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Research article

How circular is current design practice? Investigating perspectives across industrial design and architecture in the transition towards a circular economy

Giliam Dokter*, Liane Thuvander, Ulrike Rahe

Department of Architecture and Civil Engineering, Chalmers University of Technology, Göteborg, Sweden

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ABSTRACT

The transition to a circular economy (CE) produces a range of new challenges for designers and requires specific knowledge, strategies, and methods. To date, most studies regarding design for a CE have been theoretical and conceptual, hence, limited research has been conducted on the practical implications of designing for a CE. Therefore, the aim of this study is to provide a better understanding of how design practitioners interpret and implement the CE concept in practice. To capture the complexity of real-world cases, semi-structured interviews were carried out with design practitioners ($N = 12$) within the disciplines of architecture and industrial design who have actively worked with circularity in a design agency setting. The results show that the practitioners have diverse perspectives on designing for a CE, relating to (1) the circular design process, (2) the effects of the CE on design agencies, (3) the changing role of the designer, and (4) the external factors affecting circular design in practice. Some differences were identified between the architects and industrial designers, with the industrial designers more strongly focused on circular business models and the architects on the reuse of materials on a building level. In addition, circular strategies and associated (similar) terminologies were understood and applied in fundamentally different ways. As the CE blurs boundaries of scale and disciplines, there is a need for universal design frameworks and language. The CE concept is expanding the scope of the design process and driving the integration of new knowledge fields and skills in the design process. The successful implementation of the CE in practice is based on extensive collaboration with stakeholders and experts throughout all stages of the design process. Design agencies have addressed the CE by establishing dedicated CE research and design teams, facilitating knowledge exchange, developing their own circular strategies and methods, and striving for long-term client relationships that foster the engagement of designers with the lifecycles of designed artefacts rather than perceiving design projects as temporary endeavors. Ultimately, a holistic and integral approach towards design in a CE is needed to ensure that the underlying CE goals of contributing to sustainable development and establishing a systemic shift are ongoingly considered.

1. Introduction

Moving away from the current linear economy, which follows a take-make-use-dispose principle, towards a circular economy (CE) is considered to be a solution that will minimize pressure on the environment to an increasing extent. In a CE, economic growth is decoupled from resource consumption and the notion of waste is eliminated by maintaining products, components, and materials at their highest utilities and values (Ellen MacArthur Foundation, 2013). In recent years, the concept of a CE has gained widespread attention in academic institutions and significant traction within policy and business perspectives. Major companies such as IKEA, Philips and H&M have adopted ambitious CE agendas to strengthen their commitment to sustainable development. On an EU level, the Circular Economy Action Plan proposed by the European Commission (European Commission, 2020a) aims to further the realization of the CE, and many EU member states have adopted a variety of implementation strategies. Recent plans presented in light of the COVID-19 crisis consider investing in the CE as a way to create 700,000 new jobs by 2030 and strengthen European supply chains (European Commission, 2020b). Despite these pro-active measures, thus far the realization of a CE in practice has been rather limited and still appears to be in its early stages (Ghisellini et al., 2016; McDowall et al., 2017). Some researchers

* Correspondence.
E-mail address: dokter@chalmers.se (G. Dokter).

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have explained the limited progress in the CE transition by pointing to technical barriers such as the incorrect design of products (Pheifer, 2017), while other scholars have suggested that the major barriers to a CE in the EU are not of a technical nature but are attributable to hesitant company cultures, a lack of consumer interest and awareness, and a limited willingness to collaborate within the value chain (Kirchherr et al., 2018). Furthermore, the CE is still subject to conceptual and terminological unclarity and debate, which are unlikely to aid its implementation. The CE has been referred to as a "catch-all" philosophy (Whalen et al., 2018), which consists of a multitude of different definitions (Kirchherr et al., 2017; Korhonen et al., 2018b) and is interpreted in different ways by different actors (Blomsma and Brennan, 2017). However, many scholars agree that the CE necessitates a systemic view on resources and their lifecycles (Ghisellini et al., 2016; Iacovidou et al., 2017; Reike et al., 2018) and a fundamental systemic change rather than "a bit of twisting of the status quo" (Kirchherr et al., 2017).

In both academic institutions and politics, there is consensus about the importance of design to the CE. It is considered to play a crucial role in the CE transition (De los Rios et al., 2017) and it has been claimed, for example, that 80% of the environmental impact of products is determined within the design phase (European Commission, 2014). As a consequence, the potential of the CE to tackle environmental challenges particularly in the design of consumer products and the built environment is considered to be significant (European Commission, 2020a). However, to fulfill the potential that the CE offers, a systemic change is also needed in the way products, services, systems, and infrastructures are designed (Moreno et al., 2016).

For designers such as industrial designers and architects, this change imposes a range of new challenges and requires novel approaches. To develop products, buildings, and services that function within closed-loop resource flows, the entire lifecycle including the design, production, use, and waste phases needs to be addressed in a simultaneous and coherent way. This requires designers to assume a holistic and systematic approach to problem solving, focusing to a much greater extent on temporal aspects (Sumter et al., 2018) and anticipating how a building or product might function and change over time, for example.

Different methods, tools, and frameworks have been developed to support circular design, and the changing roles, competencies, and skills required of designers in a CE have also been investigated (Andrews, 2020; Bocken et al., 2016; De los Rios et al., 2017; den Hollander et al., 2017; Mestre and Cooper, 2017; Moreno et al., 2016; Sumter et al., 2018; Wastling et al., 2018). However, most of the studies have been theoretical and conceptual, and little empirical investigation into circular design has been conducted. There is a lack of knowledge on how the concept of circularity is implemented in practice by design practitioners, especially case-based evidence in which both the design and business contexts are considered. It is apparent that the CE requires a systemic shift, but it is not clear to what extent this is understood within design practice.

Therefore, the primary aim of this paper is to provide a better understanding of *how design practitioners interpret and implement the concept of a CE in practice*. Additionally, we aim to gather insights into how the role of the designer might be changing and how the design industry as such is adapting to accommodate CE principles. To gather insights that capture the complexity of real-world cases, we conducted a range of interviews with selected design practitioners who have been involved in CE-related design projects. The study investigates two types of design practitioners: namely, industrial designers and architects and explores how the CE is addressed in these individual disciplines along with a discussion of the potential similarities and differences between the disciplines. Different design disciplines, such as architecture and industrial design, may demonstrate significant differences in relation to skills, scale, materiality, lifecycle perspectives, business contexts, and regulatory constraints. Nevertheless, the aim of closing resource loops and decoupling economic growth from resource consumption is shared between disciplines. Investigating advancements and foci across design disciplines may provide insights into the overall development of design practices in relation to the CE and opportunities to compare and share knowledge and strategies.

Accordingly, the paper is structured as follows. After providing a literature review that contextualizes this research (Section 2), the utilized method is explained (Section 3). The results of this study are then presented (Section 4), and we discuss our findings and contributions in further detail (Section 5). Finally, we summarize our work in the conclusions (Section 6).

2. Literature review

2.1 Introduction to the circular economy concept

The CE is an umbrella concept (Blomsma and Brennan, 2017; Homrich et al., 2018) that encapsulates a set of resource value retention options (Reike et al., 2018) and synthesizes principles for closing material and energy loops originating from (Benyus, 1997; Boulding, 1966; Braungart and McDonough, 2002; Lyle, 1994; Pauli, 2010; Stahel, 1982). The CE as a concept can be challenging to grasp as it has its roots in various scientific fields and is subject to different interpretations and definitions that co-exist within industry and academia (Blomsma and Brennan, 2017). Some scholars have argued that it is nearly impossible to capture the concept in a single universal definition (Korhonen et al., 2018a), while others have adopted a broader definition of the concept that includes its relationship with the three dimensions of sustainable development (Kirchherr et al., 2017). The CE has the potential to facilitate the achievement of various sustainable development targets (Schroeder et al., 2019), albeit the conceptual relationship between a CE and sustainability is not always clear (D'Amato et al., 2017; Moreau et al., 2017). The unique property of the CE is that it combines the interconnected ideas of a closed-loop economy with a "restorative" design approach (Murray et al., 2017). This approach aims to "design out waste" by keeping products, components, and materials at their highest utility and value at all times (Webster, 2015), which can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, and recycling (Geissdoerfer et al., 2017). A core principle of the CE is that the encapsulated resource value retention options are ordered within a hierarchy based on the extent to which they retain the value of the resources, which are conceptualized in various R hierarchies from the 3Rs (reduce, reuse, recycling) up to the 10Rs (Reike et al., 2018).

