Circular Economy Strategies for Small Domestic Appliance Design in China

Yi Xianqin*
Faculty of Design and Architecture, Universiti Putra Malaysia, Serdang, Selangor, Malaysia
Email: gs61434@student.upm.edu.my

Maszura Abdul Ghafar*
Faculty of Design and Architecture, Universiti Putra Malaysia, Serdang, Selangor, Malaysia
Corresponding author
Email: maszu@upm.edu.my

Aidi Hizami Alias*
Faculty of Engineering, Universiti Putra Malaysia, Serdang, Selangor, Malaysia
Email: aidihizami@upm.edu.my

Received Date: **22.03.2024**; Accepted Date: **27.07.2024**; Available Online: **01.08.2024**

* *These authors contributed equally to this study*

ABSTRACT

China is the world's largest home appliance manufacturer, and the increased production of small domestic appliance (SDA) goods is leading to rising carbon emissions. Therefore, there is a need to upcycling SDA due to this phenomenon in China. The purpose of this research was to investigate the optimal circular economy (CE) strategies for SDA that would reduce the carbon footprint caused by this type of manufacturing. This study examined the current SDA design characteristics, usage features, CE concept, and circular product design. Then, based on a comprehensive examination, a circular product framework (CPD) and CE strategies for SDA design were recommended. The results indicate that when designers incorporate a CPD framework into the early stages of SDA design, product integrity could be enhanced, thus reducing carbon emissions. The research will benefit manufacturers by enabling improved SDA circularity, as well as supporting the reduction of e-waste and carbon emissions in China and worldwide.

Keywords: *Small domestic appliance design, Circular economy, Circular product design, Carbon emission, R-strategies*

INTRODUCTION

Since the 1980s, China has become a significant consumer and producer of appliances, with a wide range of small domestic appliances (SDA) having entered Chinese homes. In 2012, China's SDA market was valued at 262 billion RMB, which had increased to 372.1 billion RMB in 2020 and is projected to reach 574.1 billion RMB by 2026 (Qianzhan Industrial Research Institute, 2022). In addition, the household appliance manufacturing industry in Guangdong accounted for over 40% of China's total SDA production in 2022. Due to this extensive SDA production and consumption, the country is currently facing a peak disposal period for these products. Discarded SDAs become e-waste (any discarded electrical or electronic products that have not been reused or refurbished become e-waste). However, only 20% of this was formally recycled: the majority of e-waste generated (80%) was sent to regular garbage (Suppipat & Hu, 2022). In 2019, 4% entered household trash bins and 76% were casually treated (Forti et al., 2020). Both human health and the environment are threatened by the improper disposal of SDA as e-waste, which can contain over 1,000 harmful substances, including toxic elements like lead, mercury, arsenic, cadmium, and flame retardants, which can result in brain damage and tumors. Even when using advanced dismantling processes, environmental problems remain due to the heavy metals content and persistent organic matter. E-waste processing requires resources and poses risks, especially in countries lacking proper management, with health, air, and water all affected (Forti et al., 2020).

Despite accounting for approximately 28% of global carbon emissions, China has pledged that its carbon emissions will peak before 2030 and that it will attain carbon neutrality before 2060. To achieve these goals, China has emphasized the need to transition to a green, low-carbon economy while promoting green recovery and development (Huaxia, 2020). Therefore, SDA circularity in China must be enhanced to reduce e-waste and mitigate the current high carbon emissions.

CIRCULAR ECONOMY AND SMALL DOMESTIC APPLIANCES DESIGN

This section discusses small domestic appliance design and circular economy strategies. Firstly, the study focuses on small domestic appliance designers, as well as product development and usage. Secondly, the CE concept and related barriers are discussed, after which the impact of circular product design methods in terms of improving SDA product design is discussed. Finally, there is a synthesis and outline of three key points of departure (POD).

