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# Exploring the role of design in the new product development process towards circular business innovation: Systematic literature review and future directions

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**Abstract:** To safeguard our planet from the threats of resource depletion, pollution and climate change, a fundamental change in our production, consumption and lifestyle choices is required. Companies and designers play a central role in this transformation and are called to action by implementing New Product Development (NPD) design strategies for sustainable and circular innovation. This systematic literature review investigates the intersection between product design, new product development process and sustainability, addressing critical questions: How can design within the NPD process support organizations in moving toward sustainable and circular innovation? What challenges and obstacles hinder the incorporation of circular design practices into the NPD process? The study provides a comprehensive examination of circular design techniques, exploring their strengths, limitations, and obstacles to widespread adoption. Furthermore, the analysis charts a path for future research efforts, outlining directions that seek to harmonize NPD design processes with the circular economy, ensuring a balanced and sustainable approach to business innovation.

**Keywords:** product design; new product development; circular economy; sustainable innovation

## 1. Introduction

In order to protect the planet from the collateral effects of human activity such as climate change, destruction of natural ecosystems, resource depletion, and environmental pollution, and to assure a better future for the coming generations, it is crucial to move towards sustainable development (European Commission, 2019). This kind of development, as initially



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described in the 1987 Brundtland Report by the World Commission on Environment and Development, meets current needs without compromising the ability of the next generations to satisfy their demands (European Union, 2023).

This requires a process of transformation that shifts away from the present well-established linear models of production and consumption, linked to the logic of supply, production, use and disposal, towards a circular economy (Rizos et al., 2017). The concept of "end-of-life" disappears in this new regenerative system since products and materials are kept in circulation through maintenance, reuse, refurbishing, remanufacturing, recycling, and composting processes. The primary goal is to generate the minimum amount of waste for disposal, reduce pollution and consumption of precious resources and, at the same time, ensure greater economic resilience (Ellen MacArthur Foundation, 2013; European Parliament, 2015).

The Kyoto Protocol, the Copenhagen Agreement, and the Paris Agreement are just a few examples of international agreements that have raised awareness of the urgency to think about environmental sustainability and the significance of a green transition while outlining an action plan to curb global warming and encourage the adoption of sustainable practices (Aguar et al., 2022; Riesener et al., 2023). Ovais Sarmad, the Deputy Executive Secretary of the United Nations Framework Convention on Climate Change, emphasized the role of the circular economy in implementing the Paris Agreement: "The Paris Agreement calls for a transformation of our production and consumption patterns, particularly in developed countries. That means circular economy principles: using fewer resources, employing more sustainable materials, and recycling what we have used." (United Nations, 2021). In this context, design plays a key function in supporting businesses towards circular and sustainable innovation (van Dam et al., 2020). According to the European Commission, product design determines 80% of sustainability performance (Ellen MacArthur Foundation, 2022).

Nevertheless, the existing literature shows a scarcity of studies that in-depth investigate the complexities of design in the context of developing a circular business model (Sumter et al., 2018). Addressing this gap, this article aims to explore the following research questions: How can design within New Product Development (NPD) process assist organizations in moving toward sustainable and circular innovation? What challenges and obstacles hinder the incorporation of sustainable design practices into the NPD process?

Through a systematic literature review and qualitative analysis, the study in-depth investigates the integration of design, NPD, and circular economy. The objective of the conducted study is to critically analyze the existing knowledge in this domain, collect the major findings, and extract practical insights. These observations will encourage companies to adopt circular and sustainable design principles in NPD processes, giving them essential direction and support.

The subsequent sections of this article are meticulously structured as follows: section 2 describes the methodology and approach. The study results are presented in sections 3 and 4,

together with a full analysis of the advantages and drawbacks of implementing the new circular design techniques. Finally, section 5 focuses on the findings and the presentation of potential areas for future research.

## 2. Method

The following section outlines the methodology adopted to perform the systematic literature review and provides visual representations guiding the analysis and reflection process. To ensure methodological rigour, the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) protocol was adhered to. The Scopus database, known for its excellent published articles and comprehensive worldwide and regional coverage of scientific journals, conference proceedings, and book sources, served as the search engine (Baas et al., 2020).

The search query, (new product development" OR "NPD") AND ("design" OR "ecodesign" OR) AND ("sustainability" OR "circular economy"), was introduced within the database. The search was narrowed to results for publications that had the specified keywords in the title, abstract, or keywords section. Specifically, boolean operators ("AND" for integration between sustainability, NPD, and design, and "OR" for synonyms and related concepts) were utilized to broaden the search without missing relevant papers. Given the novelty of the topic and to encompass the most recent research, no specific time limit was set, and the Scopus database was updated until October 2023.

Figure 1 offers a comprehensive visual representation of the systematic literature review process, illustrating the application of the PRISMA method. The chart outlines the intricate stages of search and articles selection, clearly defining the inclusion and exclusion criteria employed in the study.