2.2 From design for sustainability to design for circularity

Sustainability in the field of design is a widely studied subject and well-established domain. Since the middle of the twentieth century, seminal design thinkers such as Buckminster Fuller and Viktor Papanek have raised awareness of aspects of sustainability in the design professions (Fuller, 1969; Papanek, 1972). In 2016, Ceschin and Gaziulusoy presented a comprehensive review of the historical development of the Design for Sustainability (DfS) field and richly illustrated how the scope of design has expanded, entailing "a shift from insular to system design innovation" (p.145) (Ceschin and Gaziulusoy, 2016). Design approaches have progressively expanded their focus from initially addressing sustainability in isolation (a single actor striving to e.g., improve recyclability and product efficiency) to systemic approaches such as product-service systems (PSS) for sustainability, which involve a large degree of complexity and require a variety of actors. The expanding scope of design represents a larger shift in the role of designers, moving from object-centric thinking to a more system-based design approach (Gaziulusoy and Brezet, 2015; Manzini and Vezzoli, 2003), which challenges designers to perform strategic roles to an increasing extent (Bakker, 1995; Joore and Brezet, 2015; Sumter et al., 2018). For example, activities such as establishing future visions (Banerjee, 2008) and facilitating strategic dialogs between actors and co-design processes (Meroni, 2008) have been attributed to the enhanced roles of the design professions. Accordingly, the role of the designer has become progressively more entangled with the roles of other actors (Joore and Brezet, 2015).

In the context of the CE, it is apparent that various DfS approaches (e.g., cradle-to-cradle, bio-mimicry, ecodesign) are instrumental for design practice (Ceschin and Gaziulusoy, 2016). Some DfS approaches have been criticized for their failure to consider social dimensions, and the same critique has been made of the CE. On a conceptual level, the CE has been criticized for assuming a solely “technological fix” approach and neglecting relevant social factors such as challenging consumption behavior and sufficiency-oriented lifestyles (Schulz et al., 2019). However, within design research, the recent literature shows that considerable efforts are being made to address the social implications and human-centered factors of a CE (Lofthouse and Prendeville, 2018; Mugge, 2018; Poppelaars et al., 2018; Selvefors et al., 2019; Van Weelden et al., 2016; Wastling et al., 2018).

An important distinction has to be made between sustainable development from the perspective of the current linear economy and of the CE. Sustainable development from a linear perspective may emphasize waste reduction, recycling, and the reduction of pollution (Sauvé et al., 2016). The CE, conversely, does not strive to optimize what is already there but rather to rethink the system starting from the notion of a “closed loop” of resources that avoids the generation of waste. This assumption of an ideal state can be considered utopian (Cullen, 2017; Schröder et al., 2019), but in the context of design, it focuses attention on the following question: “how can designers generate truly sustainable or circular innovations if the current methods only lead them to optimize what is already there?” (p.518) (den Hollander et al., 2017).

The CE, thus, presents specific challenges for designers such as, for example, thinking in terms of multiple lifecycles (Franconi, 2020; Mestre and Cooper, 2017), anticipating the reality of an alternative economy (Andrews, 2015), adopting a deeper understanding of materials (De los Rios et al., 2017), the concurrent development of the product design and business model (Sumter et al., 2018), and assuming a systemic view on resources and their lifecycles. The shift to a CE challenges designers, especially with regard to the cultural barriers that hinder the adoption of circular practices (Kirchherr et al., 2018), to take on the roles of solution providers rather than object creators (Moreno et al., 2016) and to develop trans-disciplinary skills and understanding (Charnley et al., 2011). Various scholars have highlighted the need for systems thinking in design practice and education in the context of design for a CE (De los Rios et al., 2017; Moreno et al., 2016; Whalen et al., 2018). Systems thinking has long been discussed in the business (Murray et al., 2017) and design literature (e.g.(Charnley et al., 2011)); yet, little is known about how such approaches are actually adopted within design practice. Accordingly, Charnley et al. note that “designers have been provided with little guidance as to how these techniques should be implemented efficiently within an operational and substantially complex design process” (p.157).

2.3 Circular design of products and the built environment

The implementation of the CE and, thus, the design of artefacts, occurs on different scales of implementation. One guiding taxonomy for these scales can be defined as micro level (products, components), meso level (buildings and eco-industrial parks) and macro level (cities, built environment) (Ghisellini et al., 2016; Kirchherr et al., 2017; Pomponi and Moncaster, 2017). Although this taxonomy is still subject to inconsistencies and ambiguities regarding its definitions (Moraga et al., 2019), it can be considered a structured and helpful classification in the discussion of design in the context of the CE. Adopting a holistic design approach towards the system and lifecycles of artefacts invites designers to consider multiple levels, such as the interaction between products and the built environment (e.g., considering the facilities as well as the services that enable the maintenance and repair of products). One of the frameworks that accommodates such a multi-level design approach is the one proposed by Joore and Brezet (Joore and Brezet, 2015), although it does not specifically consider the context of a CE. Since this research investigates the perspective of industrial designers and architects, we more specifically focus on the micro- and meso-level scales.

To support circular product design, a range of methods, tools, and frameworks have been developed by academics (e.g., (Bocken et al., 2016; den Hollander, 2018; Franconi, 2020; Mestre and Cooper, 2017; Moreno et al., 2016; Nußholz, 2018; Van Dam et al., 2017)), and some tools have been introduced in practice (Ellen MacArthur Foundation, 2017) or in the gray literature (Bakker et al., 2015). Moreno et al. proposed a conceptual design framework including various Design for Excellence (DfX) strategies that are able to contribute to designing for a CE (Moreno et al., 2016). Bocken et al. proposed a design framework by defining the terminologies of slowing, closing, and narrowing resource loops and providing an overview of design and business model strategies that can be utilized to enable circularity (Bocken et al., 2016). Den Hollander presented a design methodology for managing obsolescence, including different methods that enable industrial designers to tailor product designs to circular business models, preserve product integrity, and maximize circularity (den Hollander, 2018).

At this point, it is also relevant to discuss the advancements that have occurred regarding the CE in the built environment and construction sector, especially from the perspective of design. Thus far, CE practices in the built environment have been prominently centered around waste management and the minimization and reuse of construction and demolition waste (Joensuu et al., 2020; Munaro et al., 2020). A variety of design approaches such as adaptive reuse, design-for-disassembly (DfD), and design for repair and remanufacturing are discussed as viable options to increase the service life of buildings and promote CE practices in the built environment (Benachio et al., 2020; European Commission, 2020c; Hopkinson et al., 2020; Joensuu et al., 2020; Minunno et al., 2020; Ness and Xing, 2017; Pomponi et al., 2018). In addition, the adoption of structural components from renewable materials such as mass timber products has been discussed (Campbell, 2018). Joensuu et al. have highlighted that PSS practices could extend the service life and promote the efficient use of buildings, which would avoid resource consumption by limiting the growth of building stock (Joensuu et al., 2020).

To support the design of a circular built environment, several frameworks have been developed, for example, for the design of building components (van Stijn and Gruis, 2019) and buildings (Cambier et al., 2020; Geldermans, 2016). Other studies have also identified specific barriers to and enablers of the CE in the construction industry. Some of the main barriers discussed are the lack of a collaborative and holistic approach in the supply chain and the financial feasibility of circular models (Adams et al., 2017; Hart et al., 2019). Adams et al. emphasized the “silo” approach that exists in different stages of development and across a building’s lifecycle and pointed out the need for collaboration and systems thinking. Pomponi and Moncaster described a research framework for a CE in the built environment spanning six dimensions (governmental, economic, environmental, behavioral, societal and technological), which encourages an interdisciplinary approach towards research, and emphasizes that the greatest challenge for the CE is related to social and behavioral factors (Pomponi and Moncaster, 2017). Nonetheless, based upon the reviewed literature, it appears that there have been few empirical investigations into the practices and perspectives of architects and industrial designers, particularly in the context of the transition to a CE.

2.4 The role of designers and architects in a circular economy

The implications of the CE for design practice and the role of designers in the context of product design and the built environment have been investigated to some extent. On a product-design level, Rios et al. have emphasized the need for designers to develop deep material knowledge, proficiency in service design, and a richer understanding of social behavior. The same authors emphasized that depending upon the business-market-technology context, different designers or "design personas" might be needed (De los Rios et al., 2017). Sumter et al. investigated the changing role of designers and highlighted specific skills and competencies such as anticipating future use cycles of products, assessing environmental impacts, collaborating more extensively with stakeholders, and CE storytelling, that is, being able to engage and convince internal and external stakeholders of the meaning and value of the CE (Sumter et al., 2020). Kanters discussed the limited examples of circular design on a building scale and emphasized the increased level of complexity involved in buildings compared to products, especially regarding ownership and the number of actors involved in the design of buildings. In this regard, architects can play a pivotal role in the transition to a CE by linking different actors, but they require deeper material knowledge and leadership skills to fulfill this role (Kanters, 2020). Kozminska et al. investigated the circular design process in architecture through a set of case studies and argued that the circular design process differs significantly from the standard design approach. Interdisciplinary collaboration with experts is needed within the process, and the design process should encompass the lifecycle of the materials in order to consider and define future methods of maintenance, disassembly, and the reuse of building materials (Kozminska, 2019). To our knowledge, there have been no studies that address the roles of both architects and industrial designers in the CE.

2.5 The importance of collaboration in a circular economy

Lastly, the CE requires entire systems to be designed, which are dependent upon numerous stakeholders (Pedersen and Clausen, 2019). This requires active collaboration between all the stakeholders in the supply chain (Leising et al., 2018). Previous studies have indicated that a limited willingness within the value chain to collaborate is one of the barriers to a CE (Kirchherr et al., 2018).

