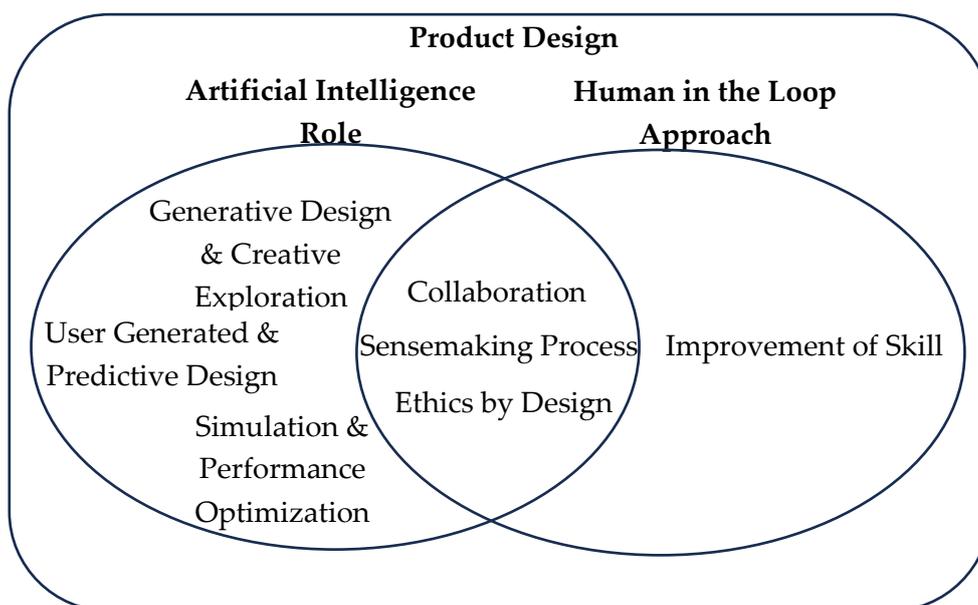| Publisher	Number of Article
Product Development and Management Association (PDMA)	1
Association for Computing Machinery (ACM)	1
Rezekne Academy of Technologies	1
7universum	1
IEEE	1
arXiv	1
Politecnico di Milano	1
Springer	1
MDPI	2
Elsevier	1
Wiley (via *Advanced Intelligent Systems*)	1

3.   FINDINGS AND DISCUSSION

Figure 1. Conceptual Framework

3. 1 Artificial Intelligence Role

Generative Design and Creative Exploration

Artificial Intelligence has emerged as a transformative force in generative design, enabling automated idea generation, design space exploration, and structural innovation far beyond human cognitive limitations. Sharma (2023) emphasizes that AI systems are capable of processing complex design parameters—such as material constraints, geometric forms, and functional requirements—to autonomously generate multiple design alternatives. This capability significantly accelerates the ideation phase, allowing designers to iterate rapidly across a broad solution space without being limited by manual methods. Such exploration is not only faster but often results in more innovative outcomes, as AI can reveal non-intuitive configurations or shapes that a human designer might overlook.

Additionally, Li, Wang, and Deng (2021) demonstrate how intelligent modeling methods such as refined composite multi-scale Lempel–Ziv complexity—originally developed for fault detection in rotary machinery—can be extended into the design domain to evaluate structural intricacies, assess risk, and identify potential performance bottlenecks before prototyping. This use of complexity metrics directly parallels the need for dynamic generative processes in AI-aided design, where solutions must account for real-time adaptability and long-term resilience. These technologies together empower designers to focus more on creative decision-making, while AI autonomously optimizes the technical configurations within defined parameters. As Sharma (2023) further notes, this fusion of machine computation with human creativity leads to more holistic and sustainable product development cycles, particularly in engineering and manufacturing sectors where innovation speed is a competitive advantage.