The initial exclusion criteria involved filtering for articles published only in English-language journals within the subject areas of engineering, business, management and accounting, environmental sciences, social sciences, decision sciences, economics, econometrics, and finance. Papers from unrelated disciplines such as agriculture, material science, and medicine were excluded due to their divergence from the research areas investigated.

Out of the 196 initial results, 99 papers satisfied the specified criteria. The titles and abstracts of these papers were thoroughly reviewed to determine the most significant contributions. Papers that lacked accessibility or relevance were not given further consideration.

Ultimately, 27 papers were meticulously chosen for analysis and systematization. The analysis was conducted using Microsoft Excel, ensuring a structured approach to data synthesis. A comprehensive list of the selected articles can be found in the accompanying Table 1.

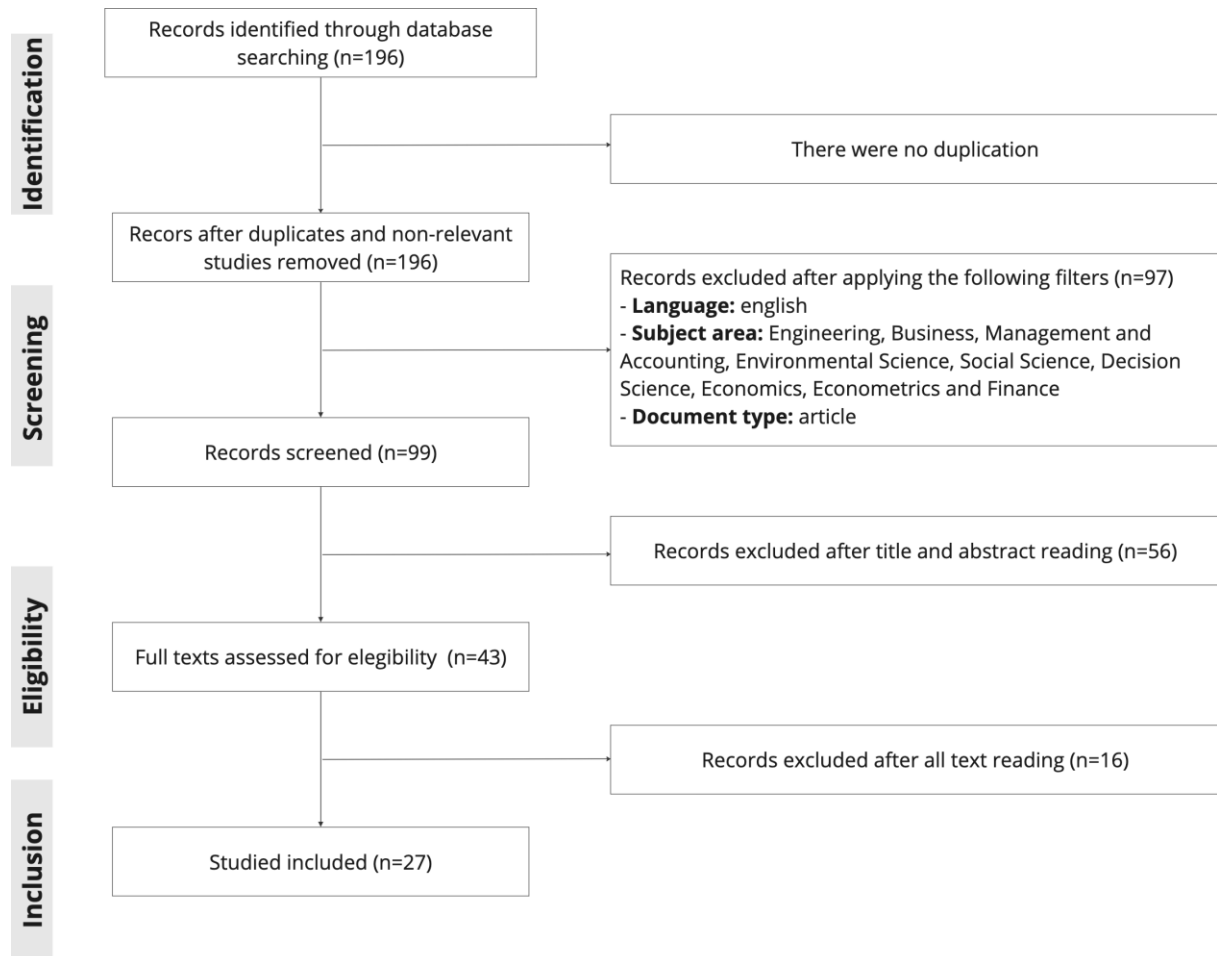


Figure 1 Overview of the systematic literature review performed adopting PRISMA methodology