Several scholars have discussed the importance of collaboration in the design process and the changing role of designers in the context of the CE. Pedersen and Clausen indicated how traditional design thinking tends to fall short within complex systems involving different stakeholders and emphasized the role of designers as "orchestrators" who use co-creation strategies and prototypes as knowledge objects to stage negotiations between stakeholders and (re) align their values (Pedersen and Clausen, 2019). In this case, the designer acts as the connector and facilitator (Manzini, 2009) who stages connections between the actors and creates a space for circular innovation. Ordonez and Rahe investigated the collaboration between designers and waste management in the effort to close material loops (Ordoñez and Rahe, 2013). Leising et al. investigated collaboration in the built environment and developed a collaboration tool to promote supply chain collaboration from the design stage to the end-of-life of buildings (Leising et al., 2018).

Accordingly, the transition to a CE will not succeed if companies attempt to overcome barriers individually; rather, they will need to establish new ways of working, new business partners, new roles for existing partners, and new kinds of collaborations between stakeholders (Aminoff et al., 2016). Therefore, the success of design projects that focus on circularity relies to a great extent on establishing constructive collaborative networks within the value chain that facilitate the closing of resource loops. This also raises the question of the role of designers in facilitating connections and collaboration between stakeholders, and how this is approached within the design process. In addition, it raises the crucial issue of how collaborations can be maintained and enhanced during and after the lifecycle of products, buildings, components, and materials. As to close the loop, design and optimization that address the end of use cycles and end-of-life scenarios become ever more important. To date, there is little knowledge concerning how collaboration in support of a CE is approached in the design process and to what extent designers can influence collaboration.

3. Methods

3.1 Research approach

We focused on gathering in-depth insights from design practitioners who have experience of participating in design projects that have had circularity as a particular focus or theme. This enabled us to gather case-based evidence of the current status of design practice for a CE. Through inquiring into the complexity of real-world cases, a rich understanding can be gained about the important factors that play a role in CE-related design projects. Considering the aforementioned needs and that the underlying aim was to investigate how certain phenomena occur, a qualitative approach was considered suitable. Qualitative data can provide rich insights into human behavior, which cannot be understood without reference to the meanings and purposes attached by human actors to their activities (Guba and Lincoln, 1994).

The empirical data were collected primarily in the form of interviews, to learn the participants' terminology and judgements and capture the complexities of their individual perceptions and experiences (Patton, 2002). The data were complemented with information about the design projects discussed during the interviews, which had been retrieved from the companies' websites. The use of semi-structured interviews allowed us to explore certain topics in depth and remain open to more detailed responses, which was considered to be beneficial given the explorative nature of this study and the fact that limited investigation into state-of-the-art practices surrounding circular design has been undertaken to date.

3.2 Participant selection

The interview participants were selected based upon the following prerequisites: a) the participant has been part of design projects with an explicit focus on circularity, and/or b) the participant operates or is engaged in an organization with an explicit focus on design for a CE, c) a balance of architects and industrial designers is represented and d) differently sized companies are included. We concentrated on recruiting participants from design and architecture consultancies, as these typically execute a variety of design projects from beginning to end for different clients, which enabled the participants to refer to their diverse experiences

Table 1
Overview of interview participants. Company size (employees): Micro (1-9), Small (10-49), Medium (50-249) and Large (250+). Role description: A (Architects) and ID (Industrial Designers).

#	Role	Organization type	Company size	Location	Experience (years)	Rationale for involvement
1	A	Architectural firm	Large	Sweden	10	Development manager circularity in firm's research lab
2	A	Architectural firm	Large	Sweden	14	Interior architect responsible for public building with circular interior. Case nominated for international design award
	A				34	Developed methods for circular interior projects in research project focusing on circular furniture flows
3	A	Architectural firm	Medium	Denmark	11	Head of research consultancy specializing in circular design
4	A	Architectural firm	Medium	Denmark	8	Part of project group in large-scale architectural project researching circular construction featuring 60+ value chain actors
5	A	Architectural firm	Micro	The Netherlands	12	Founder of firm with core focus on circular architecture
6	A	Design studio	Micro	Sweden	17	Founder of design studio with core focus on circular interiors
7	A	Circular start-up	Micro	The Netherlands	9	Founder of a start-up specializing in designing circular furniture and prefabricated products for construction
8	ID	Design company	Large	United States	26	Executive design director involved in the development of a circular design tool. Public speaker on circular design
9	ID	Design consultancy	Medium	Sweden	5	Involved in project developing a circular product and business model. Consultancy with sustainability/circularity as core service
10	ID	Design consultancy	Small	The Netherlands	33	Partner in consultancy with sustainable design/circularity as focus area
11	ID	Design studio	Micro	Sweden	33	Founder of studio with core focus on sustainability and upcycling. Nominated for several awards for upcycled design. Public speaker on upcycling
12	ID	Design studio	Micro	Sweden	16	Designed furniture with focus on circularity for international furniture brand. Won several internationally recognized design awards

in multiple cases. We sought differently sized companies to establish a broad perspective, and we found that some of the organizations that specialize in design for a CE tend to be relatively new and, therefore, of small size or in the start-up phase. Nevertheless, start-ups in particular can be interesting subjects of study as CE innovation is often first seen in new entrants rather than incumbent firms (Henry et al., 2019). Furthermore, to gather insights on circular design, it is helpful if the participants are aware and actively engaged with the topic of the CE. Certainly, there are many design consultancies producing work that addresses certain aspects of circularity without highlighting this as a particular focal point of their firms. In this study, however, we focused on organizations that explicitly state that they work with circularity or displayed cases in which circularity has been a specific focus.

For the selection of the participants, the geographical focus was upon the EU, which was considered relevant due to the ambitious CE policies that emphasize the role of design in such an economy (e.g., (European Commission, 2020a)). The scope was further narrowed to the Netherlands, Denmark, and Sweden because the authors have an established professional network in these countries, which have all adopted ambitious national strategies for a CE with a strong focus on design. An initial list of design practitioners was established using internet search engines to identify design companies that stated they either had circularity as a focus area or showcased design projects related to the CE. Twenty-nine design practitioners were contacted by email, which resulted in a total of 12 interviews. Table 1 provides an overview of the interview participants, including the size, type, and location of their organizations; the years of experience they have in the field of design; and the rationale for selecting the participant. The participants were situated in the Netherlands, Denmark, and Sweden. One participant was stationed in the United States but is active in the European context and is originally from Germany.

3.3 Data collection

A total of 12 interviews were conducted between January 2020 and July 2020, which lasted between 60 and 96 minutes. The interviews were conducted face-to-face ($n = 2$) and digitally through the communication tools Zoom ($n = 9$) and Skype ($n = 1$). All the

Table 2
An overview of interview sample questions

General	Can you describe how you work with the CE in your company? What type of activities and projects do you undertake that are related to the CE? What do you think is needed to support the wider implementation of the CE?
Project-specific	Can you recall a project that you consider has been successful in terms of circularity? Please elaborate on the key factors in the project that were important to its success. What was your approach to developing the circular solution? Did the project require new roles for the stakeholders and new types of collaboration? What role(s) did the designer/architect play in this project? What role did collaboration with the stakeholders play before, during, and after the design process? To what extent are you as a designer/architect/company involved during the life and use cycles of the products that you design? Can you recall design projects regarding circularity that have been less successful? What were the factors that made them more difficult? What in your experience so far do you see as the most significant barriers to designing solutions for a CE?
Design-specific	To what extent did your/the company's design process change to be able to work with and implement circularity? For example, lifecycles, materials, and end-of-life scenarios? Have you/the company acquired specific new knowledge or skills that enable you to better design for a CE? Please elaborate further, and how did you acquire this knowledge? What types of new knowledge and tools do you think are needed for designers to successfully design circular solutions? What do you see as the role of designers in supporting the transition to a CE?

interviews were conducted in English and the audio was digitally recorded with permission from the participants and subsequently transcribed. Interview 2 was conducted with two participants who are colleagues and had collaborated on the discussed projects. An interview guide was developed for the interviews covering general, project- and design-specific topics; see Table 2 for an overview of sample questions. Data from the interviews were complemented with written notes, and additional information regarding the discussed cases was gathered from the companies' websites.

3.4 Data analysis

As limited investigations have been conducted on how CE principles are translated into the practices of designers, the analysis procedure followed an inductive approach to support the uncovering of new concepts. Approaching fieldwork without being constrained by predetermined categories of analysis contributes to the depth, openness and details of qualitative inquiry (Patton, 2002).

To enhance the qualitative rigor, the analytical process was based upon the methodology developed by Gioia et al. (Gioia et al., 2013). The interview data were analyzed using NVivo software (Release 1.2 and 1.3). A first-order analysis was performed using informant-centric terms and codes and searching for emergent themes with little focus on establishing categories. This resulted in a total of 300+ first-order codes. Next, we searched for relationships between the first-order codes and assembled the emergent themes into a list of 21 second-order themes. During this process, several iterations took place with discussions between the authors regarding the definition and clustering of the themes. Finally, we further categorized the second-order themes into four aggregate dimensions. An overview of the final coding scheme is presented in Fig. 1.

4. Results

This section presents the results from the interviews, and it is structured according to the aggregated dimensions defined in Fig. 1. In addition to following the themes, we distinguish general findings regarding designing for a CE but also highlight the differences that we found existed between the fields of architecture and industrial design.

