Structuring Circular Objectives and Design Strategies for the Circular Economy
A Multi-Hierarchical Theoretical Framework

Franconi, A.; Ceschin, Fabrizio; Peck, David

DOI
10.3390/su14159298

Publication date
2022

Document Version
Final published version

Published in
Sustainability

Citation (APA)
Franconi, A., Ceschin, F., & Peck, D. (2022). Structuring Circular Objectives and Design Strategies for the Circular Economy: A Multi-Hierarchical Theoretical Framework . *Sustainability*, *14*(15), Article 9298. https://doi.org/10.3390/su14159298

sustainability

MDPI

Article

Structuring Circular Objectives and Design Strategies for the Circular Economy: A Multi-Hierarchical Theoretical Framework

Alessio Franconi [1,*], Fabrizio Ceschin [1] and David Peck [2]

1 Design for Sustainability Research Group, Brunel Design School, Brunel University London, London UB8 3PH, UK; fabrizio.ceschin@brunel.ac.uk
2 Department of Architectural Engineering & Technology, Faculty of Architecture and the Built Environment-BK, Delft University of Technology—TU Delft, 2628 CE Delft, The Netherlands; d.p.peck@tudelft.nl
* Correspondence: alessio.franconi@brunel.ac.uk

Abstract: Most frameworks for dealing with the complexity of designing for the circular economy have limitations in terms of correlating different domains of knowledge, correlating highly complex design strategies, and facilitating the process of design strategies' discovery and development. This paper discusses how managers and designers can create products that can be circulated for several life cycles by considering five different circular objectives (i.e., maintenance/longevity, reuse, refurbishment, remanufacture and/or recycling). To achieve one or more of these objectives, multiple design strategies can be used at various phases of each product life cycle and throughout the product's lifetime. A literature review is used in this article to evaluate how circular objectives and design strategies are classified in terms of relevance, product life cycle phases, and product life cycles. The three classifications are merged to create a novel conceptual framework, which is then tested through the use of four circular case studies to map out life cycles, circular objectives, and design strategies. The framework may help managers and designers better understand how their businesses and products interact along the supply chain, allowing them to establish more effective product lifetime plans.

Keywords: circular economy; circular objectives; design strategies; multi-hierarchical classification; product lifetime plan

Citation: Franconi, A.; Ceschin, F.; Peck, D. Structuring Circular Objectives and Design Strategies for the Circular Economy: A Multi-Hierarchical Theoretical Framework. *Sustainability* **2022**, *14*, 9298. https://doi.org/10.3390/su14159298

Academic Editors: Marina De Pádua Pieroni, Mariia Kravchenko, Daniela C. A. Pigosso and Tim C. McAloone

Received: 28 April 2022
Accepted: 27 July 2022
Published: 29 July 2022

1. Introduction

A circular economy (CE) is an industrial system that is restorative or regenerative by intention and design [1]. It replaces the end-of-pipe approach with restoration, shifting the focus from waste management to design [2–4]. Design plays an essential role in a CE because it can help to reduce waste, increase efficiency, and improve the overall sustainability of a product or system [5,6]. According to [7], a CE can be designed to handle both biological and technical material cycles. Biological materials are created by living organisms and used for human purposes before being returned to the natural environment, where they decompose and serve as nutrients for other organisms. This type of cycle is commonly linked with the food industry, although it could also apply to other sectors such as textile or wood [1]. Technical materials, on the other hand, are those that involve the use of energy and natural materials to produce synthetic materials, such as plastics or metals. This type of cycle is often used in sectors that require precision or reliability such as mobility or packaging [8].

Both biological and technical cycles have their own circular objectives to recover as much of the economic and ecological value as possible, reusing it for subsequent cycles. Within the biological cycle, Ref. [1] proposed product cascade, material extraction of biochemical feedstock, material composting and anaerobic digestion, and soil regeneration through agricultural methods. Other authors, however, have argued that these circular objectives are insufficient, proposing alternatives such as bio-based mechanical, chemical, and biological recycling [9,10]. This field of study is still in its infancy, and more research is needed to fully understand the role of design in it [9]. In order to contribute to a greater body of knowledge, this study focuses on technical cycles. Several R-lists for technical cycles have been presented in the literature [11,12], the most common being the 3Rs (reduce, reuse, recycle), 5Rs (refuse, reduce, reuse, repurpose, and recycle), and the 9Rs (refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle and recover). Although these are standard ways to organise circular objectives in the CE, the 3Rs and 5Rs do not explicitly account for refurbishment and remanufacturing objectives. In order to ensure that products and materials remain in use for as long as practicable, refurbishment and remanufacturing should be considered essential circular objectives [13]. Refuse and rethink, while in the 9Rs, as stated by [11], "they do not necessarily involve increasing the reuse of products and components, or reapplication of recycled materials". Additionally, the "Recover" objective may be considered non-circular because it does not close the loop on material cycles [14]. This means that there is a linear flow of materials and energy, which is not sustainable in the long term. The authors of [1,15] offered similar key circular objective lists, which have been reorganised in this work as follows: maintenance/longevity, reuse, refurbish, remanufacture, and recycle.

To achieve as many cycles as possible within the lifetime of a technical product, managers and designers from the same or different organisations must collaborate to meet new circular design and business challenges that require a strategic, collaborative, systematic, and managerial approach [6,16]. A product lifetime plan can give them a substantial edge as they transition to a CE. This can be viewed as a comprehensive blueprint for extending the useful life of products and components across several product life cycles and companies, recapturing value from materials at the product's end-of-life [16–18]. Managers and designers can utilise a product lifetime plan to determine how value flows through different life cycles, with specific circular objectives indicated for each cycle, to characterise the product's whole life in terms of all its cycles through to final recycling [17]. When all of the prospective multiple life cycles are defined, it is possible to develop more successful business models and product specifications [19]. However, the challenge for managers and designers is to coordinate the many objectives across each product life cycle and develop an integrated, coherent product lifetime plan that optimises energy, material consumption, and waste minimisation while positively impacting corporate performance [3,4,20].

In the product lifetime plan, all aspects of the product or service are considered simultaneously and integrated into a single, coherent design solution. This holistic approach necessitates the knowledge of diverse disciplines that work cooperatively by layering design strategies in order to coordinate and perform multiple circular objectives [16,21]. A wealth of design strategies are available to achieve varied objectives [18]. For example, [22] collected more than two hundred heterogeneous design strategies that could be used to balance environmental, economic, logistics, organisational, and marketing performances. With so many options, organising design strategies across multiple knowledge domains is crucial to coordinating and developing an appropriate product lifetime plan. Several attempts have been made to organise design strategies through the development of classification frameworks that provide a model for managers and designers to address the CE (e.g., [23,24]). However, most of these frameworks do not provide practical support for decision making. According to [25], this is due to limitations such as: (1) traditional approaches to classification and representation making it difficult to correlate knowledge across domains, (2) failure in correlating highly complex design strategies in relation to one another (even within the same domain of knowledge), and (3) discovering, structuring, and developing new design strategies for non-scientific users.

Design frameworks can assist organisations in understanding how to design their products and services to create circular value, which can significantly raise awareness, foster creativity, and strengthen cooperation throughout the internal and external value chain. Additionally, design frameworks can create a shared understanding of the value of design within an organisation, ultimately increasing cooperation and collaboration between different departments and across the value chain. In this regard, [26] identifies six reasons why frameworks are essential throughout the design phase:

1. To support researchers and practitioners in managing and using a multitude of design strategies;
2. To empirically test design strategies and their relationships over the entire product life cycle;
3. To provide an overall view of the entire product lifetime to create an overall design strategy for specific contexts;
4. To integrate relationships between different design strategies to understand the impacts and influences of different strategies and improve the overall design process;
5. To integrate different disciplines, knowledge and information throughout the entire product lifetime process, and how to prioritise the multitude of design strategies collaboratively and create value for all stakeholders involved;
6. To integrate technical and non-technical strategies.

Based on these six reasons above and the lack of available design frameworks for supporting complex decision making, this study focuses on classifying information in order to propose a novel qualitative conceptual framework for organising circular objectives and design strategies in a more accessible way. The second section of the paper outlines the research methodology used to analyse the available literature on classification structures to enable the representation of approaches and relationships in structures that reflect knowledge and approaches of the design for the CE. The third section provides an overview of the five possible circular objectives (maintenance/longevity, reuse, refurbish, remanufacture and/or recycle) and a definition of design strategies in this context. Furthermore, it examines three hierarchical and representational structures employed in the literature to prioritise design strategies according to their relevance, life cycle phases, and life cycles. The three hierarchies are then combined in order to create a new multi-hierarchical framework. The application of the framework has been tested using four case studies. The fourth section covers how managers and designers might utilise the theoretical framework to organise objectives and develop strategies. Finally, the concluding section discusses limits and areas for future research.

2. Materials and Methods

Based on [27], this theory-oriented research was conducted in four stages, as illustrated in Figure 1.

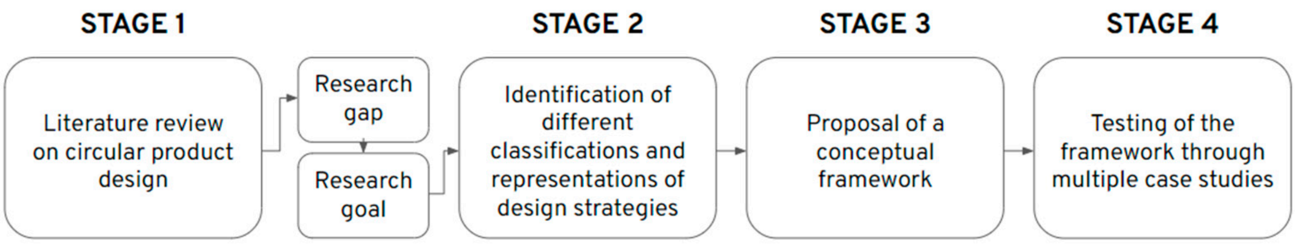

Figure 1. Research approach for a new circular product design conceptual framework.

STAGE 1: Literature review on circular product design.

In the first stage, a narrative literature review was performed to review the most recent circular objectives definition, strategic choice planning models, frameworks, and methods for circular product design [28]. Papers were selected using Google Scholar and Scopus to obtain the most comprehensive perspective possible. The following keywords were used in various combinations: "circular product design", "design for the circular economy", "design for circularity", "design for product lifecycle", "design for product life cycle", with the terms: "framework", "models", "method", and "design strategies". Four additional publications were considered in relation to the articles to provide a more complete picture. The literature review highlighted the gap this work attempts to address, and introduced the study's goal.

STAGE 2: Identification of different classifications and representations of design strategies.

Based on the previous literature review, the structure and representation of design strategies in the CE were determined. Design strategies can be structured and classified in many ways, e.g., principles, guidelines, taxonomies, checklists, and archetypes. The choice of different classifications or hierarchisation provides a multitude of possible connections between different design strategies and knowledge applications [25,29]. However, given the complexity of the CE, more holistic and dynamic structures are required to facilitate the organisation and management of design strategies [26]. As a result, the three most often used hierarchical structures in the literature have been selected, examined, and structured as follows:

(i) Classification of design strategies based on relevance;
(ii) Classification of design strategies based on phases of the product life cycle; and
(iii) Classification of design strategies based on life cycles.

STAGE 3: Proposal of a conceptual framework.

The third phase of the research highlighted and detailed the limitations of the three previously identified classifications of design strategies. The three classification structures were then combined in various ways, eventually leading to the development of a novel intuitive conceptual framework. The framework was then discussed extensively, emphasising and addressing its potential for application.

STAGE 4: Testing of the framework through four case studies.

In the fourth and last stage, the framework resulting from the previous phase was tested using four case studies. The use of case studies to evaluate theories can either reveal the theories' weaknesses or provide evidence that the theories are valid [27]. According to [27], selecting case studies that are more likely to confirm the hypothesis is preferred in initial theory-testing research. Satisfactory measuring and testing was defined for this part of the research as an exhaustive representation of various design strategies in relation to each circular objective of various case studies. The case studies were selected according to four criteria: (I) N of life cycles, (II) different circular objectives, (III) different industries, and (IV) different life cycle patterns (open and closed life cycle patterns). Finally, the findings were discussed.

3. Results

3.1. Literature Review on Circular Product Design

This section presents the literature on circular product design by outlining the circular objectives and the design strategies that can be used to accomplish them.