**Table 1** *Included papers from the systematic literature review*

Authors	Title	Year	Journal	Citations
Battesini Teixeira T.G.; de Medeiros J.F.; Kolling C.; Duarte Ribeiro J.L.; Morea D.	Redesign in the textile industry: Proposal of a methodology for the insertion of circular thinking in product development processes	2023	Journal of Cleaner Production	1
Aguiar M.F.; Mesa J.A.; Jugend D.; Pinheiro M.A.P.; Fiorini P.D.C.	Circular product design: strategies, challenges and relationships with new product development	2022	Management of Environmental Quality: An International Journal	18
Aguiar M.F.; Jugend D.	Circular product design maturity matrix: A guideline to evaluate new product development in light of the circular economy transition	2022	Journal of Cleaner Production	10
Boorsma N.; Peck D.; Bakker T.; Bakker C.; Balkenende R.	The strategic value of design for remanufacturing: a case study of professional imaging equipment	2022	Journal of Remanufacturing	4
Blagu D.; Szabo D.; Dragomir D.; Neamtu C.; Popescu D.	Offering Carbon Smart Options through Product Development to Meet Customer Expectations	2022	Sustainability (Switzerland)	2
Krawczyk-Dembicka E.; Urban W.; Łukaszewicz K.	The study of co-design in the area of manufacturing	2022	Bulletin of the Polish Academy of Sciences: Technical Sciences	1
Franzò S.; Urbinati A.; Chiaroni D.; Chiesa V.	Unravelling the design process of business models from linear to circular: An empirical investigation	2021	Business Strategy and the Environment	14
Kuys J.; Al Mahmud A.; Kuys B.	A case study of university–industry collaboration for sustainable furniture design	2021	Sustainability (Switzerland)	5
Permatasari A.; Dhewanto W.; Delyana D.	A proposed model of value co-creation through multi-stakeholder collaboration in domestic product development	2021	Business: Theory and Practice	4
Hallstedt S.I.; Isaksson O.; Rönnbäck A.A.Ö.	The need for new product development capabilities from digitalization, sustainability, and servitization trends	2020	Sustainability (Switzerland)	46
Park C.; Charnley F.; Longhurst P.; Bolton S.; Evans S.	Too fast to bother? Integrity, instrumentality, and externality factors for early sustainable design implementation in the fast-moving-consumer-goods sector	2020	Journal of Design Research	0
Brockhaus S.; Petersen M.; Knemeyer A.M.	The fallacy of “trickle-down” product sustainability: Translating strategic sustainability targets into product development efforts	2019	International Journal of Operations and Production Management	9
Alli H.; Sazwan Mohd Rashid M.S.	Users' emotional responses and perceived product quality towards sustainable design	2019	Alam Cipta	1
Haines-Gadd M.; Chapman J.; Lloyd P.; Mason J.; Aliakseyeu D.	Emotional durability design Nine-A tool for product longevity	2018	Sustainability (Switzerland)	54
Sinclair M.; Sheldrick L.; Moreno M.; Dewberry E.	Consumer intervention mapping-A tool for designing future product strategies within circular product service systems	2018	Sustainability (Switzerland)	46
Singh J.; Ordoñez I.	Resource recovery from post-consumer waste: important lessons for the upcoming circular economy	2016	Journal of Cleaner Production	278
Thomé A.M.T.; Scavarda A.; Ceryno P.S.; Remmen A.	Sustainable new product development: a longitudinal review	2016	Clean Technologies and Environmental Policy	39
Koo Y.	The role of designers in integrating societal value in the product and service development processes	2016	International Journal of Design	11
Praveen Sandeep M.; Kannan N.	Role of firm characteristics and practices on the new product development practices in fabrication industry: An empirical analysis	2016	International Journal of Economic Research	0
Gmelin H.; Seuring S.	Achieving sustainable new product development by integrating product life-cycle management capabilities	2014	International Journal of Production Economics	78
Alblas A.A.; Peters K.; Wortmann J.C.	Fuzzy sustainability incentives in new product development: An empirical exploration of sustainability challenges in manufacturing companies	2014	International Journal of Operations and Production Management	63
Dangelico R.M.; Pontrandolfo P.; Pujari D.	Developing sustainable new products in the textile and upholstered furniture industries: Role of external integrative capabilities	2013	Journal of Product Innovation Management	167
Driessen P.H.; Hillebrand B.; Kok R.A.W.; Verhallen T.M.M.	Green new product development: The pivotal role of product greenness	2013	IEEE Transactions on Engineering Management	132
Agrawal V.V.; Ülkü S.	The role of modular upgradability as a green design strategy	2013	Manufacturing and Service Operations Management	67
Petala E.; Wever R.; Dutilh C.; Brezet H.	The role of new product development briefs in implementing sustainability: A case study	2010	Journal of Engineering and Technology Management - JET-M	61
Pujari D.	Eco-innovation and new product development: Understanding the influences on market performance	2006	Technovation	469
Berchicci L.; Bodewes W.	Bridging environmental issues with new product development	2005	Business Strategy and the Environment	123

### 3. Results

The contents of the 27 papers found were thoroughly examined and coded based on the year of publication, the geographic origin, the methodology adopted and the number of citations.