Small domestic appliance designer

The Ellen MacArthur Foundation indicated that two megatrends - artificial intelligence (AI) and the CE - would intersect in the future due to the consumption of finite resources and a systemic shift (Ellen MacArthur Foundation, n.d.). Design plays a crucial role in both changes. In this study, the term ‘designers' refers to those responsible for a product’s appearance, architecture, and structural design. The following sections discuss the design, product development, and usage of small domestic appliances. Designers are vital in the early stages of product development, shaping relationships between products and consumers and offering disposal alternatives for discarded products (Lofthouse, 2004). The Ellen MacArthur Foundation noted that over 70% of a product's environmental influence is established in the design stage. Decisions made at that point can have lasting impacts, shaping a product's trajectory for years (Ellen MacArthur Foundation, n.d.). Design for the CE is an upcoming, independent field in the sustainability domain that requires a specific approach and a specific set of competencies and tools. Maszura and Rahinah (2018) identified that trans-disciplinary practices during the early design stage could enable lost time and manufacturing waste to be avoided. Meanwhile, Shahbazi and Jönbrink (2020) noted that CE adoption might be hindered by a lack of both designer awareness and incentives for corporations to invest in circular product design. Boorsma et al. (2022) pointed out that the limited readiness among designers to create circular products represents an improvement opportunity. Hailemariam and Erdiaw-Kwasie (2022) emphasized aligning CE targets with business interests, while effective internal communication could boost employees' circular knowledge and subsequently reduce a company's environmental impact. Van Dam et al. (2020) indicated that design education for the CE is essential for industrial designers. However, CE design capabilities have not been extensively discussed, while designers might prioritize a product's usability and functionality to meet customer needs, which creates barriers to designing low-carbon SDAs. Specific circular strategies must be developed across the concept, structure, and detailed design stages, while new trans-disciplinary skills should be promoted to prompt SDA circularity. During the design stage, a designer makes critical decisions about necessary processing inputs, which affects the product's life cycle. In the SDA design context, it is crucial to understand the CE capabilities, knowledge, and experience needed by designers during the design and development stages.

Small domestic appliance product development

Product development is a comprehensive process entailing a series of activities intended to produce and bring to market a product that meets customers' needs (Ulrich et al., 2020). Haessler (2020) highlighted that firms might prioritize only short-term profit maximization, leading to negative environmental impacts; in other words, some managers choose profitability over sustainability. To reduce the carbon footprint created through product manufacturing, scholars have recommended collaboration between and coordination among different company functions (Ulrich et al., 2020) ―including product architecture, material composition, industrial design, product structure, green consumers―and the avoidance of over-design, while schemes have been devised to reduce the number of production steps (Diaz et al., 2022). However, few scholars have discussed product development, despite the comprehensiveness and significance of this process. Additionally, previous studies have primarily focused on optimizing SDA design at the micro-level of product design rather than adopting a systemic perspective. Therefore, during the initial product development phases, the priorities should be conceptual design, material selection, modular design, product integrity, upgradability, and disassembly. Enhancing circularity becomes considerably more complex once a product transitions into mass production. Concurrently, the transition to a circular economy demands collaboration between different stakeholders, such as enterprises, policymakers, users, and waste management entities. Enhanced cooperation between and the integration of various departments and stakeholders could support the transition of small domestic appliance manufacturing to a circular economy.

Small domestic appliance usage

Studies have revealed that consumers' cognition of and consumption behavior toward circular products and services are influenced by product design (Mugge, 2018). In recent years, consumer behavior has been researched from different perspectives and with various results, including green consumer behavior and consumer awareness of product recyclability. Examples of these outcomes include the need to promote the CE concept in educating and nurturing the younger generation of consumers; a correlation between consumer behavior and waste discharge forms; consumer behavior barriers in terms of the CE; the impact of consumer cultural levels; the application of behavior theory in consumer substitution transformation; behavioral intention and the trend for buying energy-saving appliances; and consumer emotional durability (Testa et al., 2020). However, in-depth analysis of user needs and preferences regarding product design is required. Consumer behavior affects how SDA products are purchased, used, and disposed of. This process is closely associated with the circular economy and significantly impacts the SDA industry's carbon emissions. Consumer behavior and design for behavior change (DfBC) must be accommodated in the circular product design framework.

Based on this literature review, it was concluded that the CE capabilities of designers, small domestic appliance product development, and consumer behavior significantly impact a product's environmental footprint and have led to the high carbon emissions created by China's appliance manufacturers. Greater comprehension is needed of the complex interplay between consumer behavior and the CE capabilities, knowledge, and expertise of designers working in the SDA industry. Achieving this would involve collaboration between SDA development and design process stakeholders; the application of previously gained knowledge; and an understanding of the difficulty of acquiring concepts in CE, the usefulness of these techniques, as well as the drivers of and barriers to SDA product development.