3.1.1. Circular Objectives

Circular objectives are feasible options for a product's maintenance or recovery [30,31]. Defining a clear and explicit objective early in the design process is critical in guiding all decisions in each product life cycle [19,32]. The main objectives proposed by [1,15] have been revised for this study as maintenance/longevity, reuse, refurbishment, remanufacturing, and recycling. Although maintenance/longevity is sometimes neglected [33,34], it is a crucial aspect to minimise the activities needed to recapture value [16], and, therefore, it should be the primary circular objective whenever possible [7,35]. In each product life cycle, circular objectives can be the same, or can change (e.g., remanufacture; remanufacture and recycle or reuse; remanufacture, refurbish and recycle), and usually, only one of these options is used for each cycle [30]. Components and materials may, however, follow different recovery flows and be reintegrated into the system differently to the main product [32,36]. The different circular objectives can be used in closed-loop or open-loop cycles, where the product becomes the value for the same system or other systems [7]. If systems are kept closed, companies are more likely to be able to recover the entire value of a product, and the circular objective can be repeated through numerous product life cycles [16]. For example, Loop by Terracycle reuses its packaging up to 100 times, and in the last cycle, they recycle the packaging to produce new reusable cans [37]. However, when life cycles are left open, different companies may capture the product and benefit from it. For example, Vestiaire Collective is an online platform that retrieves luxury products and sells them as 'second-hand' products. As circular objectives transition from engineering activities to business activities, managers and designers must rethink how they create and deliver value throughout the product lifetime [15]. For this reason, if precise circularity objectives are not defined or are vague, it will be difficult to design products that can be recovered for multiple life cycles. Table 1 outlines circular objectives that managers and designers can pursue.

Table 1. Circular objectives exemplification.

Circular Objective	Description	Example of Related Design Strategies	References
Maintenance/longevity	Design for maintenance/longevity is an approach for extending the life of a product by incorporating maintenance considerations. Frequently, this circular objective is associated with the product–service system. Design for maintenance/longevity is close in meaning to design for slowing resource loops, design for long last products, design for obsolescence resilience, design for durable products, design for extending life cycle, or design for product-life extension.	Design for reliability, ease of maintenance, upgrading, repairability, modularisation, or standardisation.	[6,33,38–42]
Reuse	Design for reuse implies creating the conditions for value to be reused in a new product life cycle as-is, with minimal rework. As with the other circular objectives, planning for reuse should begin prior to the beginning of the product lifetime. While EU directives emphasise the importance of reuse [31], the design for reuse method has received less attention compared with other circular objectives. Design for reuse is different to design for creative upcycling and design for repurposing.	Design for collaborative logistics, upgrade, standardisation, robustness, return incentives or ideological pleasure.	[38,43–50]
Refurbishing	Design for refurbishing is defined as extending the product's lifetime by restoring its full functionality and/or aesthetics by reworking only what is compromised. Only portions of the product that have failed or are badly worn can be disassembled and rebuilt with old and/or new components. Consumer acceptability of refurbished products has recently become a study focus. Design for refurbishing is close in meaning to design for reconditioning.	Design for disassembly, reassembly, local reparability, or consumer acceptance.	[51–55]

Table 1. *Cont.*

Circular Objective	Description	Example of Related Design Strategies	References
Remanufacturing	Design for remanufacturing extends product lifetime by restoring used products to like-new or better-than-new condition. To clean, restore, and replace components during remanufacturing, total disassembly is required. What sets remanufactured products apart from refurbishes is their condition, performance and warranty. Some scholars consider remanufacturing to be the most promising circular objective in the CE.	Design for disassembly, cleaning, inspection, repairing, replacing, testing, and reassembling	[51,52,56,57]
Recycling	When there are no other options to extend the product lifetime except recapturing the value of materials, recycling can be considered as the main circular objective. Design for recycling ensures proper material selection, separation, and reprocessing for new material flow. Design for recycling is close in meaning to design for upcycling.	Design for ease disassemble for recycling, manual or mechanical dismantling, semi- or destructive disassembly, consumer acceptance of recycled goods.	[52,58,59]

3.1.2. Design Strategies

While circular objectives explain how value will be maintained or recovered into the system several times and drive all stakeholders' decisions [60], design strategies define how each objective will be achieved. Strategies can be implemented at various levels, including product, business, service, or legislative [5]. If different strategies at various levels are not properly coordinated, they may have a negative impact on one another, making the circular objectives less likely to be achieved [20]. However, if there is cohesiveness and cooperation in the definition of strategies that support each other, the product may be able to circulate for multiple cycles [26]. Some common product strategies that are often referred to as the design for X (DfX) approach include design for assembly and disassembly, design for modularity, and design for repairability [61]. Non-technical strategies, such as design for product attachment, design for satisfaction, or design for timeless aesthetics, are equally crucial in the product design, particularly in regard to consumer behaviour [55]. Recently, more and more attention to new business models and their relation to the product design has also emerged [16,21,62,63], highlighting the critical correlation between the two design areas [64]. Some of the business strategies presented by the literature are the access and performance model, classic long life, or industrial symbiosis [16]. Circular products and businesses can be linked through service design, which connects the user experience, touchpoints, and service flow to suit the user's demands. Strategies such as design for product take-back, or buy-back, are only a few examples. On a larger scale, strategies may include political or governmental decisions. For instance, legislators could support product maintenance/longevity by enacting legislation granting people the right to repair their products. These political strategies are unrelated to the product, yet they can significantly impact the shift to circular products [65].

3.1.3. The Research Gap and the Research Goal

The right juxtaposition of various strategies and their alignment with the circular objectives strongly depends on societal, environmental, sectoral and organisational constraints [66]. Hence, design strategies must emerge from the consideration of different variables through an iterative process where managers and designers evaluate the overall vision to find alternatives and opportunities to create a profitable cycle of value [16]. The intricacy of this process requires the coordination and prioritisation of a multitude of different domains of knowledge in order to create coherent and effective product lifetime plans [3]. Furthermore, the ineffective collaboration between different design areas and the use of sectoral vocabularies could obfuscate and hide combinations of strategies leaving potential solutions unexplored [67].

Several design frameworks for the CE have been developed to help managers and designers better understand and interpret the complexity of the CE. In this paper, a framework is defined as a collection of guidelines for designing a product or system. Frameworks can be used to guarantee that a design team is on the same page or to assess a design's circularity before it is implemented. Almost all CE frameworks are structured hierarchically around circular objectives or employ a range of design strategies to define value flow opportunities. Some of the most popular ones include the ecodesign strategy wheel [68], the framework of closing, slowing and narrowing resource loops [16], and the circular business model canvas [24].

Despite this diverse set of frameworks, it remains challenging to relate the richness of diverse knowledge required to design for a CE [3,69]. This is due to the fact that present frameworks are designed according to "classical" hierarchies, which impose classification of defined criteria in a uniform manner [25]. Frameworks connecting strategies from different domains of study are quite unusual. These rigid classifications of knowledge may not encompass all potential scenarios and may be misleading or even have negative consequences. For instance, if a business wants to maintain its product for a more extended time and operates on a service-based business model, this may necessitate additional transportation, spare parts, industrial processes, and new sales or trade points. To be really sustainable, the business should consider providing these services locally and, if the infrastructure does not yet exist, work with stakeholders to develop it [4].

A "classical" structure hierarchy excels at arranging design strategies logically. However, their linear nature makes it challenging to understand all the information when they become highly complex, even in the same domain of knowledge [25]. Design strategies in a CE should be implemented on different cycles, and in each of them, managers and designers may need to apply a separate set of design strategies. As an example, managers and designers may have multiple types of disassembly strategies for a bicycle that has been designed for three life cycles, where the first circular objective is maintenance/longevity (e.g., design for user self-disassembly), then remanufacturing (e.g., design for disassembly and reassembly), and finally recycling (e.g., design for destructive disassembly).

Furthermore, "classical" hierarchies are absolute and do not facilitate the construction, characterisation, and representation of new knowledge [25]. Knowledge interaction is critical in the CE because it facilitates communication with all stakeholders engaged in the development of circular value [60]. However, most current frameworks do not allow different managers and designers to interact with them to handle alternative solutions dynamically. For example, the business model canvas is widely used because its structure allows it to be interactive and adjust information to the needs of those using it.

This leads to the research gap this paper considers, as shown in Figure 2. To address this gap, this article aims to establish a framework that can be used collaboratively by various managers and designers who can intervene throughout the product's many phases and life cycles, allowing them to connect design strategies across different knowledge.

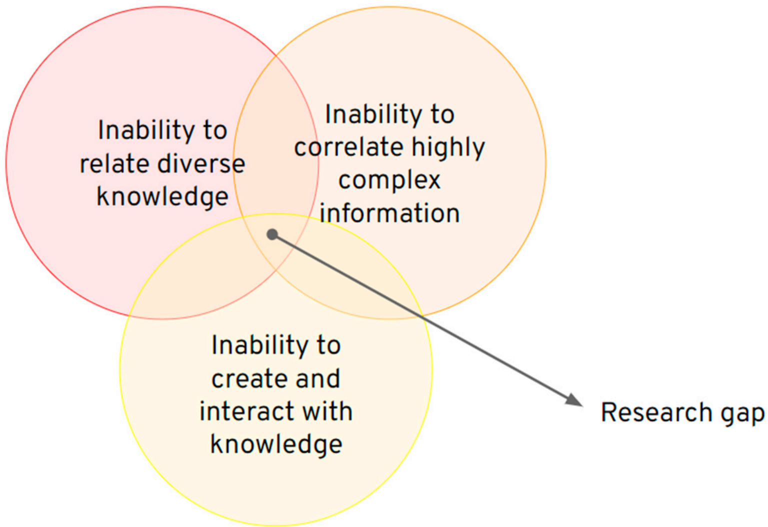

Figure 2. Definition of the research gap of this paper.

3.2. Classifications and Representations of Design Strategies in Circular Product Design

To address the aforementioned gap, it was decided to identify and analyse how various design strategies are organised and represented in the literature [26]. CE is a vast and complex body of knowledge that encompasses a wide range of design viewpoints [70,71]. Several literature reviews on design strategies have been carried out based on different classifications to organise the use of various strategies among different managers and designers involved (see Supplementary Materials). Collection, definition and classification of multiple design strategies are critical to shaping knowledge and defining opportunities and alternatives [72]. In this section, we distinguish three predominant types of classifications to organise objectives and design strategies: classification according to relevance (taxonomy), product life cycle phases (life cycle phases diagram), and life cycles (loops diagram) (Table 2).

Table 2. Typologies of design strategies classification.

Design Strategies Classifications	List of the Reviewed Articles	Complementary Literature
Classification according to relevance	[6,11,16,22,24,26,73–86]	[34]
Classification according to product life cycle phases	[23,32,87–89]	[68,90]
Classification according to life cycles	[45,47,53,91–94]	[36]

3.2.1. Design Strategies Classification According to Relevance

The literature presents a significant number of hierarchies where design strategies are categorised according to the relevance of the circular objectives or design strategies. The majority of these hierarchies use a descending sequence structure to combine design strategies with various levels of detail, as well as their relationships and interdependencies [25]. The top hierarchical element is typically a single strategy representing the overall purpose and defining the underlying strategies; there are generally multiple subset levels. Lower levels are generally more tactical, whereas higher levels are more systemic. Strategies at the same level are logically related and can be directly compared (Figure 3).

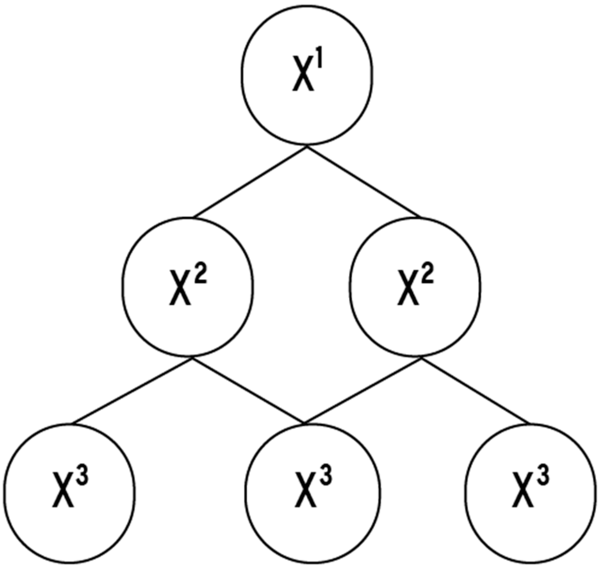

Figure 3. Sample structured classification according to relevance (taxonomy). Typically, these hierarchical frameworks are used to depict the hierarchy of design strategies from the most systemic (X^1) to the most detailed (X^3) and make it easy to compare design strategies, describe relationships, and evaluate potential options for achieving X^1.