User-Centered and Predictive Design

A second foundational role of AI in product design is its capacity for user-centered modeling and predictive personalization. By leveraging large-scale behavioral datasets, AI systems can learn user preferences, forecast interaction patterns, and adapt products accordingly. This shift towards personalization is critical in contemporary design practice, where consumer expectations are increasingly dynamic and context-sensitive. Sharma (2023) outlines how AI can capture user interaction data to continuously refine product features, interfaces, and performance outputs—an approach that turns static product development into a living, iterative process.

This personalization is further enriched by ecosystemic approaches, as discussed by Erdogan et al. (2021), who analyze how urban-to-rural innovation diffusion can inform sustainable pathways to education and training. While their research is rooted in social innovation systems, it strongly parallels AI's role in tailoring products to socio-geographic contexts. For example, an AI-assisted design platform may adapt product specifications based on rural infrastructure limitations or urban user behavior trends—thus achieving contextual relevance through learning-based adaptation. Similarly, Wang et al. (2022) describe the development of intelligent assessment systems in education, demonstrating how adaptive AI models can adjust strategies based on user profiles and feedback. Applied to product design, this methodology allows for the development of highly personalized, accessible, and inclusive products, particularly in fields such as education technology, consumer electronics, and healthcare devices. The predictive nature of AI thus not only personalizes experiences but also anticipates unmet user needs before they surface, increasing product-market fit and long-term adoption.

Simulation and Performance Optimization

AI's third critical contribution lies in simulation-based performance optimization, which allows designers to test, refine, and validate products virtually, reducing dependency on costly and time-consuming physical prototypes. AI-driven simulation tools can mimic real-world conditions—thermal

stress, structural fatigue, user interaction scenarios—to detect flaws early in the development process. Sharma (2023) underscores that AI helps in optimizing not only the design output but also the production process, thereby aligning design with manufacturing capabilities and reducing resource waste.

Li, Wang, and Deng (2021) provide a technical example of this by using intelligent algorithms to assess the mechanical behavior of rotary components under operational stress. These insights, although mechanical in nature, illustrate how AI can be used to simulate system-level responses to stress and wear, allowing designers to fine-tune structural tolerances or material selection before any physical testing occurs. Moreover, Wang, Gao, and Pikul (2023) explore the development of embedded intelligent systems that allow autonomous navigation using non-digital cues—suggesting a future where even hardware-level optimization and environment-aware adaptation can be simulated and encoded at the design stage. In this context, AI is not merely a passive tool but an active agent in system-level decision-making, contributing to resilient, energy-efficient, and sustainable product architectures.

These examples collectively demonstrate how AI-powered simulations do more than mirror physical systems—they actively optimize design architecture, ensuring that performance, safety, and user experience are all accounted for in a pre-manufacturing phase. As such, simulation and optimization become integral to reducing costs, accelerating development, and improving final product quality.

3. 2 Human in the Loop Approach

Improvement of Skills

AI can enhance efficiency and allow designers to focus on more complex and creative aspects of design; its implementation also brings the potential reduction of human designers' roles in certain stages. However, this phenomenon has the potential to impact the job landscape in the creative industry, highlighting the urgency of maintaining a balance between human creative capacity and AI capabilities to mitigate the potential loss of jobs (Talgatkyzy, 2024). The application of AI in the design industry is also reconfiguring the competencies required by designers in the future. The evolution of technology demands that designers acquire new skills, as AI can automate several design processes. Human competence, especially in terms of conceptual originality and the effective utilization of AI technology, becomes a determining factor for the successful implementation of AI in various sectors of the design industry (Irbite & Strode, 2021). Although research on AI in visual design has made significant progress, the potential applications of AI extend to other design industries, such as fashion and furniture. This study highlights the fundamental significance of design education in ensuring designers' understanding of essential design principles, empowering them to utilize AI more effectively. In this context, AI serves as a supporting instrument to enhance creativity and design quality, even surpassing the limitations of the high-tech industry (IEEE, 2024).