Circular economy concept

The CE concept was alluded to in 1966 when Kenneth Boulding proposed a circular association in the environment in his essay 'The Economics of the Coming Spaceship Earth'. In 1989, economists Pearce and Turner proposed the CE concept itself, which gained theoretical support in the field of industrial ecology (Pearce & Turner, 1989). Since then, various related theories have emerged, including 'industrial ecology', 'regenerative design', 'biomimicry', the 'performance economy', and 'Cradle-to-Cradle'. Meanwhile, CE strategies have been evaluated at the macro (national), meso (city, supply chain), and micro-levels (enterprise, product) (Neves et al., 2020). The widely adopted definition of CE is that it is a restorative and regenerative framework that aims to preserve the maximum utility and value of products. The concept is guided by three principles: designing out waste, designing out pollution, and regenerating ecological systems (Ellen MacArthur Foundation, n.d.). Other definitions of the CE have been developed, as Table 1 shows. However, none have been universally accepted, and no specific common themes and principles have emerged from the explanations provided by organizations and research institutions. Above all, the CE aims to mitigate the environmental impact of economic growth by redefining the traditional linear model. Therefore, the current authors regard the CE as constituting a production and consumption system that primarily emphasizes sustaining the continuous circulation of products, components, materials, and energy. Through these principles, the CE should preserve the maximum utility and value of products.

Table 1. Circular economy concepts proposed by institutions

Authors & Institutions	Concept Focus	Year
Circular Economy Promotion Law of the People's Republic of China (PRC)	Reducing, reusing and recycling activities	2008
European Commission (EC)	Product, materials, and resources value, minimizing generation of waste	2015
United Nations Environment Programme (UNEP)	Reduce by design, From a user-to-user perspective, From a user-to-business intermediary perspective, From business-to-business	2019
World Economic Forum (WEF)	A deliberately designed industrial system that restores or regenerates	2022
United States Environmental Protection Agency (EPA)	Elimination of waste through the superior design of materials, products, and systems	2022
Circularity Gap Reporting Initiative	Use less, use longer, use again and make clean	2023

Based on the discussion above, it was concluded that the CE is a production and consumption system aimed at promoting the circulation of products and components, maintaining their value for longer or generating new value. The CE concept remains nebulous and lacks a clear, universally accepted definition. Moreover, the ambiguous delineation of its boundaries poses challenges to advancing CE practices within the SDA manufacturing sector. A more nuanced understanding necessitates an exploration of CE applications from the diverse perspectives of various stakeholders.

Circular product design

Numerous studies have emphasized the importance of circular product design (CPD) in the transition to a CE, with proposed frameworks like R-strategies (which involve actions like rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, and recover) aiming to enhance circularity by minimizing resource consumption (Morseletto, 2020). R-strategies are named after the 're' prefix of the English language designations of the individual strategies. This prefix originally comes from Latin (meaning 'again' or 'back') (Mast et al., 2022). R-strategies can impact various aspects, such as the system, product, component, and material levels (Diaz et al., 2022). A range of strategies and frameworks have been proposed based on 3Rs, while 6Rs strategies, 10Rs strategies and frameworks (Morseletto, 2020), and even 60Rs principles have been posited (Uvarova et al., 2023). Both tangible (material, architecture) and intangible (service, business model, ecosystem) aspects have been incorporated (Diaz et al., 2022). R-strategies involve maximizing product integrity, thus enabling the continuous use of a product by the consumer until its eventual disassembly for material recovery and waste recycling. However, further research is essential to examine precisely how R-strategies can improve product integrity. For example, in the case of the repair strategy, designers encounter challenges due to the absence of specific guidelines for its implementation and the need for indicators to assess its effectiveness. Moreover, these claims primarily hinge on theoretical explorations and literature reviews, requiring further empirical validation and examinations of rebound effects, thus adding complications and hazards to the system or product manufacturing.