Ref. [26] explored the relationships between design strategies and dimensions of sustainability and formulated a three-dimensional hierarchy based on three top strategies, design for supply chain, design for social responsibility, and design for ecology. Their study invited designers to discover the value that unsustainable products lack, notably by sparking debate about environmental and societal challenges. Ref. [34] developed a theoretical hierarchy for product life extension and recycling based on the EU Waste Framework Directive. In their model, prevention, reuse and recycling were the main top-level objectives. For each, they described different possible design strategies such as design for material efficiency and longer product life for prevention, design for repair, refurbishment and remanufacturing for reuse, and design product and material recycling for recycling. Ref. [74] categorised design strategies into five broad categories: future proof design, design for disassembly, maintenance, remake and recycling. According to the authors, the final design guideline based on the five themes was not a list of independent parameters. Rather than that, it sought to illustrate some of the secondary design strategies that affect the primary design objectives. Ref. [86] categorised design solutions according to the cradle-to-cradle paradigm, i.e., material health, material reutilisation, renewable energy, water stewardship, and social fairness.

Few studies have examined the relationship between the design of the business model and the design of the product. For example, [6] developed a taxonomy based on three DfX approaches: design for resource conservation, design for slowing resources loops, and whole system design, and related these approaches to the literature on circular business models to create a new theoretical framework. They argued that product design strategies and numerous business model strategies should be interconnected for a complete circular transformation. Based on the ReSOLVE framework, developed by McKinsey, Ref. [24] classified several business and product strategies on the following criteria: regenerate, share, optimise, loop, virtualise, and exchange. With the help of this taxonomy, the author customised the business model canvas to meet the needs of the CE. Conversely, [16] argued that organisations must begin with an overall vision and implement numerous business models and design strategies in order to transition from a linear to a CE. They proposed a taxonomy with two general circular objectives: slowing (e.g., design for product-life extension and encouraging sufficiency) and closing (e.g., design for dis- and reassembly, and industrial symbiosis) resource cycles.

When describing a product lifetime strategy, all of these options can be good choices. However, there is no single best combination because different strategies may be needed for different socioeconomic situations [66]. As a result, it is critical to establish a clear picture of the strategic starting point by establishing a circular objective for each product life cycle and then investigating the options from various angles [32]. Once the number of life cycles and related circular objectives have been determined, designers can move to designing a product-specific plan to achieve them. In the case of a photocopier as a service, for example, managers and designers know that they must adopt maintenance/longevity (X^1) as the primary objective of the first life cycle to maximise revenue and profitability. They may use strategies such as design for upgradability (X^2) to change a monitor and improve the user experience or design for repairability (X^2) to make it easier for a professional to fix a broken part of the product. They can use sub-strategies such as design for standardisation (X^3), which provides more display alternatives and increases customer loyalty, or design for ease disassembling (X^3), which makes disassembling the item to be replaced, easier. They might also utilise a service strategy such as design for take back (X^3) to retrieve and resell users' dismissed components. The latter strategy can be used to swap out working components as well as return faulty ones. This hierarchy depicts the qualities of the overall design strategy, assisting in the comprehension of conflict strategies, interconnected compliant strategies, and other complex patterns.

3.2.2. Design Strategies Classification according to Product Life Cycle Phases

CE design strategies are too often perceived as stand-alone approaches rather than part of an integrated supply chain. The lack of a holistic strategy may have the opposite effect of increasing the product's environmental impact [95] (pp. 39–45). Despite this, the literature provides a variety of cycle phase diagrams that differentiate strategies at diverse product life cycle stages. The definition of boundaries between different product life cycle phases creates a logical structure for narrowing objectives, activities, skills, material flows, and advantages and disadvantages throughout the supply chain [96]. In addition, distinct life cycle phases of a product can provide an approach for evaluating and mapping stakeholders (e.g., suppliers, manufacturers, customers, resource recovery and waste managers) and tailor their specific needs, wants and values for each phase [60,80].

Ref. [68] established strategies for several product life phase-specific activities in 1998, classified in the well-known "EcoDesign Strategy Wheel". The product life cycle was divided into seven phases, each of which is represented by a stage in the framework. The phases were divided into three product levels: product component level, product structural level, and product system level. The authors also introduced a side part called "New Concept Development." The strategies for the business models were defined in this section. This is one of the first examples where business models and design strategies were linked in a framework. Several other authors have built life cycle phases diagrams based on the ecodesign strategy wheel. For example, [90] reorganised design strategies into eight product life phases: innovation, reduce material impacts, manufacturing innovation, reduce distribution impacts, reduce behavioural and use impacts, system longevity, transitional system, and optimised end-of-life. The authors gave a comprehensive range of details about each strategy in each phase, including business, technical, and change behaviour prospects in each phase, as well as descriptions of many case studies. Ref. [87] presented two clusterisations for circular product design for technical and biological cycles, based on the "EcoDesign Strategy Wheel". Both clusters were then divided further into design to slow the loops, and design to close the loops. The authors also provided four case studies to show how the strategies were implemented in detail, indicating that cross-sector and inter-business collaboration is an essential activity in the CE. Ref. [32] suggested a classification that included eight product life cycle phases: product design, packaging design, product manufacturing design, material design, product distribution design, product use design, product service design, and product EOL design. The review classified DfX strategies for numerous product life cycles, emphasising engineering strategies. Ref. [88] cauterised suitable strategies for small and medium enterprises combining different environmental management maturity levels. Strategies were classified according to take, make/transform, distribute, use/consume, recover, and industrial symbiosis. The authors showed how it was possible to increase strategies in different stages of companies by coordinating the interactions between internal factors, such as the company's resources, skills and competencies, and external factors, such as public policy, market conditions, technological development and stakeholders. Ref. [89] created a CE strategies database to design new circular products. In this paper, the product life cycle was divided into seven phases: material sourcing, design manufacturing, distribution and sales, consumption and use, collection and disposal, recycling and recovery, remanufacture, and circular inputs. The database of CE strategies was built with 45 strategies appropriate for implementing the value-chain throughout the entire product life cycle.

Unlike in taxonomies, where strategies have a father–son dependency, life cycle phase diagrams do not provide direct dependency. This classification structure is typically used to help clarify the relationships between the various strategies implemented by different design teams at various supply chain stages. Many authors have incorporated business models in the product life cycle, which is another significant point to note [68,87,90]. For example, [15,16,20,21,34] showed that product decisions made during the business phase were fundamentally linked to business decisions made during the CE design phase. On this basis, the product life cycle can be generally classified into eight phases (P), as shown in Figure 4, which include: P^1—business and networks; P^2—resources use and production; P^3—forward logistics; P^4—sales, P^5—use and operations, P^6—service and maintenance, P^7—reverse logistics, and P^8—recovery. Using the prior example of a photocopier, a business model strategy such as design for hybrid model in P^1 can be used to deliver high-quality printers to B2B customers. Thereby, managers and designers may use strategies such as design for customer experience optimisation in P^4 and P^5, or design for components take back in P^7. Additionally, they may use strategies such as design for quality in P^2, and design for ease maintenance in P^6, to reduce the time and effort necessary to maintain equipment at peak operating efficiency.

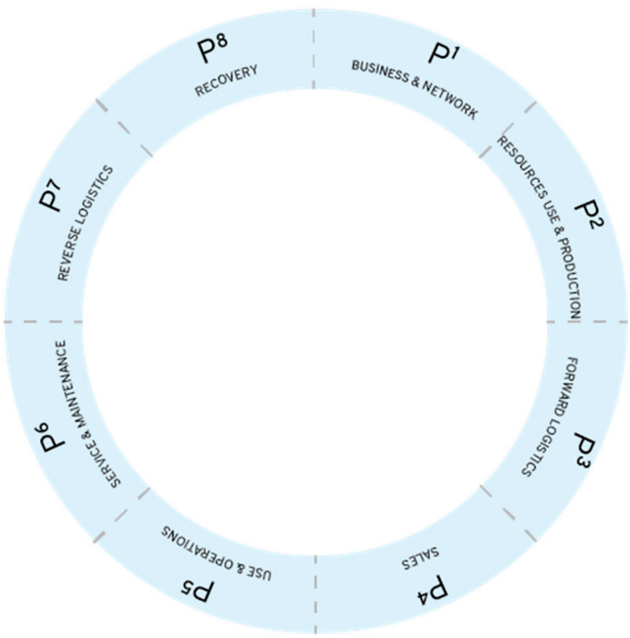

Figure 4. Classification according to product life cycle phases (life cycle phases diagram). Typically, these hierarchical frameworks are used to compare design strategies between various supply chain phases (from P^1 to P^8).

3.2.3. Design Strategies Classification According to Life Cycles

In 1994, Sirkin and Ten Houten extensively investigated, for the first time, the concept of cascading, one of the first scientific and practical attempts to decouple the use of resources from economic growth [36]. Although they are not often mentioned in the CE literature, product cascading is at the core of the CE. The authors not only provided managers and designers with several strategies to aid in the development of circular products, but they also linked these strategies across the various life cycles of the product. On the other hand, a few authors in the more recent literature discuss design strategies across the product's multiple life cycles.

The circular strategies scanner, developed by [82], is one of the few frameworks that clearly considers different product life cycles. The framework proposes a circular strategies structure for the manufacturing context, with various circular strategy definitions. It provides an example of how such a framework might be used in the early stages of a circular-oriented innovation process. Few other academics discuss specific design strategies, with an emphasis on design strategies for the subsequent life cycle following the initial one, with a particular focus on design for user behaviour change [47,53]. Ref. [47] suggested nine user change behaviour design strategies for reused, refurbished, long lasting and recycled products. Ref. [91] observed that participants who buy second-hand items simultaneously questioned the market structure, consumption, and conventional channel features and offerings of conventional retail channels. The study concluded that second-hand shops should provide users with additional technical documentation or guarantees on health, safety, compliance with technical requirements, and durability. The authors also advised that risky products, such as televisions, laptops, and appliances, should come with extra warranties. Ref. [93] analysed design strategies for the fashion industry. In their research, the authors presented four case studies to show how fashion companies are redesigning products to be used in a second product life cycle by using pre-consumer waste materials, with the intent to create "eternal" products. The overall conclusions described ten possible strategies for fashion products: seasonality, multi-functionality, modularity, alterability, repairability, physical, emotional durability, classic design, design inspiration, custom sizing. The research also found that all cases studied had strong collaborative networking to extend the product's life cycle. Ref. [53], investigated possible strategies to increase user acceptance of refurbished mobile phones in the Dutch market. In this research, three main strategies were proposed; the first strategy aimed to attract consumers by stimulating consideration of refurbished products. The second strategy was concerned with how it was possible to convince users of the product's value, to shift the risk-benefit balance. Furthermore, the third strategy stressed the importance of the involvement of users in the growth of the refurbishment development market by mobile phone companies.

An ideal circular product should be designed to be reintegrated into the system for multiple cycles to use the minimum energy and resources during the entire product lifetime. As a result, managers and designers should anticipate how the product will be used after the first life cycle (L^1), necessitating a multi-life cycles strategy that considers a plethora of additional variables, parameters, and requirements. This might be a complex undertaking that requires adopting a more structured combination of strategies to achieve economic viability. With that aim, designers should foresee which circular objective (X^1) should be applied for each product life cycle (i.e., L^1, L^2, L^3, etc.) in order to then decide on a hierarchical configuration of X^{2s} and X^{3s} (Figure 5). For example, if the circular objectives of a photocopier are to be remanufactured in L^1, refurbished in L^2, reused in L^3 and then recycled in L^4, all these objectives and related strategies to achieve each objective should be considered. A critical part of effectively implementing this product lifetime strategy is determining whether the product will be shifted to a different market between the different cycles. If so, who will be the user target for each cycle that wants to buy the remanufactured photocopier? The product could be sold on different online platforms that specifically sell remanufacturing, refurbished or reused products (e.g., Photocopiers R Us in the UK). Managers and designers can consider design for customisation, offering spare parts on the company's website, or design for peer testimonials to persuade users in L^2, L^3, and L^4 to purchase remanufactured photocopiers. In addition, the business may provide a one-year free repair period starting from the date of purchase and warranties in L^2 and L^3. Clearly, during the early design phase of the photocopier, managers and designers used strategies such as design for quality, design for disassembling and reassembling, to ensure the product would last for multiple loops. The loop diagram visualises the different loops of the photocopier and the circular loop shifting at the end of each cycle before entering a new loop.