In Figure 2, the evolution over time of the selected publications is depicted. Notably, the timeline reveals that these articles are not uniformly distributed across all years, indicating a recent surge in research concerning the intersection of new product development (NPD), design and sustainability. This aligns with the contemporary shift in research and business paradigms, where an increasing number of companies are transitioning toward sustainable and circular innovation (Brenner & Drdla, 2023).

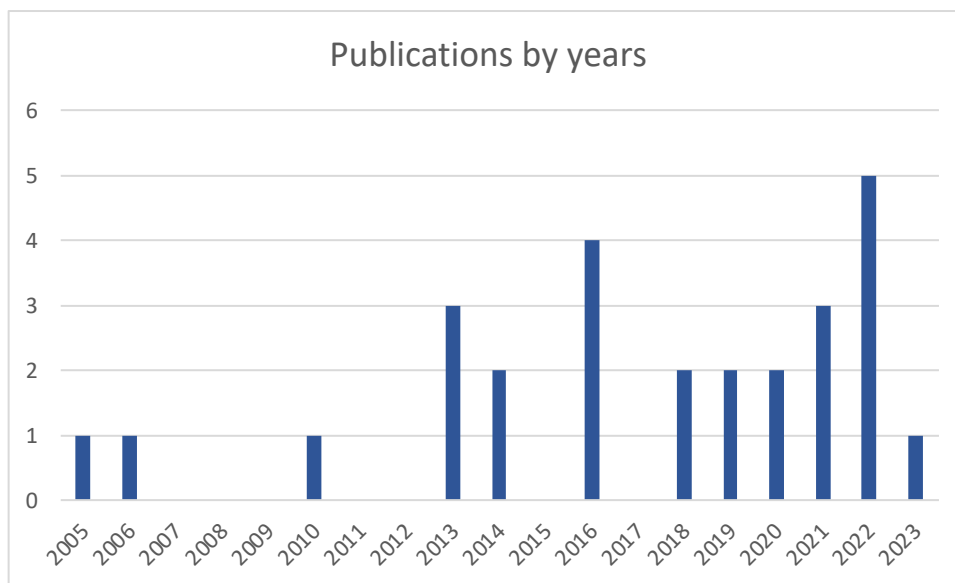


Figure 2 Number of publications by years

The first publication addressing this theme was published in 2006; however, it wasn't until 2014 that a substantial increase in publications became evident. From that point onward, there has been a notable and consistent rise in research output, indicating a growing trend. This observation underscores the contemporary significance and rising scholarly attention toward this dynamic interdisciplinary field.

Considering the first authors and their institutional affiliations, it was possible to map the 27 selected publications based on their geographical origins. As depicted in Figure 3, a substantial concentration of studies emerged in Europe, particularly in the Netherlands. Notably, the majority of these studies are attributed to authors affiliated with the Faculty of Industrial Design at Delft University of Technology. Outside of Europe, Brazil stands out as the nation with the highest number of publications, primarily from authors associated with the Production Engineering Department at UNESP University in São Paulo. Moreover, several Asian

countries, including South Korea, Indonesia, and Malaysia, have also delved into these topics, indicating a growing global interest in the field.



Country	n° of publications
USA	3
Canada	2
Brazil	4
Netherlands	5
Germany	1
Romania	1
UK	2
Italy	1
Sweden	2
India	1
Poland	1
Malaysia	1
South Korea	1
Indonesia	1
Australia	1

Figure 3 Distribution of publications by country

Figure 4 shows the authors' research methods, classified as quantitative, qualitative or mixed methodology. Interestingly, most of the studies used a qualitative approach, while only 15% adopted a mixed method model, combining both qualitative and quantitative approaches. Notably, the research corpus lacked any strictly quantitative investigations. The contributors used a range of techniques for their research, including case study analysis, observations, surveys, workshops, and semi-structured interviews. This varied methodological approach reflects a comprehensive exploration of the topic, combining theoretical analysis with practical, real-world insights.