4.1 The circular design process

4.1.1 Increased complexity in the design process

Both the interviewed architects and industrial designers discussed past and ongoing design projects in which the CE was a focal point and highlighted how the design process has adapted to address the specific challenges that arise when designing for a CE. Although some of the participants considered that the design process was not necessarily different from their established process or past projects that were not focused upon circularity, most of the participants agreed that the design process does become more complex and that the focus on circularity extends the length, costs, and overall scope of design projects. The participants explained that CE-related design projects require a more extensive knowledge of materials, biology, ecology, environmental impact assessments, stakeholder management and the structure of business models, and supply and value chains. The practitioners addressed this by engaging themselves with different disciplines, as well as consulting and including different experts early on in the design process. Designing a circular solution that strives for a closed loop of resources typically requires more stakeholders than usual to be involved in the design process, and their individual demands also need to be managed. Environmental impacts need to be calculated over the entire (or multiple) lifecycle(s), and a more extensive research phase is required to understand the system of which a product or building is a part, including the supply and value chains. All these factors typically lead to a design process with more iterations and feedback loops, which is generally "longer."

4.1.2 The use of data in the design process

The interviews indicated that the design process becomes more data-oriented in a CE context to be able to assess the environmental impacts and enable the tracking of materials and the lifecycle(s) of artefacts. Tracking the materials and the performance of the artefacts was considered by both the architects and industrial designers as a way to better understand the lifecycles of products and buildings and enable interventions that might further support the slowing and closing of resource loops. Participant 4 explained how data solutions such as material passports and digital twins can be utilized to supply information in the future about the structural integrity and materials of a building, which will further enable the feasibility of DfD strategies as information can be embedded in relation to, for example, materials, components, and intended disassembly steps. Participant 8 explained that their company has invested heavily in data analytics as a design tool and described how they can be used to analyze what value a product provides to the user over different stages of its lifespan and how such insights can be utilized to improve the design of products.

4.1.3 Design process of architects

Based on the discussed cases and design strategies utilized for a CE, the focus of the architects to date seems to be on the reuse of existing (waste) materials for the design of new buildings and structures, thus, limiting the use of new resources and reducing the overall environmental footprint of the construction. This design process takes materials as a starting point and typically begins with an "inventory" process in which building waste, secondary raw materials, and leftover building components that can be used in the design are identified, mapped, and collected. Doing so requires a level of flexibility and equivocality to be adopted within the design process, as it is not clear what components and materials will be found. This was illustrated by one of the architects (Participant 3), who stated, "You have to design somehow more conceptually. Because you doń t know if you'll get a window that is 60 or 70 or whatever width." The participants discussed to a lesser extent the design strategies that extend the lifecycles of new buildings and enable the future reuse of components and materials. For example, how a building and its components can be designed to support maintenance and repair practices and facilitate a future disassembly that allows materials to be reused in the lifecycle of another building. One of the architects (Participant 5) described a project, the design of a bike shed, that was supposed to be constructed from waste materials. Ultimately, however, the client did not want to take the risk of incorporating these materials into the design due to potential issues with guarantees. This led to a redesign in which the shed was instead made from renewable materials and could be disassembled. However, the design was no longer described as "circular." The architect noted, "In a way you can take it all apart so it's still circular, but we don't call it that." Another example was provided by Participant 6, who was involved in the interior design of a public building in which there was a focus on circularity through the strategies of reused furniture and building materials. The project was regarded as successful in achieving circularity, with a high percentage of the incorporated furniture being reused furniture, yet the architect still considers that this was a linear process. To make this process circular and "to connect the dots," as the architect explained, it would require the architect or another party to remain involved with the building, perform a "follow-up," and facilitate maintenance when

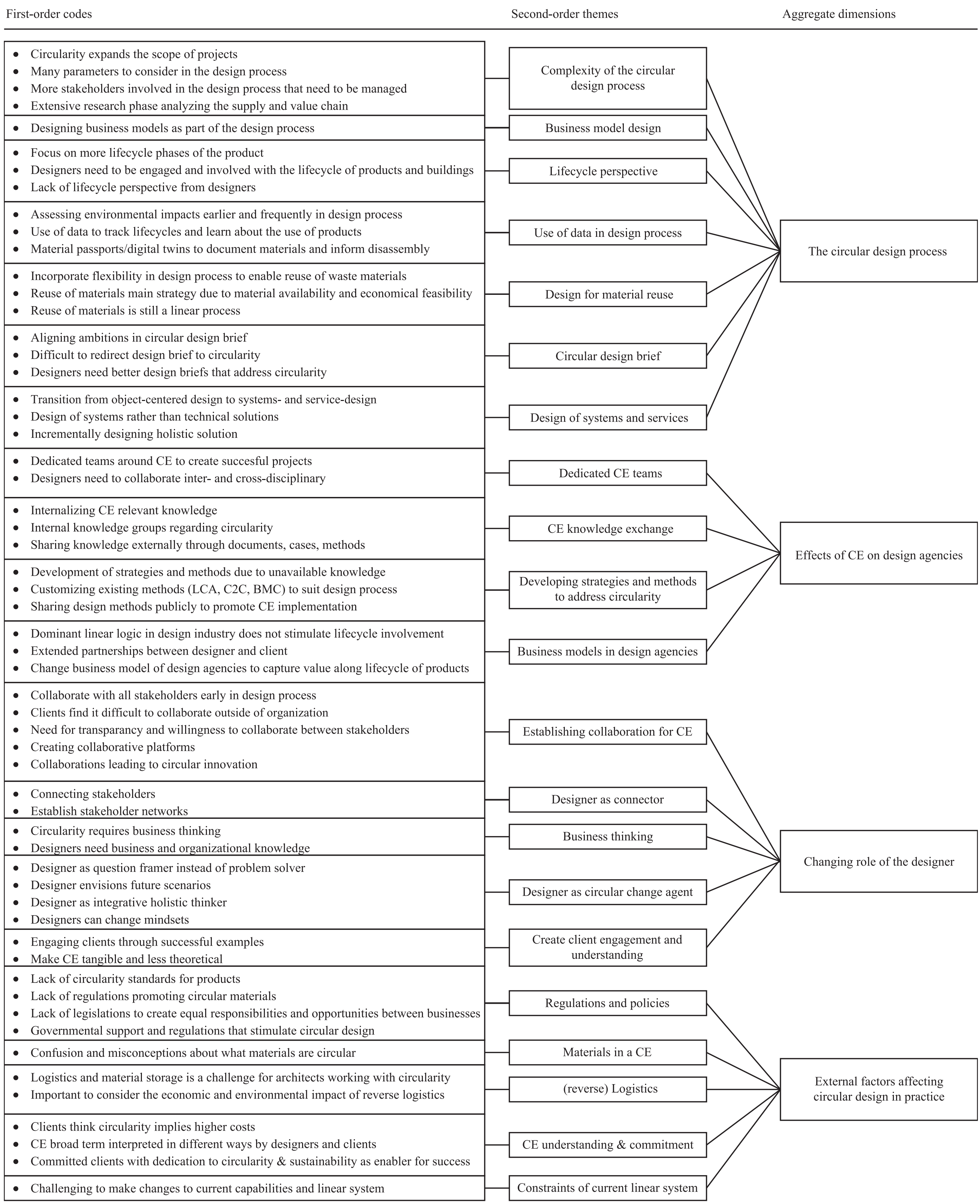

Fig. 1. Overview of the coding scheme.

needed to ensure, for example, the long-lasting lifespan of the interior. Participant 3 described how in the current CE discourse regarding the built environment it feels as though there are two separate approaches, with the "linear" architects upcycling materials, while the other approach focuses on DfD. However, the participant stressed that both approaches are required and mentioned that "in my mind, circular construction will lead to a lot of recycling, so somehow it cannot be two different paths." Some architects mentioned remanufacturing and repurposing practices, for instance, using discarded building elements such as windows in a new building or using building elements for a new purpose, for example, old spiral ducts as façade cladding. The participants highlighted several reasons for the focus on reused materials; it is considered to be the easiest way to engage with circularity, it is always better for the environment to reuse old materials than to use new materials, and it can reduce costs.

However, the process of choosing a suitable design strategy is always contextual and fluid according to Participant 5, which was illustrated through an example: "For instance, this year insulation with sheep skin is really sustainable because it is leftover material. Next year, everybody knows that, and it is very popular, and all the sheep skin is sold out. And then they have to kill sheep to get the insulation material from their skin, and then it is not sustainable anymore." Participant 4 described how they usually define some focus areas related to the CE, for example, "minimizing operational waste" or "design for maximum adaptability" and make their decision based upon what will provide the most value for the project. This participant gave an example of a recent design project for a fish market in a major global city: "It is a lot of kiosks, small and large kiosks selling various types of fish and seafood, and restaurants. Huge market. There, we said that we should design it to be very flexible, modular, and designed for disassembly, simply because the tenancies will change, some will want to grow, some will shrink, some will go out…and that made sense to the client." Lastly, the architects highlighted the challenges related to "assessing circularity" in the design process, for example, estimating which design strategies or concepts will lead to the highest degree of circularity or estimating environmental impacts during the conceptual stages of the design process when there are often many different design concepts on the table.