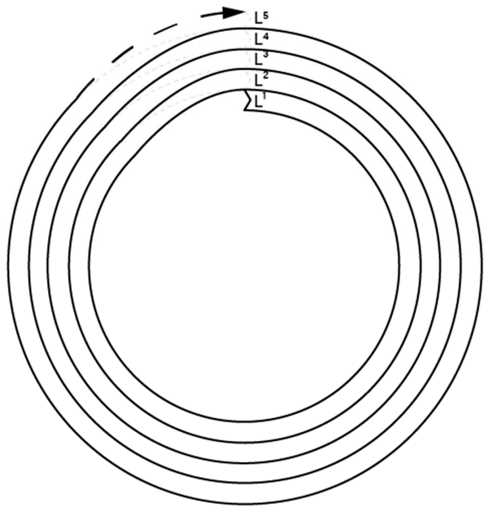

Figure 5. Classification according to life cycles (loops diagram). Typically, these hierarchical frameworks are used to compare design strategies between various life cycles (from L^1 to the last life cycle).

3.3. Proposal of a Novel Conceptual Framework

One of the most fundamental human needs to understand and handle complex phenomena is the hierarchisation of information [25,29]. Managers and designers often use hierarchies to support or analyse their decisions. The above literature indicates the most prominent examples of various hierarchy classifications authors use in different research fields to organise different aspects of the CE. Based on this analysis, a series of observations can be made:

Hierarchies:

1. Overview of hierarchical dependencies—The three hierarchies (hierarchy according to relevance, according to product life cycle phases, according to life cycles) specify only certain dependencies, making it difficult to provide a complete picture of the product lifetime strategy;
2. Limit in the visualisation of strategies following the first cycle—It is highly difficult to structure hierarchies on different temporal cycles;
3. Rigidly defined characteristics—CE is a broad topic that involves different actors and sectors on various levels, and not all of them define objectives and strategies in the same way. This is also true between different countries and continents. This could prevent the mutual understanding of the different actors involved.

Objectives and strategies:

1. Definition of multiple circular objectives—Only a taxometric hierarchical structure allows for the development of clear and simple circular objectives, which is more difficult in the structures of cycle phases diagrams and loop diagrams.
2. Conflicting strategies—When setting objectives among different departments and stakeholders, especially over multiple product life cycles, it may be possible to have strategies that come into conflict with each other.

3. Identify and coordinate multiple life cycle strategies—Strategies used in the first or subsequent cycles are rarely organised in a logical order. Explicitly identifying the strategies used in the different product life cycles can facilitate the coordination and management of product design from the very first stages.
4. Complementary strategies—To be effective, specific strategies need to be supported in different product life cycle phases with complementary subset strategies.
5. Limit the ability to reflect, discover and create new design strategies—Certain classifications make it difficult to manage the diverse design strategies required in the CE to tackle complex problems. A rigid structure can obstruct the development and refinement of circular objectives and design strategies.

Following these observations, the multi-hierarchical circular design framework depicted in Figure 6 is presented as a novel approach to formulate a product lifetime plan. The graphic elements of the framework are organised in the following way: X^1 indicates one of the circular objectives that must be addressed by all managers and designers involved in the development of the product lifetime plan. Depending on the life cycles (Ls), they may differ between maintenance/longevity, reuse, refurbishment, remanufacturing, and recycling. The design process should begin by defining all X^{1s} for each life cycle to be achieved; managers and designers should then proceed with defining and filling each X^2 and X^3 for each of them. X^2 and X^3 may vary in number and importance depending on the product or service. X^{2s} represent the strategies managers and designers use in every single phase of the product life cycle. X^2 can be one or more than one, and is defined according to X^1. X^3 represents very specific strategies that can be used to achieve X^2 (see Figure 7). All choices made in L^1 and P^1 influence all the remaining choices in subsequent cycles. The typical complexity of product lifetime planning may be managed and made more accessible and predictable by analysing each life cycle separately, as shown in Figure 8.

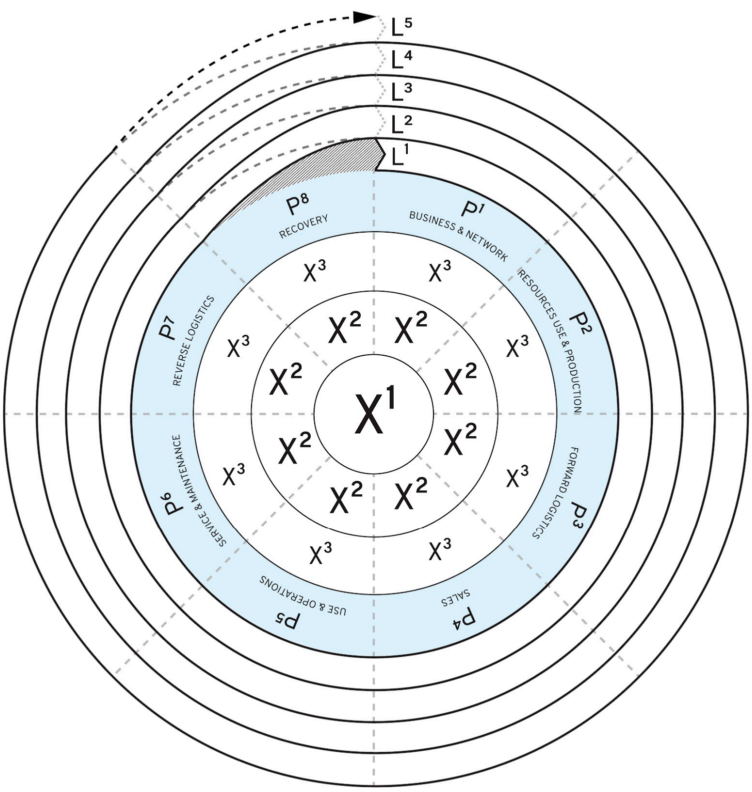

Figure 6. The multi-hierarchical circular design framework. This new framework enables the organisation of circular objectives (X^{1s}) and design strategies (X^{2s} and ^{X3s}), as well as their hierarchical relationships, in relation to their relevance in the specific supply chain phase (P) and life cycle (L).

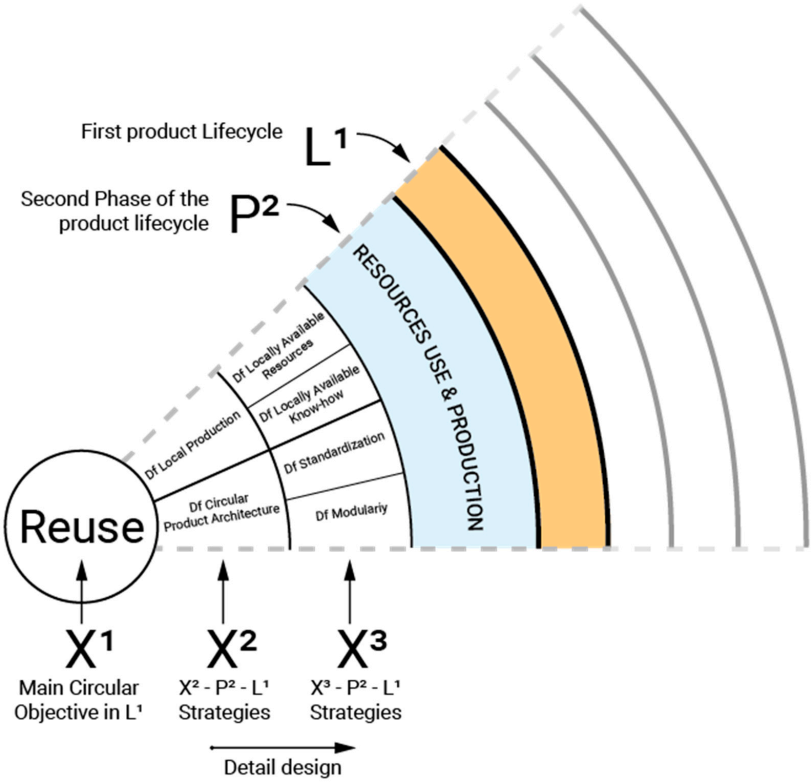

Figure 7. A comprehensive illustration of a section of the Multi-hierarchical Circular Design framework.

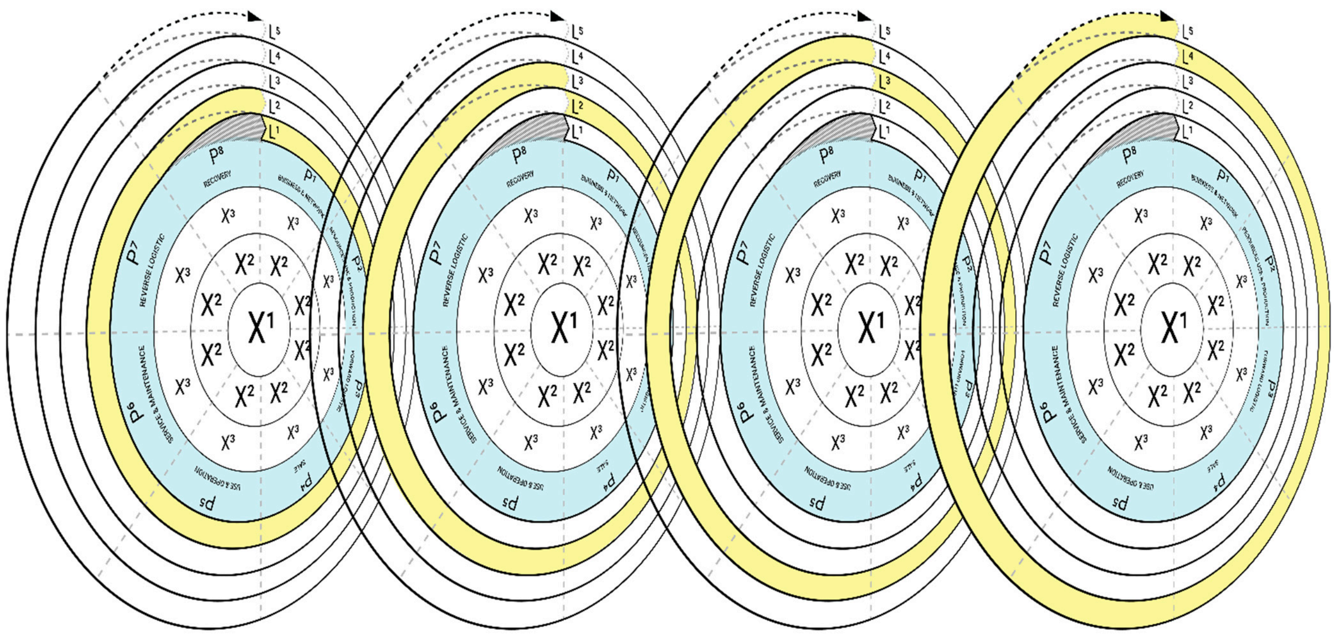

Figure 8. A demonstration of how to use the framework while designing for different circular objectives (X^{1s}) for various product life cycles (Ls). The highlighted yellow line indicates the life cycle to be examined.