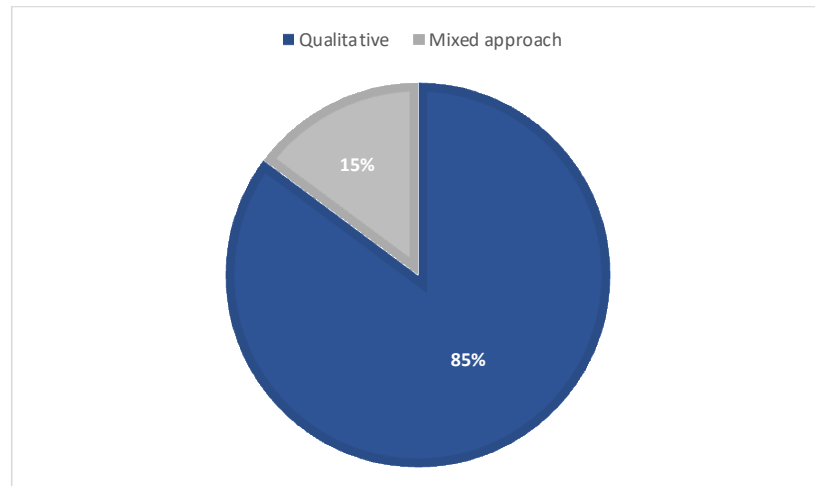


Figure 4 Methodological approaches

Finally, Table 2 highlights the top 5 most cited articles among those selected using the PRISMA method and sourced from the Scopus database.

Table 2 More cited articles from the one selected

Authors	Title	Year	Journal	Citations
Pujari D.	Eco-innovation and new product development: Understanding the influences on market performance	2006	Technovation	469
Singh J.; Ordoñez I.	Resource recovery from post-consumer waste: important lessons for the upcoming circular economy	2016	Journal of Cleaner Production	278
Dangelico R.M.; Pontrandolfo P.; Pujari D.	Developing sustainable new products in the textile and upholstered furniture industries: Role of external integrative capabilities	2013	Journal of Product Innovation Management	167
Driessen P.H.; Hillebrand B.; Kok R.A.W.; Verhallen T.M.M.	Green new product development: The pivotal role of product greenness	2013	IEEE Transactions on Engineering Management	132
Berchicci L.; Bodewes W.	Bridging environmental issues with new product development	2005	Business Strategy and the Environment	123

The following articles are primarily based on a thorough literature analysis and empirical investigation of the concepts of corporate eco-innovation and the integration of environmental sustainability within New Product Development (NPD) processes. For instance, Pujari D.'s study underscores the significance of coordination between product development professionals and environmental specialists, supplier involvement, and life cycle analysis in enhancing the market performance of eco-friendly products (Pujari, 2006). Other researchers, like Singh J. and Ordoñez I., focus on the analysis of products developed from discarded materials to comprehend resource recirculation, revealing practical challenges in implementing a circular economy. They propose a model wherein waste management plays a pivotal role in facilitating material recirculation, emphasizing the need to anticipate social, economic, and environmental challenges in product design to achieve circular economy goals (Singh & Ordoñez, 2016).

## 4. Discussion

As was previously mentioned, nowadays organizations place a high priority on sustainability in response to the urgent environmental problems our planet is currently facing (Blagu et al., 2022). This imperative demands a proactive response from designers, urging them to embrace more efficient and sustainable design practices. Indeed, through careful design of the product architecture, it is possible to significantly influence the future environmental impact of the artefact (Brockhaus et al., 2019). However, empirical studies underscore the significant challenges businesses encounter in translating sustainability goals into concrete operational targets (Alblas et al., 2014).

This systematic literature analysis has revealed several design strategies for the new product development (NPD) process, which we will examine in this section. The in-depth exploration of them is crucial, as it clarifies how companies can effectively integrate responsible practices into their NPD process, improving their environmental footprint but also contributing positively to sustainability efforts on a larger scale. Furthermore, this section will delve deeply into the inherent limitations and advantages associated with the application of these design strategies within the companies' NPD framework.

### 4.1 Eco-design

In response to the environmental challenges, the concept of eco-design has gained substantial recognition and deeper exploration. Charter and Tischner provided a comprehensive definition, describing eco-design as "Sustainable solutions are products, services, hybrids or system changes that minimize negative and maximize positive sustainability impacts – economic, environmental, social and ethical – throughout and beyond the life-cycle of existing products or solutions, while fulfilling acceptable societal demands/needs" (Charter & Tischner, 2001).

Eco-design encompasses a suite of environmentally conscious guidelines, strategies, and methods. These include concepts like "design for assembly", "design for repair", "design for recycling", and "design for maintenance" (Pigosso et al., 2015; Van Doorselaer, 2022). The primary objective of this approach is to consider a product's environmental footprint across its entire life cycle. This entails enhancing existing products through incremental improvements, marking a strategic shift toward more sustainable and responsible design practices. Often, achieving these objectives requires balancing acts with other product characteristics such as functionality, quality, appearance, and cost (den Hollander et al., 2017).

### 4.2 Circular product design

In the realm of sustainable design, there has been a notable transition from eco-design to a more holistic approach, termed circular product design (CPD) (Moreno et al., 2016). This evolution reflects a shift towards integrating circular economy (CE) principles into the core of New Product Development (NPD) processes (Aguar et al., 2022).