4.1.4 Design process of industrial designers

The industrial designers who were interviewed indicated a transition from a previously object-centered design approach to a more system- and service-centered design approach, with a greater focus on how to meet the underlying demands of users and customers. The industrial designers talked more specifically about systems thinking and systems design, which were highlighted as important challenges in being able to consider the increasingly wide range of parameters in CE-related design projects. As one of the designers (Participant 8) explained, "you not only have to design the product; you have to design the system. The system entails production, branding, sales, delivery of the product, use of the product, and the after use of the product." One of the industrial designers (Participant 9) described an ongoing project in which each part of the solution is designed simultaneously and incrementally (in this case, the physical design, the business model, and a leasing platform). This is performed in multiple loops of gradual refinement rather than through a "waterfall" approach in which one part of the solution is developed at a time. Furthermore, the industrial designers mentioned that developing solutions for a CE relies on the coherent design of a product and a business model that enables companies to profit from closing material loops and also creates incentives for the return of products and material after use.

The projects described by the designers demonstrated a strong focus on the lifecycle of a product, how products are likely to perform and change over time, how lifecycles can be extended through various strategies, and what happens at the end-of-life stage. Some of the applied strategies that were discussed were making products modular and parts exchangeable to (1) facilitate recycle, refurbish, and repair practices; (2) enable take-back schemes; and (3) adapt to the demands and preferences of different users. Participant 11 mentioned the upcycling of materials to create new products, which is considered to be an inverse way of designing, as the functionality and specification of the design is based upon the size and quality of found materials, not vice versa. Participant 12 described how circularity can be achieved by creating long-lasting or "timeless" products of high aesthetic and structural quality that require limited refurbishing. However, the designer admitted that "it is a bit naive to think that's the case" as it is not for the designer to decide what is timeless.

4.2 Effects of the circular economy on design agencies

4.2.1 Dedicated circular teams

Both the interviewed architects and industrial designers identified the increasing importance of working inter- and cross-disciplinarily in design teams to be able to design solutions for a CE. Three of the participants (1, 4, 8), who are all part of the larger organizations included in this study, highlighted that their organizations have assembled dedicated teams or research laboratories to focus upon circular design. According to one of the industrial designers (Participant 8), the CE requires different types of designers to work together, for example, designers who specialize in data, digital environments, and research. One architect (Participant 4) explained how some of the required knowledge is acquired internally, and sometimes external experts are involved in the design process. A dedicated research laboratory has been established at the architectural agency to deal with circularity and the increasing complexity of the building sector. This participant provided the example that architects do not have to be "biologists"; however, to enhance biodiversity in the design of a building, a biologist might be involved in the design process at a certain point. Other knowledge is deliberately internalized, as the participant explained: "In terms of the lifecycle assessment, the reason that we want to have that in-house is that we see that it has very big effects on the material solutions that we choose, then we need to generate that knowledge fast, not wait one or two weeks for someone to get back to us and say something." Another architect (Participant 1) explained that when they sense a knowledge gap in a project, an internal research team enables them to perform their own research and explore the ideas for which the client is not prepared to pay.

Some of the interviewed architects highlighted the importance of exchanging knowledge about the CE internally within their individual organizations as well as externally with the industry. Participant 3 described how a "recycling group" was set up at the company to exchange knowledge and facilitate discussions about recycled materials, environmental challenges, and convincing clients. Some examples of external knowledge exchange provided by the participants were publications and lectures about past projects that described the knowledge gained and the circular strategies applied.

4.2.2 Business models in design agencies

One factor that was repeatedly mentioned in a majority of the interviews was that the current business model of design and architectural agencies is founded in a linear logic that does not encourage the engagement of designers in the lifecycles of the artefacts. This, in turn, hinders the potential for circularity. Designing products and buildings most often involves a short-term effort and engagement between the designer and the client, after which the "design is handed over." Agencies are paid in the form of an hourly fee or "a lump sum based on the building cost," as one of the interviewed architects explained (Participant 4). In either case, it is assumed that the work and the design at some point are considered complete and handed over to the client, at which point the involvement and collaboration ends or becomes minimal.

Both the architects and industrial designers identified a need for extended partnerships with clients and different revenue models that enable designers to follow and evaluate the lifecycle of their designed products and buildings, thereby, stimulating engagement with the artefacts even after the design is finished. One of the architects (Participant 4) noted that it would be beneficial to observe how a building changes over time and provided an example of an alternative model in which architects would be rewarded based on the performance of a building. The architect explained how "that would help us push for circularity, to see things as less static and less finished. Try to do contracts that can reflect that or pay for schemes that reflect that it is not finished. It is kind of a process."

One of the industrial designers (Participant 12), who works mostly with the furniture industry, explained how it would be beneficial for designers to be able to evaluate the products at several points during their lifecycles to observe how they wear and tear. However, given that the payment consists of royalties according to the number of pieces sold, the designer admitted that it "doesn't really help that I would want to push people into reusing my product" and mentioned that "I also have to make a living." Another industrial designer (Participant 10) described how there is value left at the end and all along the lifecycle of the product in circular business models and explained that the business model of their design consultancy should adapt to capture the value along the lifecycles of products and shift to a model where they are paid, for example, in shares or royalties or by different stakeholders in the process. However, this was also considered challenging, "because instead of just doing your design trick and getting paid, more and more you become an entrepreneur and you have to be involved in the circular business yourself and allow for that." According to Participant 8, who works for a large design consultancy, the business models within the design industry are changing. This company works with long-term partnerships spanning many years and aims to "make the design team a part of the network you are working with".

4.2.3 Developing strategies and methods to address circularity

The participants belonging to both the smaller and larger organizations described how they actively develop tools, methods, and documentation to support the design process and help to tackle the challenges related to a CE in design projects. Because the CE is a relatively new concept, the required knowledge is not always available and sometimes companies have to "reinvent the wheel" themselves. For example, during the early stages of the design process, feedback on the estimated impact of material and design choices is required to support the generation and optimization of design concepts. Existing methods to calculate impacts and evaluate lifecycles such as life cycle assessment (LCA) methods and cradle-to-cradle (C2C) certifications are considered too slow or not supportive during the design process.

Participant 7 described how they customize these methods to suit their own needs and explained how they develop their own methods. An example of this is a customized and summarized version of the business model canvas (Osterwalder and Pigneur, 2010) to support business model thinking, especially in the early stages of the conceptual design process and to summarize, present, and optimize the processes around a product. Participant 8 explained how their organization found there were limited concepts of ways to apply the CE theory in the industry, which led to their development of a design guide containing a range of different tools and methods that can be used across different stages in the design process. The guide has been made publicly available and supports the industry in applying the CE concept. Participant 2 described how their studio developed a circular design brief and project brief template to help practitioners include requirements related to circularity in the design brief and ask relevant questions when working on projects related to the CE. However, it seems to be primarily the larger organizations that have engaged in the development and distribution of methods and documentation to support the adoption of circular principles in design practice.

4.3 The changing role of the designer

4.3.1 Establishing collaborations for a circular economy

Both the interviewed industrial designers and architects mentioned the increased importance of collaboration in a CE and that stakeholders across the whole supply chain should be involved during multiple stages of the design process. The participants emphasized the importance of transparency and openness in projects that focus on circularity due to the uncertainty of the outcomes and because designing solutions for a CE require more extensive collaborations with, for example, material suppliers, waste management, environmental specialists, and biologists. Some of the architects mentioned that collaboration has always been essential for any design process, especially in the context of architecture in which building processes usually depend upon a large number of people and stakeholders. However, the scale and complexity increase in circular projects as (ideally) all the relevant stakeholders are included early on in the design process, which requires more extensive stakeholder management. One of the industrial designers (Participant 10) explained, "I think that's where the complexity lies in these kinds of projects. That there are so many different stakeholders that you have to manage and that you have to somehow balance in the appropriate way. I think that is the real challenge, so the focus is a little bit removed from just a physical thing, the physical product. It's more about how do I deal with this complexity?" One of the architects (Participant 4) highlighted that waste management companies may be material providers in the future and, therefore, emphasized the importance of establishing collaborations with them. Participant 10 mentioned that they are increasingly collaborating with environmental specialists to accurately calculate the footprints of different designs.

According to Participant 8, many clients find it difficult to collaborate outside their own organizational structures and as such are "hindering the collaborative nature that needs to be happening when you want to enter the CE." To address this, some participants have been part of or helped to develop collaborative platforms and networks in the public and private sectors, with the aim of facilitating collaborations between different parties and disciplines in the context of the CE. Participant 8 has been part of the development of a collaborative platform launched under the name of the design studio that aims to connect organizations, which are invited to participate in a co-design process that starts with "big" questions such as how to tackle the environmental impact within a certain industry. During a high-paced intensive design process or "design sprint" questions are made tangible, translated, and moved to a place where the companies involved can continue to examine them internally, or the collaboration with the involved partners or the design studios continues afterwards. The participant explained how such a platform invites unlikely partners or competitors and establishes a certain willingness for an open and transparent collaboration. According to this participant, the key aspect is changing traditional vendor-client relationships. For example, for product manufacturers to change their current mindset from seeing suppliers as companies that provide materials to thinking of them as innovation partners. Such developments are also occurring in the public sector. Participant 2 described a case in which different cities were brought together to tackle certain questions regarding the CE. In this particular case, specialists in the environment, economics, and furniture gathered to exchange knowledge and promote circular practices in interior design amongst the different cities involved. Two participants pointed out that there is intensified collaboration with material suppliers. Participant 12 described being more inquiring towards suppliers regarding different materials and their composition, and challenging suppliers to develop circular alternatives. Regarding the selection of fabrics in furniture design projects, the participant explained that "if you look at it and it is 25% wool, 70% polyester and then 5% elastane or something, then it is difficult to say that it is a circular fabric. In that sense, I have been discussing this more with different material suppliers than I would normally do in another project." Participant 7 explained that their company receives requests from material suppliers to find applications for new "circular" materials that are not yet on the market.