This framework can assist managers and designers in three different ways. First, it may be used for the formulation of a new product lifetime plan; this usually occurs early in the design process and provides the initial analysis for a new circular product or service. Second, the framework can be used to implement an established product lifetime plan or to convert a linear product to a circular one. Third, it can be used to qualitatively evaluate a product lifetime plan of a circular company and map its circular objectives and related strategies. The following aspects allow for a wide range of applications:

1. *Formulate clear and concise circular objectives in a new and more methodical way.* To be successful, almost every article or book regarding management and strategy design discusses the importance of defining objectives. The CE is no exception. Objectives define the strategic approach; they can help to determine the product lifetime plan and how many life cycles the company may be able to achieve. In the beginning, it is all about creating circular objectives;
2. *Make connections between circular business and design strategies based on the circular objectives*. Circular objectives should make it easy to comprehend how the business model can support them and, thus, how products or services should be designed to ensure that they can be reintegrated. This should be repeated each time the circular objective changes;
3. *Improved product life cycle understanding of users and contexts*. Managers and designers should examine factors such as who the users are in different life cycles and if there are optimum conditions to recover the product in a given environment, depending on the different life cycles and the intended circular objective;
4. *Uncover hierarchical linkages, dependencies, correlations, or conflicts and formulate the optimal solutions throughout the supply chain and life cycles*. Once the first overview of the circular model has been shown, it is much easier to verify whether the strategies conceptualised between distinct product life phases support one another. If the framework is employed early in the design phase, it is relatively affordable to modify and improve them;
5. *Accept increasing complexity in order to build strategies that have an impact on the second, third and so on cycle.* Managing the complexity of designing circular products and services across multiple life cycles is among the most significant challenges in the CE. By adopting an aggregated structured visualisation of hierarchies supporting expanding complexity, the multi-hierarchical circular design framework can assist managers and designers in integrating numerous life cycles and critical strategic considerations;
6. *Identifying which organisations in the supply chain are the most well-suited for collaborating to achieve one or more circular objectives.* Creating a product lifetime strategy allows a company to assess its strengths and limitations, as well as the stakeholders with which it may partner to achieve circular value creation successfully;
7. *Facilitating cross-disciplinary and cross-sectoral cooperation and formulation of integrated objectives and strategies among various actors.* Dialogue and understanding are crucial to establishing synergies amongst various stakeholders. This can be achieved by clearly communicating how the synergy of two or more organisations can generate circular value together;
8. *Promote the development of specific complementary strategies to support the transition from one life cycle to another*. It is crucial in a CE to build products and services that meet third-party technical specifications, particularly in open-loop systems. This can be accomplished through collaboration and co-creation for a shared product lifetime strategy;
9. *Enable the articulation of novel design strategies both between circular objectives and strategies across domains of knowledge*. The ability to see the big picture of the many life cycles and strategies employed over the various product life cycles makes it easier to identify any considerations that have been overlooked and design solutions to address them.

An empirical observation to test the framework was conducted in order to support the validation of the framework. This initial testing aimed to find evidence of the framework's potential application.

3.4. Testing of the Framework through Four Case Studies

According to [27], the multi-hierarchical circular design framework was tested using four case studies: Patagonia, Bugaboo, Loop by Terracycle and Fairphone. The case studies were first chosen using four criteria: (I) number of life cycles, (II) different circular objectives, (III) different industries, and (IV) different life cycle patterns (open and closed life cycle patterns). These criteria were chosen to include case studies demonstrating the complex classification of design strategies across multiple fields of expertise (see Table 3).

Table 3. Case studies selected according to the number of life cycles, circular objectives and life cycle patterns.

Case Study	No. of Life Cycles	Circular Objective	Industry	Life Cycle Pattern	Source
Patagonia	Potentially 2	Maintenance/longevity Reuse Recycle	Fashion	Open-loop	[46,97–99]
Bugaboo	3	Refurbish (first two cycles) Refurbish (second-hand market)	Personal transportation vehicle	Closed-loop	[100,101]
Loop by Terracycle	Potentially 100	Reuse (over 100 cycles) Recycle	Packaging	Closed-loop	[37,102–104]
Fairphone	1	Maintenance/longevity Recycle	Consumer electronics	Open-loop	[87,105,106]

Following that, a literature review of the four case studies was conducted in order to collect data. The authors of this paper examined and classified the various circular objectives and strategies used in each case study, based on the framework. Design strategies were categorised as DfX or design with X (DwX), where X denotes a sustainable solution. The qualitative test was utilised to map the many circular objectives and design strategies within the framework, as seen in Figures 9–11. Satisfactory assessment testing was characterised as a comprehensive representation of multiple design strategies in relation to each circular objective of various case studies. The test results are presented in Section 4.

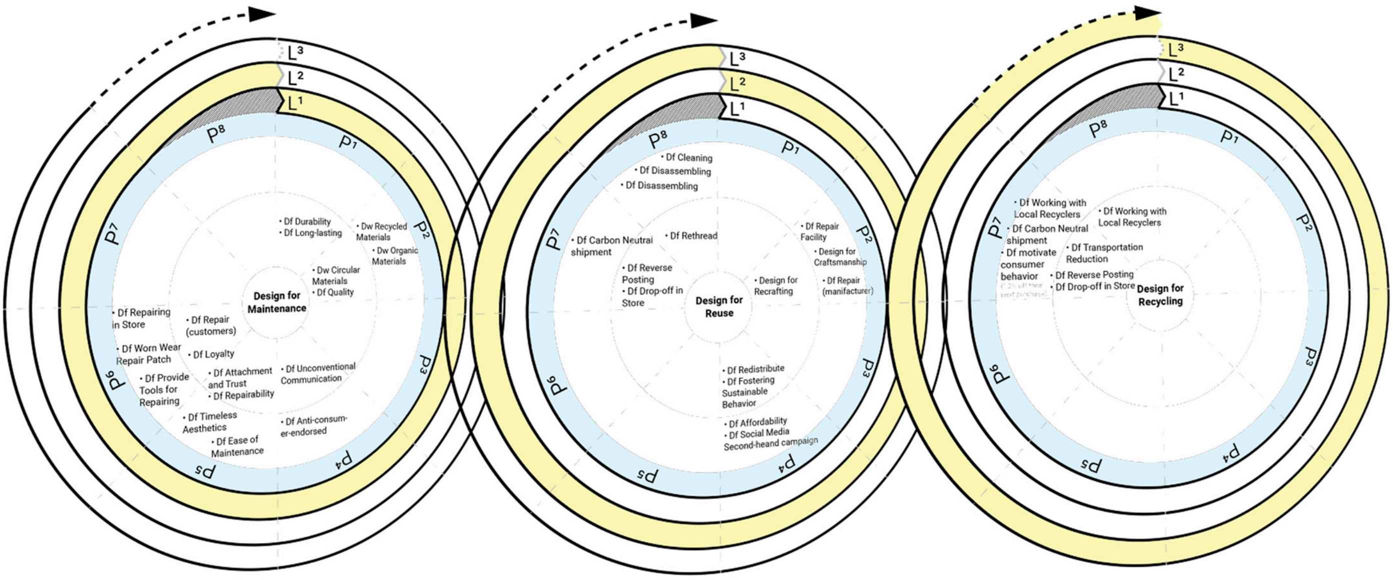

Figure 9. Patagonia case analysis.

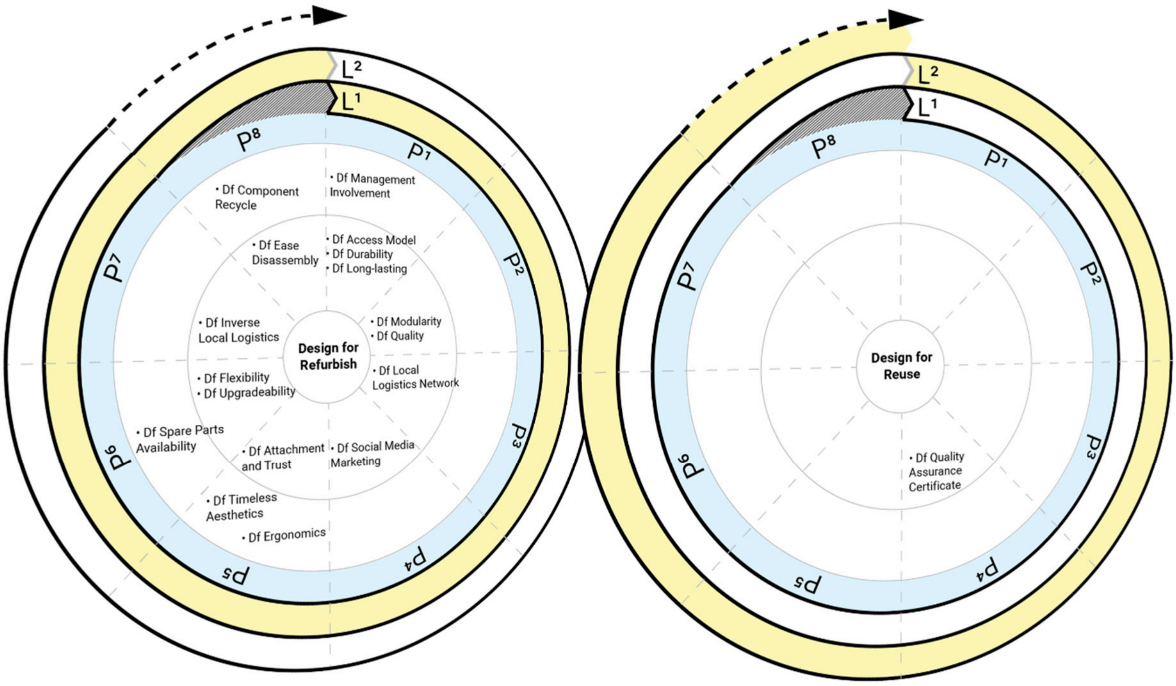

Figure 10. Bugaboo case analysis.

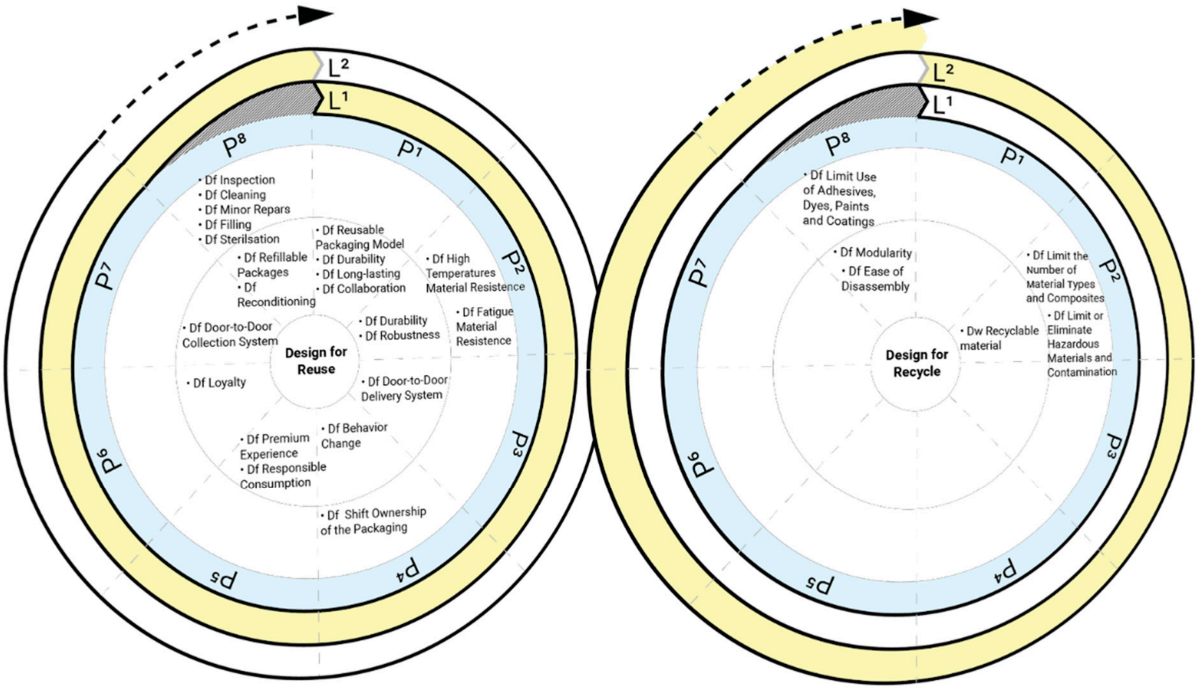

Figure 11. Loop by Terracycle case analysis.

3.4.1. Patagonia

Patagonia is a well-known American fashion brand that incorporates the principle of maintenance/longevity into all its products. Patagonia helps its customers repair their products at no cost through DIY repair guides. If this is not possible, they accept products for repair at reasonable prices at the repair centre in Reno, Nevada. Additionally, the company uses unconventional communication strategies to persuade customers not to buy new products. In 2011 they launched a provocative ad in The New York Times on Black Friday telling people, "Don't Buy This Jacket". Patagonia also has a program called Worn

Wear to extend the garment's life cycle by reusing it. Here, people can buy high-quality used products guaranteed by Patagonia. Although Patagonia uses an open-loop supply chain, customers in the first life cycle are incentivised to trade their product in stores or mail it for credit, which can be spent on WornWear.com and Patagonia.com. When the product is beyond repair, Patagonia recycles it, closing the life cycle of the product. Between 2005 and 2016, Patagonia recycled 95 tons of garments, including their own garments, into polyester fibers to produce new clothing. Figure 9 shows how the company defined a specific circular stage for each life cycle.