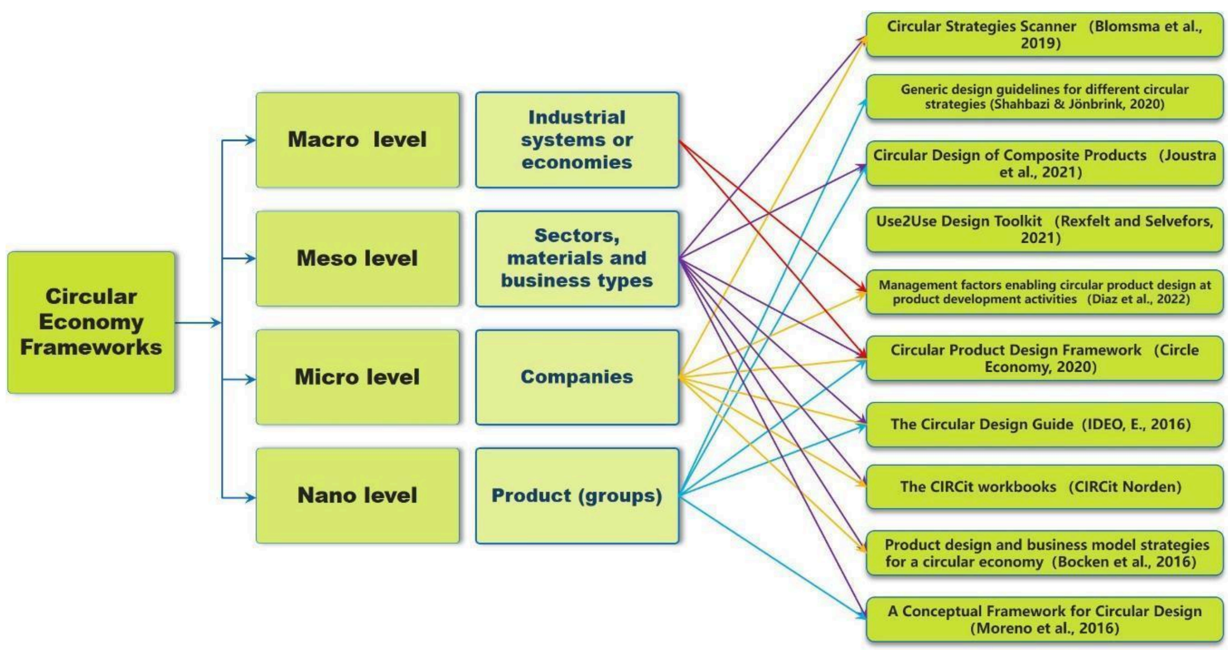

Figure 1. Circular Product Design Frameworks
(Source: Author's illustration)

The limited literature on CPD guidelines includes work on design for sustainability, such as a circular strategies scanner (Blomsma et al., 2019), a CPD framework for composite products (Joustra et al., 2021); a Use2Use Design Toolkit (Rexfelt & Selvefors, 2021), and CIRCit workbooks. Three dimensions (product material, architecture, and product ecosystem) have been linked to the corresponding R-strategies (Diaz et al., 2022), as illustrated in Figure 1. These CPD frameworks focus on 'system' improvement, which is confusing for SDA designers to adopt, especially in product design and development, and requires more detailed planning. In summary, design for the CE is an upcoming, independent field in the sustainability domain that needs a specific approach and a specific set of competencies and tools. However, many scholars have proposed strategies or CPD methods based on systems, services, products, components, and material levels. The lack of an obvious border between the design for each CE strategy has led to design guideline overlaps, while identical design principles might be used in specific strategies. In general, CPD focuses on product integrity to improve circularity, but more specific product design steps are needed, requiring more actionable guidance and empirical validation. The most effective CE strategies must be identified to enhance the circularity of SDAs in product design processes.

Circular economy barriers

The implementation of CE practices in manufacturing industries is facing numerous challenges. These include a lack of financial capability, insufficient collaboration between stakeholders, a dearth of governmental information, inadequate technical and supply and demand networks, and a shortage of CE expertise (Melati et al., 2021). The hindrances are multifaceted, encompassing environmental, economic, social, technological, and management factors (Tura et al., 2019), all compounded by risk aversion among business leaders (Tan et al., 2022). One example of this is the deficient assessment of an enterprise's progress in realizing circularity. Collectively, these complex challenges impede the widespread adoption of CE practices within the manufacturing sector. Promoting CE practices requires consumer education measures, stakeholder alignment, assured economic benefits, responses to regulatory pressures, and the garnering of government support.

In conclusion, various drivers and barriers must be identified when implementing the CE in manufacturing. These encompass technological, economic, managerial, regulatory, and social factors, with risk aversion, a lack of technical skills, and poor information being notable hindrances. Stakeholder cooperation is regarded as especially crucial for successful CE adoption. Meanwhile, CE drivers include mitigating environmental impacts, addressing resource scarcity, improving business performance, and ensuring effective policy actions. Moreover, these barriers must be overcome through, for example, promotional measures such as providing green education to stakeholders, as well as collaboration and support from multiple stakeholders. Consumers' education, stakeholder alignment, economic benefits, regulatory pressures, and government support are needed to drive CE practices.