4.3.2 Designers as connectors

Several participants, in particular the architects, described how connections are established between clients, suppliers, manufacturers, and other players in the value chain to find opportunities for circularity and transform relationships that enable collaboration and dialog. One of the architects (Participant 4) explained that "connecting the dots" is nothing new for architects; however, the CE expands the scope within which this needs to be performed, and the challenge of inducing the value chain to work is also expanding the role of the designer. Another architect (Participant 5) described how their architectural firm was briefed for the redesign of an office and was involved more as a circularity consultant than they were as architects. They selected circular strategies, analyzed the materials the client was initially planning on using, and recommended suitable materials for different elements according to their expected lifespans. They acted as "connectors" by finding suppliers and producers for the interior who met the demands imposed by circularity. This role as described by the interviewee was "actually quite new." For example, the architects set up a collaboration with a producer who made lamps from folded paper. The lamps had previously been made from new paper, but the collaboration between the architect and manufacturer led to a redesign in which recycled paper was used for this project, thereby, lowering the carbon footprint of the lamps. The participant felt that many architects are communicating their circular ambitions but do not receive any responsibility with regard to materials and "just follow the list and the demands of the clients." However, the participant considers a higher degree of circularity in architecture could be achieved if architects took the initiative in claiming this role. One of the industrial designers (Participant 8) explained how, in a design project, they discovered that their client had manufacturing capabilities in another part of the organization that could be used to realize the design of the product. The designer explained, "They were not set up to work with that part of the organization; they had no idea how to do it because they had never worked together. We had to help make that connection. You need to understand how a big organization like that works."

4.3.3 Business thinking

Based upon the interviews, it is apparent that for both industrial designers and architects designing solutions for a CE requires a more extensive knowledge of business and economics. Clients need to be convinced of circular value propositions, the financial benefits of which are usually only apparent when considering multiple lifecycles of products and buildings and over longer periods of time. One of the industrial designers (Participant 8) explained how business thinking or "business design" is an important service they provide as a design consultancy and pointed out that "A CE is an economic model. We need to understand the economy in order to change it. I think designers have to learn about business and the needs and the issues that the clients are dealing with." For products, a circular design relies upon the combination of the physical design and the business model; therefore, both aspects should be simultaneously discussed and developed early on in the design process. Another industrial designer (Participant 10) explained that in projects related to circularity, "we don't start with a piece of paper and a pencil anymore." Instead, the process begins with numbers and spreadsheets to model the business and obtain a grasp of the impacts related to the business, environment, and society. One of the architects (Participant 4) highlighted the need for better business knowledge amongst architects and explained that because many people think sustainability or circularity is "just more expensive," architects should be able to convince clients of a circular value proposition and the financial benefits that are provided over time. Another architect (Participant 7) designs and develops furniture and building components (such as kitchens and interior walls) that are modular and designed to be disassembled. This participant explained that if there is no financial incentive for clients to return these products, it can never be a circular business. The same participant described a project involving the renovation of an office space where they proposed the solution of constructing meeting rooms from modular building blocks. When it became clear that the limited budget of the client made this impossible, the architects instead suggested a proposal for a 5-year partnership within which they would gradually expand the office with the modular solution to lower the initial investment and adapt the space to fluctuating demands and occupation.

4.3.4 Designer as circular change agent

In relation to the CE, the industrial designers and architects foresee how their roles are changing, that is, gradually becoming less about the actual designing of objects and more about efforts to create internal alignment within companies, changing the "linear" mindset to make clients think in new ways, and framing questions in a way that makes the challenges of the CE both tangible and actionable. Ultimately, the designer acts more as a change agent who designs the conditions within which circularity can be manifested. One of the designers (Participant 8) explained how clients have ambitions regarding circularity, such as retrieving components and materials; however, while they can see the intended outcomes, they struggle with knowing how to attain them. It is here that designers have the opportunity and, according to this participant, the "responsibility" to help clients think in new ways and make these challenges tangible, "otherwise nothing will change." The participants mentioned the importance of helping clients to look ahead, engage with the CE, and anticipate and envision future perspectives. The reason for this, as one of the industrial designers (Participant 10) explained, is because "the future perspective of most entrepreneurs, most clients, is one to two years ahead."

One of the interviewed designers (Participant 11) described how one design project can inspire larger changes in a company. In a design project for a manufacturer of wooden furniture, the designer had an idea for an upcycled stool made from the off-cuts created in the production of wooden chairs. A pivotal point in this was visiting the factory, where the designer noticed the triangles that were being cut off and burned in the production of the chair seat. The designer explained, "they were putting the seat into the CNC machine and would cut off two triangles, and they produce 15,000 [name of chair] a year so 30,000 of these hardwood triangles were burned. They couldn't burn them as they were; they had to grind them down to small pieces." The project led to a strong internal awareness of the high-quality off-cuts that were being wasted and has since led to the discontinuation of burning these pieces for energy. Instead, these off-cuts are now being reused in the production of children's furniture.

The participants generally found it important to create an understanding of the CE and convince clients of its potential and feasibility through various strategies, such as showing them successful examples, showcasing projects and exhibitions, providing numbers and infographics upon (potential) climate and financial savings, and using pitches and storyboards to render the CE concept visible. Such strategies can help create understanding and alignment between the designer and client, and also internally at the client's organization, thus, elevating the CE from a theoretical and conceptual discussion to something that is tangible and actionable. For example, Participant 5 described how their company started reimagining famous iconic buildings from a circular perspective and shared these as case studies. For instance, how a particular iconic building would appear if it were made from reused or renewable materials and showing people what this would mean in terms of potential climate savings.

4.4 External factors affecting circular design in practice

4.4.1 Regulations and policies

Many participants highlighted the need for better regulations that promote circular practices. The industrial designers emphasized that standards and certifications are needed for circular products and materials. One of the participants highlighted existing product certifications such as the Nordic Swan label and EU Ecolabel but noted that these only support CE practices to a limited extent. The architects mentioned how the current regulations in the building industry and the challenges regarding guarantees for reused components hinder the reuse of building components and, therefore, the potential for circularity. One of the architects (Participant 5) explained that it is easier to deconstruct components and recycle the source material than to reuse components. The architect added that "if you could take a whole part of a façade and reuse that whole thing in another building, that's a lot better than crushing it to make a new brick out of it." However, another architect (Participant 2) explained that there are fewer regulations concerning what is put inside of a building, and that, partly for this reason, there are more advanced circular practices in interior design, such as the reuse of furniture and other interior elements. Two participants from the Netherlands also indicated positive developments regarding policies and regulations on a national level that promote circular design practices, such as governmental support for circular initiatives and products, and stricter regulations regarding the calculation of the environmental impact of design solutions, thereby, creating equal responsibilities amongst designers for following such practices.

4.4.2 Materials in the circular economy

The interviewed industrial designers emphasized that there is confusion and some misconceptions amongst clients and consumers about renewable and circular materials. Sometimes nonrenewable materials such as plastics and metals can be a better choice from a circularity perspective when considering the environmental impact over an entire lifespan; however, clients' negative perceptions of these materials can result in friction and challenges in design projects. Participant 10 described a project for the design of a bus stop that required them to prove that aluminum was a better choice than wood, considering it has an expected lifespan of 15 years. The designer stressed, "The perception is so strong that, for example, wood, even though you would have to paint it, would be better than aluminum that it actually messes up the whole discussion in such a project about what is good and what is not good." Another designer (Participant 12) described the positive perceptions people have of renewable materials, such as leather and wood, compared to synthetic materials. However, according to the participant, in some cases synthetic materials may be better when considering closed material loops: "You might choose to use polyester instead of leather because it is better when it comes to circularity. But if you write that in an ad, it won't sound as good."

One of the interviewed architects (Participant 3) described how reusing materials for another purpose can be challenging when it defies people's preconceptions of how certain materials or design elements traditionally appear. In a large renovation project of suburban houses, the architects suggested reusing high-quality parquet flooring, which was abundant, as interior wall cladding. However, when the tenants were given the choice between a wooden wall and a white gypsum wall, not one of the 1,000 tenants chose the wooden option. The architect emphasized that this was related to aesthetical preferences and stressed the importance of aesthetical factors when reusing materials.