3.4.2. Bugaboo

Bugaboo is a dynamic Dutch design-driven company known for its ergonomic and modular strollers. According to [101], in 2013, the company embarked on an ambitious pilot project to transform the Bugaboo Cameleon stroller into a circular business model. The company committed to establishing a closed-loop access model to refurbish the product at the end of each life cycle for the first and second life cycles. Although the product was not purposely designed for an access business model, the high quality of the product made the servitisation possible anyway. In the third life cycle, along with its certificate of guarantee released by the company, the stroller was sold in an open-loop system as a second-hand product [101]. Figure 10 shows how the company decided to have two different circular stages with the same objective.

3.4.3. Loop by Terracycle

Loop by Terracycle is an e-commerce food platform that only uses reusable packaging. The company partners with existing retailers to design packaging-free products that mostly use materials such as alloys (e.g., stainless steel), glass, and engineered plastics. The packaging is owned by the retailers and given as a service in a closed-loop system, enabling companies to invest in long lasting packs. The service is disruptive and changes the way customers buy, use and dispose of their packaging. The company provides other services such as the reusable tote used to move food packages safely, delivery and collection of the tote, and sanitisation of empty packages. According to [37], Loop's packaging is designed to be reused at least 100 times. All Loop's products are designed to be resistant to high temperature, chemicals and sanctification processes used during the reconditioning process that makes products commercially safe for users. At the end of the product lifetime, materials are recycled and can be reused again for the same purpose. Figure 11 shows how, although products can reach more than 100 life cycles, the company has only two circular stages.

3.4.4. Fairphone 4

By focusing on four primary issues: fair materials, acceptable working conditions, long-lasting design, and reuse and recycling, Fairphone 4 is a smartphone that has a minimum environmental and social impact. The company is committed to sourcing conflict-free minerals, using recycled materials, and providing fair working conditions for its employees and suppliers. The phone is made from recycled materials, including plastic and metal, and is assembled in a factory that uses renewable energy. The phone is also designed to be repaired and upgraded, with replaceable parts that the user can swap out. One of the most critical features for extending the product life cycle is the long-term availability of spare parts, which is combined with software support upgrading and comes with a five-year warranty. This can aid in the avoidance of both technological and economic obsolescence. Figure 12 illustrates how the representation and separation of the design strategies, i.e., maintenance and recycling, can increase comprehension of the design strategies used in each circular objective.

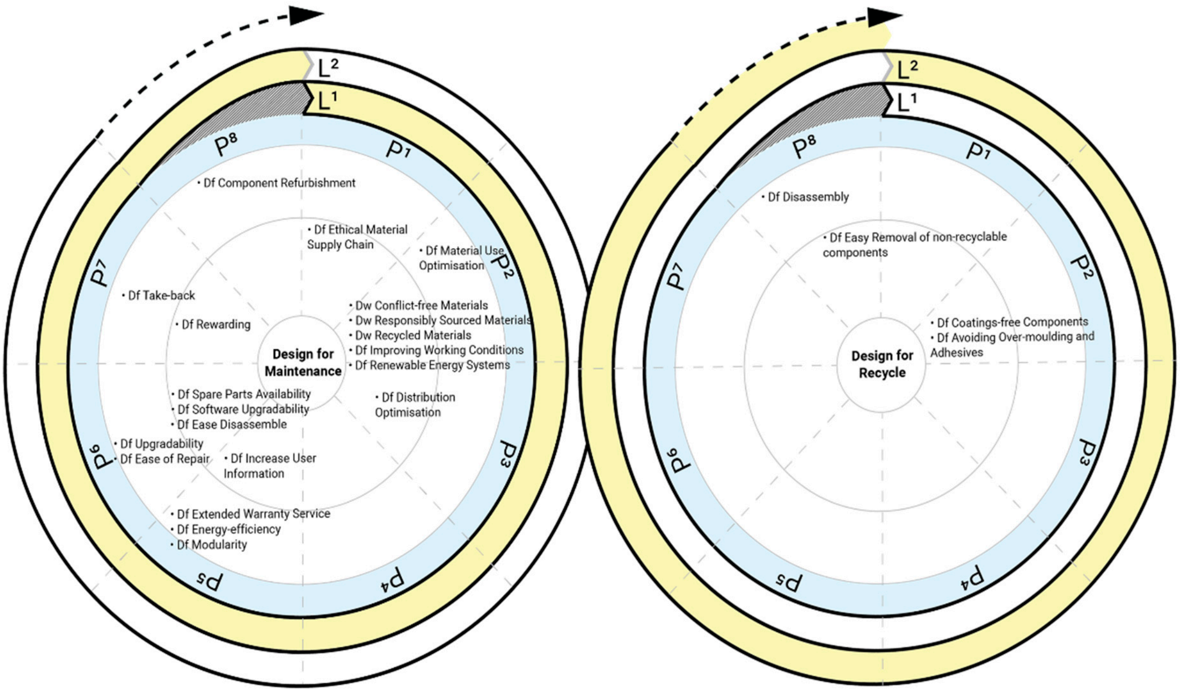

Figure 12. Fairphone 4 case analysis.

4. Discussion

The primary objective of the qualitative mapping test based on the literature from the four case studies was to create a comprehensive representation of multiple design strategies in relation to each circular objective of the various case studies. While the literature review examines circular business and design strategies conventionally, the analysis of the product lifetime plans of the four case studies using the framework sheds new light on the complexity of the circular lifetime plans. This is critical for both managers and designers, as well as researchers who are analysing different design options for the CE transition. According to these findings, the framework provides a basic and straightforward qualitative overview of the circular objectives and strategies used in each cycle.

This study tested the framework only for mapping circular objectives and design strategies related to the business models and product design. On the other hand, the framework can be used to map more complex strategies and implement a new product lifetime plan. Although these various applications should be tested separately, combining these approaches could be highly effective in evaluating innovative product lifetime plans. The multi-hierarchical circular design framework might be used to support the development of these more detailed plans, with the first stage determining a more generic product lifetime plan that is more appropriate (e.g., from L^1 to L^3, and X^1, in L^1, L^2 and L^3, respectively), and the second phase examining a number of more detailed options (i.e., X^2, X^3, for each P).

A key benefit of the framework is that it focuses on each life cycle objective (X^1) to build a circular business around it. The selection of strategies in relation to this provides information that can be easily understood and shared between different design teams and the stakeholders involved. Making this information explicit increases transparency in decision making and facilitates collaboration. Similarly, evaluating strategies on the different phases of the product or service life cycle reduces the potential for subjective bias of individual teams. The debate on which alternative strategy is preferable now depends solely on the goal defined in X^1. Ideally, the definition of the multiple X^{1s} should be performed by a group of expert stakeholders. These experts are within the organisation and stakeholders and should include companies active in disassembly, remanufacturing, or recycling, as well as companies that specialise in maintenance and life cycle extension.

A key element of the framework is the potential feedback to stakeholders for verification at each stage of the process (i.e., product or service life cycles, circular objectives, strategy hierarchy and results combined). Any confusion or misunderstanding could be addressed immediately. Nevertheless, it is also possible that certain design strategies may conflict over the various life cycles, especially if, as in the case of Bugaboo, the business strategy involves the product to have both closed and open loops. In this situation, managers and designers might also define priorities using quantitative methods, such as the (expected) return rates of the product in succeeding cycles. This could assist in evaluating the potential benefits and costs of various design strategies and making more informed decisions.

A potential shortcoming in the framework is that different teams, even within the same organisation, frequently pursue diverse and occasionally contradictory objectives. This could, to some extent, influence their strategic inclinations, potentially leading to internal strife. An examination of objective prioritisation could help unblock this circumstance and favour teams with more clout inside the organisation.

Early in the design process, Refs. [16,43] state that identifying how value will be recovered and maintained over life cycles is essential. The relevance of having tools and solutions that can steer a strategy through multiple life cycles from the beginning of design, is thus critical. Despite this, there are not many frameworks in the literature that can assist managers and designers in developing solutions that support a long-term and product lifetime plan. The multi-hierarchical circular design framework can be used as an alternative approach to set up the "big picture" and coordinate shared circular objectives and design strategies. Additionally, the framework can be used to understand how different design strategies can be combined to create a more holistic approach. This is important because it can help designers to create more innovative and effective solutions that consider entire products' lifetimes. Potentially, the framework could be used in conjunction with other tools and frameworks to gain a better understanding of alternative solutions and how to create circular value. Stakeholder mapping, product tear-down, and whole system design thinking are just a few of the methodologies that could be integrated.

5. Conclusions

This paper has presented a new theoretical framework to organise circular objectives and related design strategies based on the aggregation of three hierarchies (Figures 3–5). After various tests of the framework's configuration aimed at integrating the different hierarchies, the multi-hierarchical circular design framework was defined (Figure 6). While multiple hierarchies must be defined and specific visualisations must be used to organise opportunities and solutions in the CE, this information should also be used in a coordinated manner to reduce total environmental impacts while meeting other criteria. The multi-hierarchical circular design framework provides a possible approach for designing how an organisation and its partners can create value in the CE. With an intuitive and simplified representation of all product life cycle stages, managers and designers can collaborate more effectively, both internally within the company and outside with stakeholders. Thus, the major contribution of this study is a multi-hierarchical framework that takes into account three possible hierarchies to integrate and combine methodologies from different levels of detail, phases of the life cycle, and throughout the product's lifetime. Using these several hierarchies in relation with one another can help the process of circular decision making. It brings many implicit assumptions that guide decision-making to the surface in the absence of quantifiable decision-supporting tools. The newly introduced framework has the intent of being relatively simple to apply, and offers elements that may influence the decisions on each option so that they are relatively straightforward to identify.

The replicability and robustness of the framework must be tested further both through theory-oriented and practice-oriented research [27]. Future research with a similar theoretical focus as this work could employ alternative search engines or expand the current keyword search, while future practice-oriented studies could validate it in two potential ways. First, the framework's ability to correlate complex design strategies and domains, and to facilitate the design process, could be validated by developing a step-by-step process for setting circular objectives and defining design strategies around them. This may involve workshops in which managers and designers from various parts of the supply chain work together to structure synergies across diverse phases of a product's life cycle and life cycles. Observations as to which strategies each stakeholder would adopt and how they would be supported by the framework, through the development of a complete product lifetime plan, would allow the strengthening of the framework. As a product progresses through its various life cycles, it would also be interesting to study how the implementation of strategies evolves and adapts to shifting socioeconomic conditions. A second approach for validating the framework may involve its integration into a systemic software tool that facilitates the navigation of numerous design strategies and displays key interconnections and detailed information on each strategy and between strategies. This may help to organise more complex design strategy hierarchies and their allocations, as well as tailor a combination of various design strategies that are more effective. It could also be used to compare strategies, understand the connections between strategies and objectives, and describe how strategies are organised inside the business. The software may be tested with managers and designers who deal with product lifetime plans.

In conclusion, it has been observed that, in the current literature on classifications and representations of design strategies in the CE, classifications are usually focused on relevance and product life cycle stages place. This puts a strong emphasis on the first cycle of business and product-related initiatives, but not on long-term value creation. In contrast, in the introduced life cycle classification, the strategies primarily focus on influencing user behaviour across multiple cycles. This may suggest that by shifting current hierarchical classifications to multiple life cycles presents an opportunity for the scientific community in order to better tackle the challenges of designing for long term value creation.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su14159298/s1, Table S1: Classification of design strategies according to relevance in literature; Table S2: Classification of design strategies according to product life cycle phases in literature; Table S3: Classification of design strategies according to life cycles in literature.