Key Points of Departure (POD)

Table 2 (below) summarizes the key results as points of departure (POD), based on the systematic literature review and synthesis process reading related to the topics of small domestic appliance design, the circular economy concept, and circular product design.

Table 2. Key Points of Departure (POD)

POD	Construct Description	POD Results
POD 1	Small Domestic Appliance Design	Designers' circular economy capabilities, knowledge, and experience, and consumer behavior are essential to small domestic appliance design during the design and development phases.
POD 2	Circular Economy Concept	The concept of the circular economy remains nebulous, lacking a clear and universally accepted definition.
POD 3	Circular Product Design	The Circular Product Design focuses on product integrity to improve circularity, but it needs more specific steps for product design, requiring more actionable guidance and empirical validation.

RESEARCH METHODOLOGY

The study utilizes the "Systematic Literature Review Synthesis Process" (Ibrahim & Mustafa Kamal, 2018) to locate pertinent literature and provide a theoretical foundation for generating research ideas. Employing Ibrahim's (2011) research question (RQ) construct taxonomy technique for identifying subjects, three separate RQ constructs - "Who", "What", and "How" - were identified in developing the main research question. "Who" refers to the elements impacted by the research; "What" refers to the information or knowledge base required to solve the problem; and "How" refers to the research's targeted impact. In this study, the "Who" refers to small domestic appliances design, the "What" refers to the circular economy concept, and the "How" here refers to the circular product design. Figure 2 shows the flowchart of the review methodology.

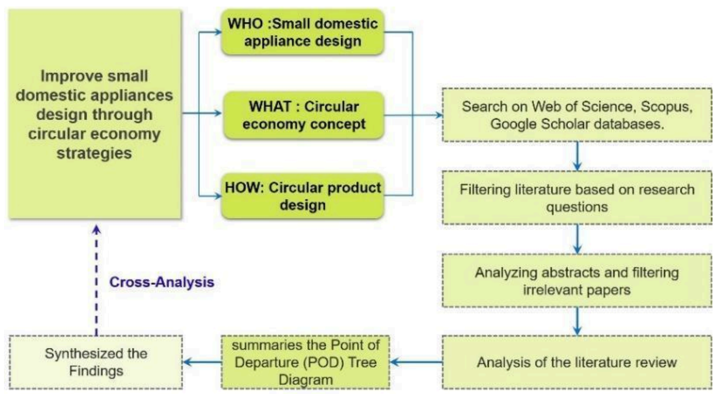

Figure 2: Workflow of the systematic literature review and synthesis process.

The following process phases were followed during this study. Firstly, a comprehensive search for relevant literature was performed using the Scopus, Web of Science, and Google Scholar databases, with keywords connected to the selected RQ constructs, such as product design and development, the circular economy concept, and circular product design. This systematic review produced synthesized summaries of each topic, which were then subjected to additional cross-analysis. Potential approaches were integrated, and prioritization allowed the identification of high-probability solutions with CE strategies for SDA design that could be used by China's appliance manufacturers. Subsequently, the researchers examined the synthesis of small home appliance design, the circular economy concept, and circular product design, thereafter proposing three main points of departure (POD). Ultimately, through a series of cross-analyses, a POD tree diagram showing circular economy strategies for small domestic design was obtained. The POD tree diagram was based on the work of Ibrahim and Mustafa Kamal (2018); shown in Figure 3, the diagram illustrates the key outlines formed. The synthesis process was documented using the EAGLE System (Ibrahim & Mustafa Kamal, 2018).

FINDINGS

The review results informed several conclusions based on the sub-topics of the three POD. These refer to small domestic appliance design, the circular economy concept, and circular product design. The conclusions integrate and prioritize the three synthesized POD. The first specific step was a cross-analysis of the previously generated POD1, POD2, and POD3. POD4 synthesizes information from POD1 and POD2; POD5 synthesizes information from POD2 and POD3; and POD6 synthesizes information from

POD1 and POD3. This process involved comprehensively analyzing POD4, POD5, and POD6. Similarly, POD4 and POD5 were further cross-analyzed to synthesize POD7, and POD5 and POD6 were used to synthesize POD8. POD9, the final theoretical proposition is defined as follows: analyzing the circular economy capabilities, knowledge, and experience of designers to develop an actionable circular product design framework to enhance product integrity in SDA design. Figure 3 depicts the step-by-step inferential process followed.