This shift, driven by the concept of a circular economy, poses a substantial challenge to designers. They are tasked with envisioning products and materials through a circular lens,

seeking innovative solutions that redefine the traditional linear approach (Aguiar & Jugend, 2022; den Hollander et al., 2017). At its essence, CPD aims to extend the longevity of products, preventing premature obsolescence. This objective is approached at various levels, including product and component integrity design. Here, the focus is on preserving both the physical and emotional essence of objects, ensuring they can be reused across multiple cycles by different users (den Hollander et al., 2017).

Additionally, CPD emphasizes material-level strategies, ensuring efficient recyclability and minimizing the consumption of virgin raw materials, thus conserving precious fossil resources (Ghisellini et al., 2016). Numerous authors have explored practices to enhance product circularity. Noteworthy among these is (Cayzer et al., 2017), emphasizing factors such as durability, modularization, regeneration, and the use of non-harmful, recycled, and recyclable materials. Furthermore, the advent of Industry 4.0 technologies has catalyzed the seamless integration of circular economy principles into new product development. These technologies optimize material usage, facilitating closed loops and reducing waste throughout a product's lifecycle (Aguiar et al., 2022)

However, embracing CPD is not a simple task, particularly in industries still rooted in traditional New Product Development (NPD) models. Many companies, driven primarily by profit, tend to prioritize speed-to-market over sustainability and quality, resulting in products that often lack circularity (Aguiar & Jugend, 2022). In contrast, forward-thinking brands are pioneering the concept of closed-loop products. One such example is Patagonia, renowned for its transparency and sustainability practices. Through their innovative business model, customers can return clothing items for store credits, enabling the resale of these products and significantly extending their lifespan while curbing waste (Subramanian et al., 2019). This paradigm shift underscores the imperative for designers and industries to adapt, embracing circular product design as not just a concept but a transformative approach that aligns profit with environmental responsibility.

### *4.3 Design for remanufacturing*

The concept of designing products for remanufacturing has garnered significant attention in the literature, primarily due to its potential to augment resource productivity and foster sustainability. By facilitating the disassembly, refurbishment, and reassembly of products, businesses can extend the lifecycle of their offerings, reducing the demand for virgin raw materials. This approach not only conserves valuable resources but also aligns with the principles of circular economy, wherein products are kept in use for as long as possible (Boorsma et al., 2022).

Despite the evident advantages, integrating remanufacturing into the early stages of product design presents challenges. Research conducted by Hatcher G. D. et al. reveals a predominant focus on cost savings and optimization for the initial usage cycle. Companies often struggle to anticipate customer demand for subsequent usage cycles, leading to difficulties in designing products that seamlessly transition through multiple lifecycles (Hatcher et al., 2013).

To overcome these challenges, a paradigm shift is necessary. Companies need to adopt a forward-thinking approach that transcends the traditional linear product lifecycle. This entails understanding market demands not only for the product's initial use but also for its subsequent lifecycles. By leveraging market insights, businesses can create products that are not only cost-efficient in their initial use but are also adaptable and easily remanufactured for subsequent cycles (Boorsma et al., 2022).

#### *4.4 Modular design*

Modular design is another potential strategy that businesses could adopt, offering significant advantages across various stages of the product lifecycle. By reusing the same modules, it minimizes the need to produce virgin components and improves the use of materials and processes during production. Modular products streamline maintenance during use, resulting in quicker and more economical repairs. This simplified method also improves the product's ability to be repaired. Modular items are easy to deconstruct for disposal, which makes recycling, reuse, and remanufacturing processes easier. Adopting modular design encourages resource efficiency and can help businesses adopt more environmentally friendly and sustainable practices (Sonego et al., 2018).

#### *4.5 Emotional Durable Design (EDD)*

A circular strategy explored by Haines-Gadd et al. in their study with Philips Lighting is Emotional Durable Design (EDD). Specifically, EDD revolves around the user and the relationship established between the user and the product. It delves into unexpressed emotional experiences, exploring the reasons that drive consumers to use, consume, and dispose of certain products more quickly than others. The goal of this approach is to reduce the use of natural resources by encouraging and promoting longer-lasting and resilient relationships with products (Haines-Gadd et al., 2018).

This strategy emphasizes understanding the psychological aspect of products alongside their physical reality. Designing long-lasting items is pointless if the end consumers are unwilling to maintain them. Several studies have highlighted key factors that determine the emotional connection between users and products, fostering attachment. These factors include memories associated with the product, pleasure and enjoyment derived from its use, usability, utility, and reliability (Haines-Gadd et al., 2018).

Companies need to recognize the profound impact of emotional connections between users and products, as these connections significantly influence consumer behaviours. By acknowledging and incorporating these emotional factors into the design process, businesses can create products that not only endure physically but also resonate emotionally with consumers, fostering longer-lasting, meaningful relationships with their products (Chapman, 2015).