Author Contributions: Conceptualisation, A.F., F.C. and D.P.; methodology, F.C., A.F.; validation, A.F., F.C. and D.P.; formal analysis, A.F.; investigation, A.F.; data curation, A.F.; writing—original draft preparation, A.F.; writing—review and editing, A.F., F.C. and D.P.; visualisation, A.F.; supervision, F.C. and D.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Ellen MacArthur Foundation. *Towards the Circular Economy Vol. 1: An Economic and Business Rationale for an Accelerated Transition*; Ellen MacArthur Foundation: Cowes, UK, 2012.
2. Ghisellini, P.; Cialani, C.; Ulgiati, S. A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *J. Clean. Prod.* **2016**, *114*, 11–32. [CrossRef]
3. Tam, E.; Soulliere, K.; Sawyer-Beaulieu, S. Managing complex products to support the circular economy. *Resour. Conserv. Recycl.* **2019**, *145*, 124–125. [CrossRef]
4. Castro, C.G.; Trevisan, A.H.; Pigosso, D.A.; Mascarenhas, J. The rebound effect of circular economy: Definitions, mechanisms and a research agenda. *J. Clean. Prod.* **2022**, *345*, 131136. [CrossRef]
5. Ceschin, F.; Gaziulusoy, I. Evolution of design for sustainability: From product design to design for system innovations and transitions. *Des. Stud.* **2016**, *47*, 118–163. [CrossRef]

6. Moreno, M.; de los Rios, C.; Rowe, Z.; Charnley, F. A Conceptual Framework for Circular Design. *Sustainability* **2016**, *8*, 937. [CrossRef]
7. McDonough, W.; Braungart, M. *Cradle to Cradle: Remaking the Way We Make Things*; North Point Press: London, UK, 2009.
8. De Schoenmakere, M.; Gillabel, J. *Circular by Design: Products in the Circular Economy*; European Environment Agency: Copenhagen, Denmark, 2017; p. 6.
9. Ribul, M.; Lanot, A.; Pisapia, C.T.; Purnell, P.; McQueen-Mason, S.J.; Baurley, S. Mechanical, chemical, biological: Moving towards closed-loop bio-based recycling in a circular economy of sustainable textiles. *J. Clean. Prod.* **2021**, *326*, 129325. [CrossRef]
10. Bakker, C.; Balkenende, R. A renewed recognition of the materiality of design in a circular economy: The case of bio-based plastics. In *Materials Experience 2*; Butterworth-Heinemann: Oxford, UK, 2021; pp. 193–206.
11. Potting, J.; Hekkert, M.P.; Worrell, E.; Hanemaaijer, A. *Circular Economy: Measuring Innovation in the Product Chain*; PBL Netherlands Assessment Agency: Hague, The Netherlands, 2017.
12. Reike, D.; Vermeulen, W.J.; Witjes, S. The circular economy: New or refurbished as CE 3.0?—Exploring controversies in the conceptualization of the circular economy through a focus on history and resource value retention options. *Resour. Conserv. Recycl.* **2018**, *135*, 246–264. [CrossRef]
13. Bauer, T.; Zwolinski, P.; Nasr, N.; Mandil, G. Characterization of circular strategies to better design circular industrial systems. *J. Remanufacturing* **2020**, *10*, 161–176. [CrossRef]
14. Morseletto, P. Targets for a circular economy. *Resour. Conserv. Recycl.* **2020**, *153*, 104553. [CrossRef]
15. Lüdeke-Freund, F.; Gold, S.; Bocken, N. A Review and Basic Typology of Circular Economy Business Model Patterns. *J. Ind. Ecol.* **2018**, *23*, 36–61. [CrossRef]
16. Bocken, N.M.; De Pauw, I.; Bakker, C.; Van Der Grinten, B. Product design and business model strategies for a circular economy. *J. Ind. Prod. Eng.* **2016**, *33*, 308–320. [CrossRef]
17. Den Hollander, M.C.; Bakker, C.A.; Hultink, E.J. Product Design in a Circular Economy: Development of a Typology of Key Concepts and Terms. *J. Ind. Ecol.* **2017**, *21*, 517–525. [CrossRef]
18. Konietzko, J.; Bocken, N.; Hultink, E.J. Circular Ecosystem Innovation: An Initial Set of Principles. *J. Clean. Prod.* **2020**, *253*, 119942. [CrossRef]
19. De Magalhães, R.F.; Danilevicz, D.M.F.; Palazzo, J. Managing trade-offs in complex scenarios: A decision-making tool for sustainability projects. *J. Clean. Prod.* **2019**, *212*, 447–460. [CrossRef]
20. Prendeville, S.M.; O'Connor, F.; Nancy, B.M.P.; Bakker, C. Uncovering Ecodesign Dilemmas: A Path to Business Model Innovation. *J. Clean. Prod.* **2017**, *143*, 1327–1339. [CrossRef]
21. Pieroni, M.; Pigosso, D.; McAloone, T. Exploring the synergistic relationships of circular business model development and product design. In *DS 92: Proceedings of the DESIGN 2018 15th International Design Conference*; The Design Society: Glasgow, UK, 2018; pp. 2715–2726.
22. Kazancoglu, Y.; Kazancoglu, I.; Sagnak, M. A New Holistic Conceptual Framework for Green Supply Chain Management Performance Assessment Based on Circular Economy. *J. Clean. Prod.* **2018**, *195*, 1282–1299. [CrossRef]
23. Umeda, Y.; Takata, S.; Kimura, F.; Tomiyama, T.; Sutherland, J.W.; Kara, S.; Herrmann, C.; Duflou, J.R. Toward Integrated Product and Process Life Cycle Planning—An Environmental Perspective. *CIRP 881 Ann.* **2018**, *61*, 681–702. [CrossRef]
24. Lewandowski, M. Designing the Business Models for Circular Economy—Towards the Conceptual Framework. *Sustainability* **2012**, *8*, 43. [CrossRef]
25. Kwasnik, B. The Role of Classification in Knowledge Representation and Discovery. *Summer* **1999**, *48*, 22–47.
26. Arnette, A.N.; Brewer, B.L.; Choal, T. Design for sustainability (DFS): The intersection of supply chain and environment. *J. Clean. Prod.* **2014**, *83*, 374–390. [CrossRef]
27. Dul, J.; Hak, T. *Case Study Methodology in Business Research*; Routledge: London, UK, 2007. [CrossRef]
28. Danson, M.; Arshad, N. The literature review. In *Research Methods for Business and Management: A Guide to Writing Your Dissertation*; Goodfellow Publishers Limited: Oxford, UK, 2014; pp. 37–57.
29. Rowley, J.E.; Farrow, J. *Organizing Knowledge: Introduction to Access to Information*, 1st ed.; Routledge: London, UK, 2017.
30. Thierry, M.; Salomon, M.; van Nunen, J.; van Wassenhove, L. Strategic Issues in Product Recovery Management: California Management Review. *SAGE J.* **1995**, *37*, 114–136. [CrossRef]
31. King, A.; Burgess, S.; Ijomah, W.; McMahon, C. Design for End-of-Life: Repair, Recondition, Remanufacture or Recycle? *Am. Soc. Mech. Eng. Digit. Collect.* **2008**, *3*, 745–754. [CrossRef]
32. Go, T.F.; Wahab, D.A.; Hishamuddin, H. Multiple Generation Life-Cycles for Product Sustainability: The Way Forward. *J. Clean. Prod.* **2015**, *95*, 16–29. [CrossRef]
33. Gits, C.W. Design of Maintenance Concepts. *Int. J. Prod. Econ.* **2015**, *24*, 217–226. [CrossRef]
34. Bakker, C.; Wang, F.; Huisman, J.; den Hollander, M. Products That Go Round: Exploring Product Life Extension through Design. *J. Clean. Prod.* **1992**, *69*, 10–16. [CrossRef]
35. Stahel, W.R. *The Performance Economy*, 2nd ed.; Palgrave Macmillan: Basingstoke, UK; New York, NY, USA, 2010.
36. Sirkin, T.; Houten, M.t. The Cascade Chain. *A Theory and Tool for Achieving Resource Sustainability with Applications for Product Design. Resour. Conserv. Recycl.* **1994**, *10*, 213–276. [CrossRef]
37. Unilever. We're Introducing Reusable, Refillable Packaging to Help Cut Waste. Available online: https://www.unilever.com/news/news-search/2019/we-are-introducing-reusable-refillable-packaging-to-help-cut-waste/ (accessed on 17 April 2022).

38. Stahel, W. *The Utilization-Focused Service Economy: Resource Efficiency and Product-Life Extension. The Greening of Industrial Ecosystems*; National Academies: Washington, DC, USA, 1994; pp. 178–190.
39. Department of Energy. *Human Factors/Ergonomics Handbook for the Design for Ease of Maintenance (DOE-HDBK-1140-2001)*; United States Department of Energy: Washington, DC, USA, 2001.
40. Bocken, N.M.P.; Short, S.W.; Rana, P.; Evans, S. A literature and practice review to develop sustainable business model archetypes. *J. Clean. Prod.* **2014**, *65*, 42–56. [CrossRef]
41. Montalvo, C.; Peck, D.; Rietveld, E. A Longer Lifetime for Products: Benefits for Consumers and Companies. In *Study for Internal Market and Consumer Protection (IMCO) Committee*; European Parliament: Strasbourg, France, 2014.
42. Haines-Gadd, M.; Chapman, J.; Lloyd, P.; Mason, J.; Aliakseyeu, D. Emotional Durability Design Nine—A Tool for Product Longevity. *Sustainability* **2018**, *10*, 1948. [CrossRef]
43. EU—European Union. Sustainable Product Policy; EU Science Hub—European Commission. 2018. Available online: https://joint-research-centre.ec.europa.eu/scientific-activities-z/sustainable-product-policy_en (accessed on 26 May 2020).
44. Gedell, S.; Johannesson, H. Design rationale and system description aspects in product platform design: Focusing reuse in the design lifecycle phase. *Concurr. Eng.* **2012**, *21*, 39–53. [CrossRef]
45. Daae, J.; Chamberlin, L.; Boks, C. Dimensions of Behaviour Change in the context of Designing for a Circular Economy. *Des. J.* **2018**, *21*, 521–541. [CrossRef]
46. Bürklin, N. Worn Wear: Better than New—How Patagonia's Social Marketing Campaign Enhances Consumers' Responsible Behavior. *Soc. Mark. Action* **2019**, 187–201. [CrossRef]
47. Kunamaneni, S.; Jassi, S.; Hoang, D. Promoting reuse behaviour: Challenges and strategies for repeat purchase, low-involvement products. *Sustain. Prod. Consum.* **2019**, *20*, 253–272. [CrossRef]
48. Gelbmann, U.; Hammerl, B. Integrative re-use systems as innovative business models for devising sustainable product–service-systems. *J. Clean. Prod.* **2015**, *97*, 50–60. [CrossRef]
49. Fortuna, L.M.; Diyamandoglu, V. A novel method for material characterization of reusable products. *Waste Manag.* **2016**, *52*, 14–24. [CrossRef] [PubMed]
50. Paras, M.K.; Ekwall, D.; Pal, R.; Curteza, A.; Chen, Y.; Wang, L. An Exploratory Study of Swedish Charities to Develop a Model for the Reuse-Based Clothing Value Chain. *Sustainability* **2018**, *10*, 1176. [CrossRef]
51. Nasr, N.; Thurston, M.; Remanufacturing: A Key Enabler to Sustainable Product Systems. Remanufacturing: A Key Enabler to Sustainable Product Systems. *Rochester Inst. Technol.* **2006**, 15–18. Available online: https://www.mech.kuleuven.be/lce2006/key4.pdf (accessed on 28 April 2019).
52. Gharfalkar, M.; Ali, Z.; Hillier, G. Clarifying the disagreements on various reuse options: Repair, recondition, refurbish and remanufacture. *Waste Manag. Res. J. A Sustain. Circ. Econ.* **2016**, *34*, 995–1005. [CrossRef]
53. Van Weelden, E.; Mugge, R.; Bakker, C. Paving the way towards circular consumption: Exploring consumer acceptance of refurbished mobile phones in the Dutch market. *J. Clean. Prod.* **2016**, *113*, 743–754. [CrossRef]
54. Mugge, R.; Jockin, B.; Bocken, N. How to sell refurbished smartphones? An investigation of different customer groups and appropriate incentives. *J. Clean. Prod.* **2017**, *147*, 284–296. [CrossRef]
55. Mugge, R.; de Jong, W.; Person, O.; Hultink, E.J. 'If It Ain't Broke, Don't Explain It': The Influence of Visual and Verbal Information about Prior Use on Consumers' Evaluations of Refurbished Electronics. *Des. J.* **2018**, *21*, 499–520. [CrossRef]
56. Gray, C.; Charter, M. *Remanufacturing and Product Design: Designing for the 7th Generation*; Centre for Sustainable Design: Surrey, UK, 2007.
57. Boorsma, N.; Peck, D.; Bakker, T.; Bakker, C.; Balkenende, R. The strategic value of design for remanufacturing: A case study of professional imaging equipment. *J. Remanufacturing* **2022**, *12*, 187–212. [CrossRef]
58. Worrell, E.; Reuter, M.A. Definitions and Terminology in Handbook of Recycling. In *Handbook of Recycling 2022*; Worrell, E., Reuter, M.A., Eds.; Elsevier: Boston, MA, USA, 2014; pp. 9–16. [CrossRef]
59. Calvo-Porral, C.; Lévy-Mangin, J.-P. The Circular Economy Business Model: Examining Consumers' Acceptance of Recycled Goods. *Adm. Sci.* **2020**, *10*, 28. [CrossRef]
60. Salvioni, D.; Almici, A. Transitioning Toward a Circular Economy: The Impact of Stakeholder Engagement on Sustainability Culture. *Sustainability* **2020**, *12*, 8641. [CrossRef]
61. Sassanelli, C.; Urbinati, A.; Rosa, P.; Chiaroni, D.; Terzi, S. Addressing circular economy through design for X approaches: A systematic literature review. *Comput. Ind.* **2020**, *120*, 103245. [CrossRef]
62. Bakker, C.A.; den Hollander, M.C.; van Hinte, E.; Zijlstra, Y. *Products That Last—Product Design for Circular Business Models*, 1st ed.; TU Delft Library/Marcel den Hollander IDRC: Delft, The Netherlands, 2020.
63. Franco, M.A. A system dynamics approach to product design and business model strategies for the circular economy. *J. Clean. Prod.* **2019**, *241*, 118327. [CrossRef]
64. Schäfer, M.; Löwer, M. Ecodesign—A Review of Reviews. *Sustainability* **2019**, *13*, 315. [CrossRef]
65. Lomsma, F.; Brennan, G. The Emergence of Circular Economy: A New Framing Around Prolonging Resource Productivity. *J. Ind. Ecol.* **2017**, *21*, 603–614. [CrossRef]
66. Ceschin, F. *Sustainable Product-Service Systems: Between Strategic Design and Transition Studies*; Springer Science Business Media: Berlin/Heidelberg, Germany, 2013.