4.4.3 (reverse) Logistics

The interviewed architects highlighted (reverse) logistics as a major challenge for the recirculation of materials, both in terms of practicalities (e.g., material storage) and the associated environmental and economic impacts. In the context of the built environment, where the reuse of building elements and construction waste recycling practices are scaling up, a challenge exists regarding the storage and transportation of these materials and components and which player could take this role. One of the interviewed architects (Participant 4) gave an example of a carpet manufacturer with take-back arrangements who remanufactures carpets but also stressed that this is "just one little piece of a building." This participant also described how the reuse of building components and logistics could be approached on a more systematic level by waste handling companies, who could take the role of material suppliers in the building design process. This would increase the viability of reuse strategies and reduce risks in the logistical process. Another architect (Participant 2) described an interior design project that involved carpenters who took a key role as logistical partners, which was a new way of working for the architectural agency. The project included a high level of reused furniture and components, such as chairs and old tabletops, and in addition to building the furniture, the carpenters also took care of sourcing materials and storing them during the development process.

4.4.4 Understandings of and attitudes towards the circular economy

Several of the design practitioners considered that clients were often hesitant to engage with and commit to the CE and circular design directions due to the financial risks, the higher costs associated with circular solutions, and the perceived constraints of the current linear system (e.g., changing supply chains and established ways of operating). Designing circular buildings and products that allow multiple life cycles usually requires more value to be allocated at the beginning as a result of the costs of durable high-quality materials, new technical solutions, or changes to existing manufacturing capabilities, for example. Clients need to be able to see the business value and there is a reliance on external funding for many of the projects. Product manufacturers and the construction industry are considered reluctant to implement solutions that would imply changes to their current ways of working and existing capabilities. One of the industrial designers (Participant 12) described the design of a modular storage system for a major European furniture brand that can be easily disassembled and rebuilt in different configurations. The modularity in the design was a direction introduced by the designer based upon the reflection that modern offices require considerable flexibility. Despite the successful launch of the product and the fact that it has been sold to many offices in need of rebuild possibilities, the designer stated that the client was initially skeptical of the higher costs of the technical solution: “I think that is often the case with circularity as well, they [products] tend to be more expensive because you must build something that can be used not just once. The cheapest way to put two pieces together would be a wooden dowel and some glue or a screw or something that is very simple. But if you think about circularity, you need to have a different way to put them together and that often makes them more expensive. They [the client] were a bit hesitant about that in the beginning.” Although the participants mentioned the use of various methods to convince clients to commit to a circular design objective such as emphasizing climate impact reductions, long-term economic benefits, and the publicity value, it was considered challenging to do so if the client did not have a fundamental understanding of and commitment to circularity and if they were steered by short-term gains.

The results of the interviews also indicate that the CE concept is often understood and interpreted in different ways by companies and designers as it is such a broad term. One of the participants explained that it is good as a collective term but that “being circular is not the solution for the problem” and stressed that it is important to keep the overall CE goals of reducing waste issues and climate impacts in mind. Some participants also described projects with clients in which, prior to the project, the client already had the right “mindset” and an understanding of and commitment to sustainability. This was considered a key factor for successful projects, whereby, clients take the risk to invest extra time and money in finding better circular solutions. One of the architects (Participant 4) noted that the demand for circularity as a focal point in projects has increased in recent years. The participant explained that previously they had to convince clients but “now we have clients that are asking for it which is a big change and a positive one.” The same participant described a project that involved designing a LED lamp fitting from upcycled ocean plastic, in which the aim of making the material further recyclable implied research into the right material mix, reconfigurations in the value chain, and investments in new machines. The participant explained that the client’s demand for circularity ultimately led to a successful implementation but, without the client driving the project, the manufacturer of the fitting would have said “don’t spend time on it, just use regular plastic; it is much easier.”

5. Discussion

The aim of this study was to provide a better understanding of how the CE concept is interpreted and implemented by design practitioners. In addition, we explored how the CE is affecting the process and practice of designers. The study gathered data from interviews with 12 design practitioners, consisting of architects and industrial designers, who have been actively working with CE-related design projects. To date, there have been limited studies investigating the perspectives of designers in the context of the CE, and to our knowledge there have been no studies addressing both the perspectives of industrial designers and architects. In the following section, we discuss the overall contributions made by the results of this study in terms of how design practitioners currently interpret and implement the CE concept in practice, how their role is changing and how the design industry as such is adapting to accommodate CE principles. Following this, we discuss the study’s limitations and finally summarize the conclusions and provide some directions for further research.

5.1 Implementation of the circular economy concept across the disciplines of architecture and industrial design

It is apparent from the literature that the scope within which designers operate has vastly expanded over the second half of the twentieth century, and sustainability efforts in the design professions have become increasingly more complex, shifting from object-centric thinking to a more system-based design approach (Ceschin and Gaziulusoy, 2016; Gaziulusoy and Brezet, 2015; Manzini and Vezzoli, 2003). The results of this study indicate that the design practitioners who were interviewed consider the CE to be a multi-faceted challenge that further expands the scope of design processes and projects. Striving for the closing of resource loops not only requires increased cross-disciplinary knowledge (e.g., of materials, business models, value/supply chain structures) but typically requires the involvement and management of more stakeholders in the value chain from early on in the design process. Data technologies such as material passports and digital twins are discussed in the literature as enablers of a circular built environment (Debacker et al., 2017) and were mentioned in this study as supportive tools for engaging with and optimizing the lifecycles of designed artefacts.

This study found some differences between the interviewed industrial designers and architects in terms of how the CE concept is approached and implemented in practice. From the cases discussed by the architects, it appears that the implementation of the CE concept in practice thus far has primarily focused on the reuse of existing (waste) materials for the design of new buildings and structures. This requires architects to adopt more flexibility in the conceptual stages of the design process, as it is typically unknown what components and materials might result from the “inventory” process. The implications of this for the architectural design process have previously been discussed, for example, by Kozminska (Kozminska, 2019). In our study, the architects reflected to a lesser extent on designing buildings and components that can be disassembled so that parts and materials can be reused in the future.

Previous research has primarily focused on waste management and the reuse of secondary raw materials in the built environment and emphasized a lack of incentives aimed at designing buildings that can be dismantled at the end of their lives (Munaro et al., 2020). It has been suggested that more efforts on investigating DfD strategies and PSS practices to expand the service life of buildings are needed (Joensuu et al., 2020). It appears that in some cases there is a strong perception on the market side that circular architecture relates to the reuse of waste materials, as illustrated by the example case of the bike shed that was no longer described as “circular” after deviating from the initial plan of reusing waste materials.

The interviewed industrial designers seem to have a greater focus on establishing business models that promote circularity through designing long-lasting products and modular products, and products that can be disassembled to promote repair and maintenance practices and product-service-systems. It appears that circular business models and PSS practices thus far are more focused on the micro level (products) than the meso level (buildings). Kanters have pointed out the increased complexity of the building scale, especially in regard to ownership, as a possible explanation for this (Kanters, 2020).

According to Pomponi and Moncaster, the solutions suitable for manufactured products are unlikely to be applicable to buildings as manufacturing and the useful lifespan of buildings extend over a significant timespan. Additionally, buildings are constructed of manufactured products but become unique, complex, long-lived, and ever-transforming entities once assembled (Pomponi and Moncaster, 2017). Each step towards circularity in products and the built environment can be considered beneficial, but it also appears to be essential to take a holistic and integral approach towards circular design. As illustrated by one of the participants in this study, the dismantling of products to facilitate repair, reuse, and recycle practices can be made easier, but if there is no system or (financial) incentive in place to motivate such practices to occur, the design as such cannot be considered circular. This emphasizes the need for the CE to be understood holistically and as a fundamental systemic change (Kirchherr et al., 2017) and for the provision of clear indicators on how to measure circularity (Moraga et al., 2019). Further fragmentation of the concept may be unavoidable if only parts of the concept are considered and implemented in the design process, while disregarding the "bigger picture" and the overarching goal of establishing a systemic shift that decouples economic growth from resource consumption, closes material loops, and reduces climate impact. This is likely to lead to incremental improvements at best rather than fundamental change, with the CE ending up as just another buzzword of sustainable development (Kirchherr et al., 2017).

Various R frameworks such as the 9R model (Potting et al., 2017) are prominently used in the CE discourse, as they provide a coherent taxonomy of different resource-life extending strategies (Blomsma and Brennan, 2017) or, defined in a more inclusive form as, resource value retention options (Reike et al., 2018). These frameworks can be a useful guide for designers by covering different circular strategies from a holistic and hierarchical perspective such as repairing, reusing, and recycling. However, these frameworks focus on the micro level (products, components) and are less useful for the meso (buildings) and the macro levels (cities, built environment). During this study, it was observed that terms such as "reuse," for example, were used by both architects and industrial designers in fundamentally different ways, whereby reuse for architects means the reuse of building waste, spare materials, and components for new construction, while reuse for industrial designers refers to how products can be designed in order to be reused by another consumer in the future. In this regard, Reike et al. have highlighted the conceptual ambiguity that exists within the various R frameworks and stressed that for the successful implementation of a CE, it is critical to establish a shared understanding of key notions, especially where "different languages and professional jargon are used by stakeholders possessing different underlying paradigms" (p.254) (Reike et al., 2018).

As a CE blurs the boundaries of scale, it could be helpful to have universal guidelines and frameworks and a common language that support designers in considering these multiple levels in the context of a CE. It would not be surprising if the transition to a CE implies closer collaborations between different types of designers, be they industrial designers, service designers, strategic designers, or architects. Such initiatives appear to have been set into motion on a political level in the EU, as the European Commission recently announced the formation of "a new European Bauhaus," "a co-creation space where architects, artists, students, engineers, designers work together" to help Europe move toward a CE (European Commission, 2020d).