#### *4.6 Co-design*

The systematic literature review conducted revealed a compelling theme: the invaluable role of co-design. Co-design, an inclusive approach involving collaboration between designers,

end-users, and stakeholders, emerged as a transformative practice in shaping the development of new products. This symbiotic relationship between designers and consumers fosters the creation of products meticulously attuned to user requirements, resulting in heightened customer satisfaction. The overarching objective remains the creation of enduring products, ones that are not only utilized extensively by customers but also contribute significantly to their long-term contentment (Krawczyk-Dembicka et al., 2022). Prahalad C. K. and Ramaswamy V., in their seminal work, posit a fundamental concept: the value of a product, when co-created with active user involvement, surpasses that of products developed through conventional means (Prahalad & Ramaswamy, 2004).

#### *4.7 From traditional NPD to CE-NPD*

The term New Product Development (NPD) refers to the process of developing a new product from ideation to market introduction, involving collaboration across various organizational functions (Iheanachor et al., 2021). Over time, several NPD models have been developed. In 1990, Cooper introduced the stage-gate model, comprising five main phases (scoping, build business case, development, testing and validation, launch) separated by verification and control gates (Cooper, 1990).

However, the significant challenge faced by industries, professionals, and researchers lies in understanding how to incorporate environmental considerations into the NPD process while aligning with new regulations and market demands (Berchicci & Bodewes, 2005). Unlike traditional NPD, which is based on distinct stages separated by control gates, Circular Economy-oriented New Product Development (CE-NPD) introduces greater complexity due to the incorporation of CE considerations throughout the process. Consequently, companies must invest more time and resources in the development phase (Subramanian et al., 2019).

A substantial body of literature addresses the integration of various sustainability aspects into product development processes, a task that is both demanding and long-term oriented (Thomé et al., 2016). In the context of the NPD process, cooperation between important departments like marketing, design, R&D, quality, and customer service is required. Clear leadership by the program manager is vital to effectively oversee circular product development (Pujari, 2006).

Moreover, scholars such as Albaek et al. (2020) and Desing et al. (2021) stress the critical significance that early NPD phases play in defining the circularity and sustainability of a product. Choices regarding material selection, energy consumption, waste management options, and various other factors like cost, appearance, and environmental impact are fundamental (Aguar & Jugend, 2022). The concept of sustainable design, if not discussed and developed at an expert level during the initial stages of the NPD, may inadvertently be neglected in subsequent phases, risking the product's overall sustainability. To tackle this challenge, it is necessary to engage in in-depth discussions during the front-end phase, which is the period between an opportunity's initial assessment and the idea's development readiness. In this context, it is essential to design the entire product lifecycle from the outset, involving necessary

partners throughout the journey. This proactive approach ensures that sustainability considerations are embedded in the product's core, leading to the development of goods that not only satisfy market demands but also follow sustainable and circular principles (Park et al., 2020).

#### ***4.8 Benefits of circular design strategies in NPD***

Paying attention to sustainability through the production of green products can yield several business advantages. Firstly, it leads to greater efficiency in resource utilization. Additionally, by differentiating their products, organizations have the opportunity to distinguish themselves from competitors, gaining a more significant competitive edge.

Economic advantages are also notable. Several studies have highlighted that implementing circular economy practices could increase the European Gross Domestic Product (GDP) by approximately 11%, generating benefits close to €1.8 trillion by 2030 (Ellen MacArthur Foundation, 2013). Moreover, emerging economies outside Europe, not confined by traditional business models, can also benefit. They can more easily introduce and consider circular aspects in the new product development process (Aguiar & Jugend, 2022).

Krawczyk-Dembicka E. et al. discuss the idea of co-design and highlight its significance for the manufacturing industry and upcoming sustainable transition. Integrating the user into the development process leads to the creation of more customized products, more in line with the final consumers' needs. Through this teamwork involving designers and users, we see the generation of creative and innovative ideas that consider key aspects of sustainability (Krawczyk-Dembicka et al., 2022).

Lastly, the adoption of sustainable and circular strategies positively impacts the company's image. This leads to enhanced brand visibility and recognition, contributing to its overall reputation and credibility. As businesses increasingly embrace sustainability, they not only contribute to environmental preservation but also strengthen their market position and financial prospects, making it a win-win scenario for both the company and the environment (Dangelico et al., 2013).

#### ***4.9 Challenges of circular design strategies in NPD***

The adoption of circular production and consumption patterns in the business sector encounters numerous challenges, requiring a comprehensive approach embedded in design and systems thinking. This design methodology goes beyond the traditional approaches, considering not only the individual components of a product or a process but also their intricate connections, interactions, and impact on the broader context (Jones & Kijima, 2018; Sevaldson, 2022).

Numerous studies have identified technological, financial, consumer behavioral, and organizational barriers, hindering the integration of Circular Economy (CE) principles into the new

product development (NPD) process. Designing for circularity inevitably requires new investments from companies, often involving a complete overhaul of existing products, without a guarantee of market success (Aguiar et al., 2022).