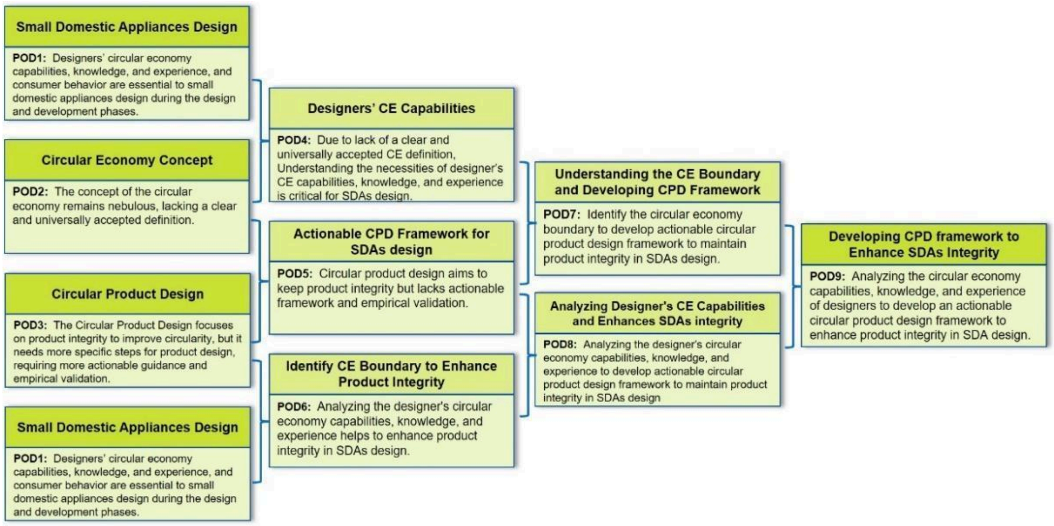

Figure 3. POD tree diagram of CE strategies for SDA design
(Source: Author's illustration)

Analyze the circular economy capabilities of designers

SDA designers are highly important in shaping a circular future for product design and consumption. They must comprehend entire product life cycles, making critical decisions during the design stage. These might involve choosing environmentally friendly materials; emphasizing recyclability, biodegradability, and low-carbon design; and exploring innovative design techniques. These capabilities include circular design proficiency, material selection expertise, life cycle assessment, modularity design, and innovation integration. Concurrently, a framework should be tuned to the practical skills, knowledge, and experience of designers. The proposed circular product design-small domestic appliance (CPD-SDA) framework aligns with the practical expertise and experience of designers, and it was structured so it could be seamlessly integrated into product design and development processes.

Identify circular economy concept and boundary

The circular economy (CE) lacks a universally accepted definition despite numerous scholarly efforts to provide one, leading to varied interpretations across contexts and disciplines. In different disciplines such as ecology, economics, and management, various definitions of and strategies for the CE have been proposed at the macro, meso, and micro levels, complicating the already expansive scope of the CE. Additionally, most research has been theoretical and conceptual, making it difficult for designers to use it in practice as they require specific competencies, methods, and tools. Effective CE strategies could keep products, components, and materials in the loop for extended periods, preserving the maximum value of products and materials. Pivotal to this exploration are defining and delineating the boundary of the circular economy, as well as elucidating the stages when circular principles should be applied. These boundaries must be identified so that actionable CPD-SDA frameworks can be developed that maintain product integrity in SDA design. Concurrently, potential rebound effects of the CE are being considered, while the challenges and opportunities associated with transitioning to the CE are being addressed.

Develop an actionable circular product design framework

Academic investigations suggest that enhancing stakeholder collaboration would facilitate product circularity and the transition to the circular economy. Enhancing product integrity, which is related to products, parts, and materials, could extend the lifespan of the economic system, while improving the product integrity of SDAs could minimize their environmental impact. These factors contribute to extending the life cycles and resource efficiency of products, thereby reducing their environmental impact. However, further empirical research is needed to validate the current research, as well as to develop an actionable CPD-SDA framework and methodologies for achieving the CE in the SDA industry. Developing such a framework that prioritizes circularity is a complex and multidisciplinary task that requires collaboration between designers, manufacturers, policymakers, consumers, and other stakeholders. A CPD-SDA framework should apply directly to the stages of product design and development, thus providing reliable support for these industry aspects. This type of comprehensive approach would contribute to enhancing product integrity in the context of the CPD-SDA framework. Figure 4 presents the conceptual CPD-SDA framework.