Collaboration

AI offers significant potential to collaborate effectively with human designers in stimulating creativity, especially in divergent cognitive activities such as research, ideation, elaboration of alternative designs, and prototype exploration. In this context, AI serves as an instrument that expands creative capacity and enhances the operational efficiency of designers, empowering them to steer the creative process more strategically, rather than becoming a substitute (Khan et al., 2025). Comparative studies on the modalities of collaboration between humans and AI in design show that intermittent interactions provide greater opportunities for designers to maintain control over the creative process with AI as a facilitator, unlike continuous collaboration which tends to encourage AI to take a dominant role and potentially reduce human creativity contributions (Figoli et al., 2022).In line with these findings, participants' responses to AI inaccuracies in design tasks show differences in expectations based on the type of task. Tolerance for inaccuracies tends to be high in divergent tasks (idea

generation/limitation), but expectations for accuracy and trust significantly increase in convergent tasks (style integration). Variations in trust levels during the ideation process further emphasize the importance of transparency and user control in AI-human interactions to build effective collaboration (Jeon et al., 2021).

The Sensemaking Process

Although AI plays a crucial role in modern innovation and design through the automation of decision-making tasks and the provision of data-driven design solutions, there is a fundamental difference with human sensemaking.AI is capable of automating structured problem-solving and generating design solutions, but it cannot fully replace sensemaking, which is the human ability to interpret and make sense of complex, ambiguous, or incomplete situations, involving contextual understanding, intuition, and value considerations. Therefore, although AI accelerates certain aspects of decision-making and innovation, the human element in sensemaking remains essential because it involves the attribution of meaning and the formulation of goals that cannot be automated by the system (Verganti et al., 2020).

Ethics by Design for AI

The implementation of AI in the design industry requires comprehensive ethical considerations (Brey et al., 2024). The formation of Ethics by Design for AI (EbD-AI) can be carried out through several systematic stages. First, the integration of ethical values into the design process inherently includes transparency, fairness, privacy, and accountability, ensuring that ethical considerations are not an addendum but rather the foundation of AI development. Second, the use of ethical evaluation instruments, such as checklists and ethical assessments, proactively identifies and addresses potential ethical issues during the development cycle, transforming ethical principles into operational actions in design. Third, the multidimensional engagement of stakeholders, including developers, users, and other relevant parties, accommodates diverse perspectives and values, enriching the decision-making process and ensuring the sustainability of ethical aspects. Fourth, the formulation and implementation of clearly defined and operational ethical principles, translated into design requirements and concrete actions, go beyond an approach based on abstract principles without specific implementation. Fifth, harmonize with policies and regulations, including national standards to ensure compliance and ethical sustainability. Sixth, a multidisciplinary approach that integrates technical expertise and ethics bridges the dichotomy between technological and moral aspects in AI development. Finally, the operationalization of ethical principles in design transforms high-level ethical imperatives into specific actions and procedures that can be implemented in the AI design and development process. Following these stages systematically and effectively will ensure that ethical considerations are integrally internalized in the developed AI technology.

CONCLUSION

Artificial Intelligence (AI) is strategically supporting various aspects of the design process, including generative exploration, user-centered design, and simulation-based performance optimization. AI facilitates accelerated innovation, increased efficiency, and deeper product personalization, particularly in the high-tech and manufacturing sectors. However, the effective use of AI requires collaborative interaction between humans and AI, where the human role remains critical in sensemaking and creative decision-making. This indicates that AI has not entirely replaced human creativity but is a facilitator that can expand creative capacity when applied through an appropriate collaborative strategy.

The findings suggest that the impact of AI on human creativity requires further exploration. While AI has the potential to stimulate idea generation and accelerate design iteration, there is no conclusive evidence as to whether it enhances or constrains designers' creative space. Moreover, this discussion

highlights the urgent need to address AI implementation's ethical and social dimensions, including the potential displacement of human roles in the creative industry and the unresolved issues surrounding the intellectual property rights of AI-generated designs.

Furthermore, although AI applications in design have been extensively studied in the context of high-tech and manufacturing industries, their implementation in other sectors, such as fashion, furniture, and consumer products, remains considerably limited. Therefore, further research is necessary to understand how AI can be effectively and ethically implemented across various industrial contexts and how it can genuinely enhance human creativity without replacing it.

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