67. Sauvé, S.; Bernard, S.; Sloan, P. Environmental sciences, sustainable development and circular economy: Alternative concepts for trans-disciplinary research. *Environ. Dev.* **2016**, *17*, 48–56. [CrossRef]
68. Brezet, H.; van Hemel, C. *Ecodesign: A Promising Approach to Sustainable Production and Consumption*; United Nations Pubns: Hague, The Netherlands, 1997.
69. Velte, C.J.; Steinhilper, R. Complexity in a Circular Economy: A Need for Rethinking Complexity Management Strategies. In Proceedings of the World Congress on Engineering, London, UK, 29 June–1 July 2016; Volume 29.
70. Ziout, A.; Azab, A.; Atwan, M. A holistic approach for decision on selection of end-of-life products recovery options. *J. Clean. Prod.* **2014**, *65*, 497–516. [CrossRef]
71. Saidani, M.; Yannou, B.; Leroy, Y.; Cluzel, F.; Kendall, A. A taxonomy of circular economy indicators. *J. Clean. Prod.* **2018**, *207*, 542–559. [CrossRef]
72. Franconi, A.; Badalucco, L.; Peck, D.; Nasr, N. A Multi-Hierarchical Design for X Framework for Accelerating Circular Economy. In Proceedings of the Conference: Product Lifetimes And The Environment, Berlin, Germany, 18–20 June 2019; Volume 3. [CrossRef]
73. Brennan, G.; Tennant, M.; Blomsma, F. Business and Production Solutions: Closing Loops and the Circular Economy. In *Sustainability: Key Issues 2019*; Kopnina, H., Shoreman-Ouimet, E., Eds.; Routledge: London, UK, 2015; pp. 219–239. Available online: https://www.routledge.com/products/9780415529860 (accessed on 14 February 2021).
74. Van den Berg, M.R.; Bakker, C.A.; A Product Design Framework for a Circular Economy. Proceedings of the PLATE Conference, Nottingham, UK, 17–19 June 2015. Available online: http://resolver.tudelft.nl/uuid:307f8b21-f24b-4ce1-ae45-85bdf1d4f471 (accessed on 14 February 2021).
75. Moreno, M.A.; Ponte, O.; Charnley, F. Taxonomy of design strategies for a circular design tool. In Proceedings of the PLATE Conference, Delft, The Netherlands, 8–10 November 2017. Available online: https://dspace.lib.cranfield.ac.uk/bitstream/handle/1826/12740/Taxonomy_of_design_strategies-2017.pdf?sequence=1&isAllowed=y (accessed on 14 February 2021).
76. Ræbild, U.; Bang, A.L. Rethinking the Fashion Collection as a Design Strategic Tool in a Circular Economy. *Des. J.* **2017**, *20*, S589–S599. [CrossRef]
77. Bakker, C.; Balkenende, R.; Poppelaars, F.; Balkenende, R.; Poppelaars, F. *Design for Product Integrity in a Circular Economy. Designing for the Circular Economy*; Routledge: London, UK, 2018. [CrossRef]
78. Bovea, M.D.; Pérez-Belis, V. Identifying design guidelines to meet the circular economy principles: A case study on electric and electronic equipment. *J. Environ. Manag.* **2018**, *228*, 483–494. [CrossRef] [PubMed]
79. De Pádua Pieroni, M.; Blomsma, F.; McAloone, T.C.; Pigosso, D.C.A. Enabling circular strategies with different types of product/service-systems. *Procedia CIRP* **2018**, *73*, 179–184. [CrossRef]
80. Urbinati, A.; Latilla, V.M.; Chiaroni, D. The Role of Product Design in Circular Economy Business Models. In Proceedings of the ISPIM Innovation Symposium. The International Society for Professional Innovation Management (ISPIM), Stockholm, Sweden, 17–20 June 2018. Available online: http://arl.liuc.it/dspace/handle/2468/6163 (accessed on 13 October 2021).
81. De Mattos, C.A.; De Albuquerque, T.L.M. Enabling Factors and Strategies for the Transition Toward a Circular Economy (CE). *Sustainability* **2018**, *10*, 4628. [CrossRef]
82. Suárez-Eiroa, B.; Fernández, E.; Méndez-Martínez, G.; Soto-Oñate, D. Operational principles of circular economy for sustainable development: Linking theory and practice. *J. Clean. Prod.* **2019**, *214*, 952–961. [CrossRef]
83. Blomsma, F.; Pieroni, M.; Kravchenko, M.; Pigosso, D.C.; Hildenbrand, J.; Kristinsdottir, A.R.; Kristoffersen, E.; Shahbazi, S.; Nielsen, K.D.; Jönbrink, A.-K.; et al. Developing a circular strategies framework for manufacturing companies to support circular economy-oriented innovation. *J. Clean. Prod.* **2019**, *241*, 118271. [CrossRef]
84. Kristensen, H.S.; Mosgaard, M.A. A review of micro level indicators for a circular economy—Moving away from the three dimensions of sustainability? *J. Clean. Prod.* **2020**, *243*, 118531. [CrossRef]
85. 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. *Manag. Environ. Qual. Int. J.* **2021**, *33*, 300–329. [CrossRef]
86. Ünal, E.; Shao, J. A taxonomy of circular economy implementation strategies for manufacturing firms: Analysis of 391 cradle-to-cradle products. *J. Clean. Prod.* **2018**, *212*, 754–765. [CrossRef]
87. Mestre, A.; Cooper, T. Circular Product Design. A Multiple Loops Life Cycle Design Approach for the Circular Economy. *Des. J.* **2017**, *20*, S1620–S1635. [CrossRef]
88. Prieto-Sandoval, V.; Jaca, C.; Santos, J.; Baumgartner, R.J.; Ormazabal, M. Key strategies, resources, and capabilities for implementing circular economy in industrial small and medium enterprises. *Corp. Soc. Responsib. Environ. Manag.* **2019**, *26*, 1473–1484. [CrossRef]
89. Kalmykova, Y.; Sadagopan, M.; Rosado, L. Circular economy—From review of theories and practices to development of implementation tools. *Resour. Conserv. Recycl.* **2018**, *135*, 190–201. [CrossRef]
90. White, P.; Pierre, L.S.; Belletire, S. *Okala Practitioner: Integrating Ecological Design*; IDSA: Phoenix, AZ, USA, 2015.
91. Guiot, D.; Roux, D. A Second-Hand Shoppers' Motivation Scale: Antecedents, Consequences, and Implications for Retailers. *J. Retail.* **2010**, *86*, 355–371. [CrossRef]
92. Shafiee, M.; Chukova, S. Optimal upgrade strategy, warranty policy and sale price for second-hand products. *Appl. Stoch. Model. Bus. Ind.* **2012**, *29*, 157–169. [CrossRef]

93. Connor-Crabb, A.; Miller, K.; Chapman, J. Design Strategies for the Eternal Reoccurrence of the New. *Fash. Pr.* **2016**, *8*, 22–43. [CrossRef]
94. Wallner, T.S.; Magnier, L.; Mugge, R. An Exploration of the Value of Timeless Design Styles for the Consumer Acceptance of Refurbished Products. *Sustainability* **2020**, *12*, 1213. [CrossRef]
95. Vezzoli, C.A.; Manzini, E. *Design for Environmental Sustainability*, 1st ed.; Springer: Berlin, Germany; London, UK, 2020.
96. Keoleian, G.A.; Menerey, D. Sustainable Development by Design: Review of Life Cycle Design and Related Approaches. *Air Waste* **1994**, *44*, 645–668. [CrossRef]
97. Rattalino, F. Circular advantage anyone? Sustainability-driven innovation and circularity at Patagonia, Inc. *Thunderbird Int. Bus. Rev.* **2017**, *60*, 747–755. [CrossRef]
98. Michel, G.M.; Feori, M.; Damhorst, M.L.; Lee, Y.-A.; Niehm, L.S. Stories We Wear: Promoting Sustainability Practices with the Case of Patagonia. *Fam. Consum. Sci. Res. J.* **2019**, *48*, 165–180. Available online: https://doi.org/10.1111/fcsr.12340 (accessed on 15 February 2021). [CrossRef]
99. Madrigal, G. Patagonia Rethread: Creating a Retail Recycling Program for Post-Consumer Clothing. June 2020. Available online: http://dspace.calstate.edu/handle/10211.3/216835 (accessed on 15 February 2021).
100. Dijkstra-Hellinga, A. Bugaboo Circular Experience. Innoboost. Video. Available online: https://www.youtube.com/watch?v=TWgAn-0S198 (accessed on 7 January 2021).
101. Sumter, D.X.; Bakker, C.A.; Balkenende, A.R. The role of product design in creating circular business models: A case study on lease and refurbishment of baby strollers. *Sustainability* **2018**, *10*, 2415. [CrossRef]
102. Grace, R. In the Crosshairs: Single-Use, Disposable Packaging: New Loop Circular Platform Promotes Reusable Consumer Product Packaging. *Plast. Eng.* **2018**, *75*, 18–23. [CrossRef]
103. Makower, J. Loop's Launch Brings Reusable Packaging to the World's Biggest Brands, Greenbiz. 2019. Available online: https://www.greenbiz.com/article/loops-launch-brings-reusable-packaging-worlds-biggest-brands (accessed on 27 June 2022).
104. Mohan, A.M. P&G Designs 11 Refillable, Reusable Products and Packaging for Loop Shopping Platform. Packaging World. Available online: https://www.packworld.com/home/article/13295808/pg-designs-11-refillable-reusable-products-and-packaging-for-loop-shopping-platform (accessed on 9 February 2019).
105. Reuter, M.A.; Ballester, M.; van Schaik, A. Limits of the Circular Economy: Fairphone Modular Design Pushing the Limits. *World Metall.-Erzmetall* **2018**, *2*, 68–79.
106. Fairphone—Press Release for Immediate Release; Amsterdam, The Netherlands, 27 August 2019. Available online: https://www.fairphone.com/wp-content/uploads/2021/03/FP3FP3.pdf (accessed on 27 June 2022).