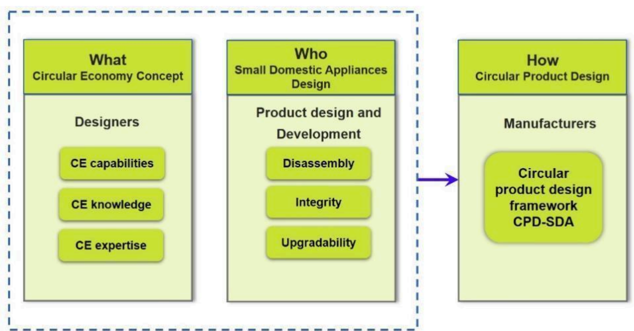

Figure 4. Proposed conceptual circular product design framework for SDA design
(Source: Author's illustration)

Overall, improving design that ensures product integrity can enhance circularity and reduce carbon emissions in manufacturing by enabling better durability, performance, quality, and reliability, all of which preserve product value. Adopting a systematic and holistic approach would enable the development of effective and practical CE strategies for reducing the carbon emissions of China's appliance manufacturers while improving product circularity. Further development is needed of the circular design assessment tools that would assist designers, inventors, innovators, and decision-makers in implementing the identified strategies. Future researchers should explore strategies for fostering positive stakeholder relationships and mitigating the impact of conflicting interests on CPD initiatives. Above all, CPD is a critical component of the CE, focusing on the design approach of product disassembly, integrity, upgradability, and recyclability. CPD emphasizes collaboration between designers, engineers, and other stakeholders to ensure the successful implementation of CE strategies. Concurrently, the CPD frameworks need more specific product design steps, for which more actionable guidance is required.

CONCLUSION

This paper systematically reviews and synthesizes the small domestic design and circular economy; discusses the design characteristics of SDAs, as well as the definition and boundaries of the CE; and analyzes the existing CPD frameworks. The blurred boundaries and lack of a widely accepted definition of the CE increase the complexity of formulating a CPD-SDA framework. No clear line exists between the design for each circular strategy and the similarities between circular strategies, making it difficult for SDA designers to implement these in the product design and development stages. Moreover, the current CE strategies and CPD frameworks need more empirical research and enhanced applicability.

Enhancing SDA circularity in terms of disassembly, upgradability, and integrity with the CE strategies, as well as changing consumer behavior, could ensure that products, components, and materials are utilized for extended periods and that carbon emissions are reduced. SDA designers could incorporate a CPD framework into the early stages of SDA design, thus enhancing product integrity. This review of SDA design reveals that various CE strategies could be applied to maintain product, component, and material continuity over extended periods. Product circularity can be improved by enhancing product integrity as much as possible during SDA design, as well as maintaining the integrity of products, components, and materials to extend their service time. Furthermore, material selection, structural design, waste minimization, zero toxic waste, and emissions should be considered during a product's concept development and system design stages. Identifying the CE capabilities, knowledge, and experience of designers is critical to developing an actionable CPD-SDA framework.

It is essential to understand the application of CE methods during the SDA design process and the stakeholders involved in SDA development. It is also necessary to comprehend the complex interplay between consumer behavior, CE capabilities, and the knowledge and expertise of designers working in the SDA industry. Therefore, actionable CPD-SDA guidance needs to be developed to maintain product integrity in SDA design, based on the actual skills and knowledge characteristics of SDA designers. This research could be applied in SDA manufacturing and academia so that SDA industry stakeholders can identify their circular economy opportunities and activities, understand the various business processes, and then develop optimal CE practices. This would also support the reduction of e-waste and carbon emissions in China and worldwide. Although this study is limited by the subjectivity inherent in keyword screening and sample selection, it offers valuable insights for manufacturers and designers eager to progress toward circular strategies in product design and development. Future researchers should aim to deepen the theoretical explorations of design strategies that enhance product circularity.

ACKNOWLEDGMENT

This paper is a part of a research study by the authors at Universiti Putra Malaysia.

REFERENCES

Maszura Abdul Ghafar & Rahinah Ibrahim (2018). The Malaysian AEC Professionals Work Culture Could Improve Organizational Team Productivity during Industrialized Project Delivery. *Pertanika Journal of Social Sciences & Humanities, 26*(3).

Blomsma, F., Pieroni, M., Kravchenko, M., Pigosso, D. C., Hildenbrand, J., Kristinsdottir, A. R., ... & McAloone, T. C. (2019). Developing a circular strategies framework for manufacturing companies to support circular economy-oriented innovation. *Journal of cleaner production, 241*, 118271.