Additionally, Gloria et al. assert that limitations in using Environmental New Product Development (ENPD) tools stem from the poor quality and availability of data, the complexity of environmental issues, and the high costs of implementation. Many companies are risk-averse, requiring clear and explicit justifications, along with objective data, to invest time and money in green projects (Gloria et al., 1995).

Consumers also pose a significant obstacle to Circular Product Design (CPD) implementation. Despite increasing consumer awareness of environmental issues, the higher prices of sustainable products hinder their purchase. Additionally, another interesting aspect is the need to educate consumers about reusing and buying second-hand products. This presents a significant challenge, necessitating a shift in consumer behaviour toward a more sustainable attitude (Holtström et al., 2019).

Within the corporate environment, another limitation lies in the lack of organization and a systematic product development process that incorporates considerations aligned with circular business models. Moreover, the culture of circular economy is not yet thoroughly explored and integrated into all departments of a company. Therefore, it is crucial to promote education on sustainability principles for new product development, involving all stakeholders in the NPD process. This helps prevent potential barriers by equipping them with the necessary skills aligned with CE requirements (Marrucci et al., 2019).

Literature analysis reveals that companies face significant challenges in managing sustainability in NPD processes. Clear research scopes and concrete sustainability goals are necessary. Without well-defined sustainability goals from the outset, marketing cannot justify corporate investments in sustainability initiatives. Addressing these challenges requires a holistic approach involving collaboration between consumers, businesses, and policymakers. Educating all stakeholders, setting achievable sustainability goals, and fostering a culture of circular economy within organizations are key steps toward overcoming these barriers and promoting the successful implementation of Circular Product Design in the NPD process (Aguiar & Jugend, 2022).

Incorporating circular economy principles into New Product Development is a multifaceted endeavour. It requires not only an in-depth understanding of sustainability aspects but also effective coordination among diverse organizational functions. Through clear leadership, constant adaptation to evolving regulations, and seamless collaboration, organizations can navigate the complexities of CE-NPD, paving the way for the development of innovative and sustainable circular products. This multifaceted approach is based on design and systems thinking, recognizing the interconnection of elements, and embracing a holistic perspective to promote truly sustainable innovation.

## 5. Conclusions and future perspectives

Through a comprehensive literature analysis, 27 papers were meticulously examined to explore the pivotal role of design in the new product development process, guiding companies toward sustainable innovation. Current trends, design strategies, approaches, challenges, and barriers hindering implementation were investigated, emphasizing the need for an integrative approach rooted in systemic design and thinking.

The design strategies identified for new product development (NPD), particularly eco-design and circular product design (CPD), present comprehensive frameworks. However, a critical review questions the viability of implementing these strategies in real-world settings, highlighting the difficulties in balancing sustainability goals with other product features and the tension between speed to market and sustainability. While designing products for remanufacturing and embracing modular design show promise, their practical implications need to be examined. Anticipating customer demand for subsequent usage cycles and dealing with the complexities of module reuse raise feasibility issues. Emotional Durable Design (EDD) introduces a human-centered approach, emphasizing emotional connections, but challenges arise regarding maintaining those connections in a disposable consumer culture. The transformative concept of co-design, presented as a game-changer, brings up concerns about scalability and resource intensity.

The transition from traditional NPD to circular economy-oriented NPD (CE-NPD) introduces complexities that require clear leadership and proactive discussions. The study outlines benefits, but a critical review questions the extent to which these can offset challenges such as increased costs and the need for explicit justifications. Furthermore, early integration of sustainability considerations in the NPD, especially during the front-end phase, proves indispensable. An essential theme arising from this literature analysis is the imperative need for corporate education on sustainability, circular economy principles, new business models, and environmental management. This education ensures that all departments engaged in the new product development process are attuned to these themes, empowering them to contribute meaningfully to sustainable innovation by making decisions in line with circular economy principles.

Considering the evolving landscape of sustainable product development, a compelling future perspective lies in the exploration and integration of the Sustainable Product-Service System (S.PSS) design concept. Prominent academics like Prof. Carlo Vezzoli of Politecnico di Milano are leading the charge on this notion, which significantly changes the old product-centric approach by seeing products as part of service systems. Investigating S.PSS design within the framework of circular economy principles, new product development and consumer behaviour offers a promising avenue for future research. This exploration not only enriches our theoretical understanding but also provides practical insights, guiding industries toward innovative, sustainable, and customer-centric business models in line with global environmental objectives. (Su et al., 2023; Vezzoli et al., 2022).



In conclusion, the journey towards sustainability necessitates a thoughtful consideration of industry-specific constraints, consumer behaviours, and the delicate equilibrium between profitability and environmental responsibility.

It's essential to acknowledge the limitations of this work, including the choice of keywords and the reliance on a single database. Additionally, the screening process during the systematic literature analysis might involve subjective elements during the reading and selection of the most relevant papers, along with potential distractions leading to selection errors.

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