Boorsma, N., Polat, E., Bakker, C., Peck, D., & Balkenende, R. (2022). Development of the Circular Product Readiness Method in Circular Design. *Sustainability, 14*(15), 9288.

Diaz, A., Reyes, T., & Baumgartner, R. J. (2022). Implementing circular economy strategies during product development. *Resources, Conservation and Recycling, 184*, 106344.

Ellen MacArthur Foundation. (n.d.). Circular economy introduction. Retrieved February 14, 2024, from https://ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview

Forti, V., Balde, C. P., Kuehr, R., & Bel, G. (2020). The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential.

Haessler, P. (2020). Strategic decisions between short-term profit and sustainability. Administrative Sciences, 10(3), 63.

Hailemariam, A., & Erdiaw‐Kwasie, M. O. (2022). Towards a circular economy: Implications for emission reduction and environmental sustainability. Business Strategy and the Environment.

Huaxia. (2020, September 23). Xi Focus: Xi announces China aims to achieve carbon neutrality before 2060. Xinhua net. Retrieved March 12, 2024, from http://www.xinhuanet.com/english/2020-09/23/c_139388764.htm

Ibrahim, R. (2011). Demystifying the arduous doctoral journey: The eagle vision of a research proposal. *Electronic Journal of Business Research Methods, 9*(2), pp130-140.

Ibrahim, R., & Mustafa Kamal, R. (2018). Templates for Thinking. Unpublished Literary. Copyright MYIPO LY2018002437.

Joustra, J., Flipsen, B., & Balkenende, R. (2021). Circular design of composite products: A framework based on insights from literature and industry. *Sustainability, 13*(13), 7223.

Lofthouse, V. (2004). Investigation into the role of core industrial designers in ecodesign projects. *Design studies, 25*(2), 215-227.

Mast, J., von Unruh, F., & Irrek, W. (2022). R-strategies as guidelines for the Circular Economy.

Melati, K., Nikam, J., & Nguyen, P. (2021). *Barriers and drivers for enterprises to transition to circular economy*. Stockholm Environment Institute. Retrieved from barriers-drivers-enterprises-circular-economy-sei-brief.pdf

Morseletto, P. (2020). Targets for a circular economy. *Resources, Conservation and Recycling, 153*, 104553.

Mugge, R. (2018). Product design and consumer behaviour in a circular economy. *Sustainability, 10*(10), 3704.

Neves, A., Godina, R., Azevedo, S. G., & Matias, J. C. (2020). A comprehensive review of industrial symbiosis. *Journal of cleaner production, 247*, 119113.

Pearce, D. W., & Turner, R. K. (1989). Economics of natural resources and the environment. Johns Hopkins University Press.

Qianzhan Industrial Research Institute. (2022, January 18). Market size, competition pattern and development trend of China's small household appliance industry in 2021. From https://xw.qianzhan.com/trends/detail/506/220118-7b22ff71.html

Rexfelt, O., & Selvefors, A. (2021). The use2use design toolkit—Tools for user-centred circular design. *Sustainability, 13*(10), 5397.

Shahbazi, S., & Jönbrink, A. K. (2020). Design guidelines to develop circular products: Action research on nordic industry. *Sustainability, 12*(9), 3679.

Suppipat, S., & Hu, A. H. (2022). A scoping review of design for circularity in the electrical and electronics industry. *Resources, Conservation & Recycling Advances, 13*, 200064. https://doi.org/10.1016/j.rcradv.2022.200064

Testa, F., Iovino, R., & Iraldo, F. (2020). The circular economy and consumer behaviour: The mediating role of information seeking in buying circular packaging. *Business Strategy and the Environment, 29*(8), 3435-3448.

Tura, N., Hanski, J., Ahola, T., Ståhle, M., Piiparinen, S., & Valkokari, P. (2019). Unlocking circular business: A framework of barriers and drivers. *Journal of cleaner production, 212*, 90-98.

Ulrich, Karl T., Eppinger, Steve D., and Yang, Maria C., Product Design and Development. 7th ed., McGraw-Hill Education, 2020.

Uvarova, I., Atstaja, D., Volkova, T., Grasis, J., & Ozolina-Ozola, I. (2023). The typology of 60R circular economy principles and strategic orientation of their application in business. *Journal of Cleaner Production,* 137189.

Van Dam, K., Simeone, L., Keskin, D., Baldassarre, B., Niero, M., & Morelli, N. (2020). Circular economy in industrial design research: a review. *Sustainability, 12*(24), 10279.