In terms of research, investigating the potential of cross-pollinating circular design knowledge amongst different design disciplines may lead to fruitful insights and a more unified understanding along with the further development of the methods and tools needed to translate circular principles into design practice.

5.2 The effects of the circular economy transition on the practice of design

The results of this study indicate that in the context of the CE, design practitioners are questioning the linear logic of the business models on which many design consultancies are founded. Design projects are still often temporary efforts after which designed artefacts are "handed over" to the client. Such models are considered to inhibit the potential for circularity as they do not encourage the engagement of the designer (and other stakeholders) with the lifecycles of designed artefacts, especially as many design challenges related to the CE are likely to appear once products are in use (Sumter et al., 2018). Some design practitioners (aspire to) transform the business model used in agencies to facilitate long-lasting partnerships, and some of the interviewed participants from larger companies are already pursuing such a model. Such a model encourages designers to become more thoughtful of and involved in the lifecycle of designed artefacts and better understand how they "wear and tear"(Lilley et al., 2019). Furthermore, assuming that buildings and products are not static but transform over time enables designers to focus upon ways to capture value throughout the lifecycles of these artefacts.

Previous studies have identified barriers to the transition to a CE such as a hesitant company culture and limited willingness to change, limited willingness to collaborate in the value chain, the existing linear system, lack of governmental support, and attitudes to and knowledge of the CE (Kanters, 2020; Kirchherr et al., 2018; Ritzén and Sandström, 2017; Rizos et al., 2016). Some of the challenges experienced by the design practitioners in this study are similar to the general barriers to the CE previously identified by scholars, such as clients who are wary of the costs and risks associated with circularity, linear constraints, and attitudes to the CE.

The participants in this study demonstrated how some challenges are addressed in practice, for example, through engaging clients with the CE and establishing connections and collaborative networks among actors. Some of the participants seem to effectively use what Sumter et al. described as "circular economy storytelling"(Sumter et al., 2020), that is, being able to engage internal and external stakeholders with the CE concept in the design process. The participants achieved this by utilizing various methods such as showing stakeholders successful examples, infographics, storyboards, and demonstrative case studies.

Previous research has highlighted the importance of collaboration across whole supply chains in the context of the CE (Aminoff et al., 2016; Leising et al., 2018), and the role designers can play as connectors (Manzini, 2009) who facilitate strategic dialogs between actors (Meroni, 2008), establish future visions, and act as agents of change (Banerjee, 2008). The results of this study show that design practitioners are performing and claiming such roles and that facilitating connections and collaborative spaces between actors can play a vital role in developing solutions and innovations for a CE. This is in line with earlier findings by Sumter et al., who highlight the importance of the interpersonal competency of industrial designers in facilitating collaboration between internal and external stakeholders (Sumter et al., 2020, 2018). In the CE context in particular, closing resource loops on a larger scale might imply the need to facilitate dialogs and collaboration between actors who are normally competitors with conflicting interests. The example given by one of the participants, whose company facilitates a "neutral" collaborative platform and co-design process as a design service, illustrates the role design can play in establishing (willingness for) collaboration between various actors.

Still, the success of design projects is often measured by their physical and tangible outputs. Pedersen and Clausen described how in a CE context the key to success is not solely the design of physical objects but rather the design of the network or relationships (Pedersen and Clausen, 2019). A question that arises is whether the available design training, methods, and strategies sufficiently support design practitioners and students in tackling the complicated challenges encountered in practice, which often require cross-disciplinary collaboration and co-creation. The role of the designer as facilitator has been discussed in design research (Manzini, 2009) and in the contexts of participatory design

(Luck, 2007) and whole-systems design (Charnley et al., 2011) but has not yet been widely investigated in the context of the CE.

An additional challenge of a CE, aside from establishing and facilitating collaboration between the actors in the design phase of artefacts, will be to facilitate such collaborations throughout the lifecycles of artefacts and beyond so that artefacts can be improved for circularity and the slowing and closing of resource loops can be further optimized. It is certain that the transition to a CE will require more extensive collaboration between the actors in design processes, but it remains uncertain how and by whom this can be best facilitated and coordinated. Kanters argued that architects could play a central role in linking actors, but additional knowledge is required (e.g., in leadership)(Kanters, 2020). Here, tools that help to enhance collaborations in support of a CE would be helpful, such as the one proposed by Leising et al. (Leising et al., 2018). Through acknowledging and further investigating collaboration and the design of networks as an important parameter of circular design projects, they will become a more integrated part of the design process for designers.

Although some of the participants mentioned a lack of regulations and policies that support circularity, significant positive developments are also taking place in this regard, such as stricter regulations regarding the calculation of the environmental impact of design solutions, which creates equal responsibilities amongst designers aiming at a CE. Previous research discussed the regulatory barriers to the CE (Pheifer, 2017; Rizos et al., 2016), but these do not appear to be one of the core barriers within the EU (Kirchherr et al., 2018). Certainly, policy and regulations play an important role in enabling circular business models and design strategies (Moreno et al., 2016). The architects in this study indicated that, especially in the context of the built environment, there are regulatory barriers that hinder the reuse of building components (e.g., relating to quality assurance), which appear to be less of an issue in the context of interior design and the reuse of furniture.

In addition, user perspectives and the acceptance of circular value propositions are discussed in the literature as important challenges for the CE transition (Selvefors et al., 2019; Wastling et al., 2018). It is important to emphasize the importance of the inclusion of the user in the circular design process (Lofthouse and Prendeville, 2018; Selvefors et al., 2019), as they play a crucial role in the success of resource recovery and are ultimately a deciding factor in the adoption and acceptance of circular value propositions. These aspects were only mentioned to a limited extent by the participants in this study. Some of the participants highlighted some potentially paradoxical challenges for circular design regarding consumer acceptance of certain materials. For example, negative associations towards plastics might prevent designers from using such materials; but in some cases, plastics may be better from the perspective of establishing a closed-loop system. Additionally, aesthetical considerations and acceptance of materials that are "reused" seems important to investigate, illustrated by the example in this study of the flooring that was reused as wall cladding but was not the first choice of the tenants. In this regard, consumer acceptance towards circular offerings has been discussed (Gullstrand Edbring et al., 2016; Tunn et al., 2019; Van Weelden et al., 2016) and researched to some extent in the context of repurposed materials in the built environment (Sieffert et al., 2014).

5.3 Limitations

Due to the explorative nature of this study and the fact that it utilized a qualitative approach, the findings cannot be generalized. Nevertheless, the study provides in-depth insights into current design practices regarding the implementation of the CE and is the first to investigate the perspective of both industrial designers and architects in the context of the CE.

The main limitation of this study is the small number of interviews included in the sample. Therefore, the results of this study should be regarded as tentative and as a basis for further research. The participant recruitment process was confronted with challenges as it took place at the beginning of the COVID-19 pandemic. In addition, the number of design agencies that have completed CE design projects or explicitly state that they work with circularity are still rather limited, as it still is an emerging field.

Lastly, the geographical distribution amongst the participants is limited. Consequently, different national policies and regional contexts may have influenced how and to what extent circular design practices have been adopted.

6. Conclusion

The role of design is considered to be crucial in the transition to a CE. For designers, the CE produces a range of new challenges and requires specific knowledge, strategies, and methods. To date, most studies regarding designing for a CE have been theoretical and conceptual. Limited empirical investigations have been conducted into the practical implications of designing for a CE, and there is little knowledge on how the concept of circularity is implemented by design practitioners. Therefore, the aim of this study was to provide a better understanding of how design practitioners interpret and implement the concept of a CE in practice. Based upon semi-structured interviews with design practitioners ($N = 12$) within the disciplines of architecture and industrial design who have actively worked with the CE in a design agency setting, this study provides in-depth insights into current design practices regarding the implementation of the CE. To our knowledge, this is the first study to investigate the perspectives of both industrial designers and architects in the context of the CE.

Overall, the findings indicate how the complex and multi-faceted nature of the CE concept is expanding the scope of the design process and, thus, driving the integration of new knowledge fields and skills within that process. The findings also emphasize the need for extensive collaboration with stakeholders and experts throughout all the stages of the design process. Although collaboration can be considered an essential aspect in any design process, the cases discussed illustrate the role designers can play in facilitating connections and collaborative spaces between the actors, which may play a vital role in developing solutions in support of a CE. The cases demonstrate that the "design" of networks and relationships is an important part of CE-focused design projects for both industrial designers and architects and can be regarded as an integral part of the circular design process. Accordingly, it seems vital to raise awareness and support design practitioners and students with appropriate training and strategies to support effective and long-lasting collaborations throughout the whole design process and lifecycle of designed artefacts.

Furthermore, the findings indicate how the design process in the context of the CE is further shifting its focus from a singular object/artefact/building to the creation of systems, business models, collaborative networks, and future visions; thus, ultimately helping clients to look ahead and render the pathways towards circularity tangible. To tackle the challenges, design agencies are responding by creating internal circularity-focused research and design teams, facilitating CE knowledge exchanges, and developing their own circular strategies and methods.

There were differences between the architects and industrial designers with regard to the challenges encountered and how the CE concept has been interpreted and implemented into practice. For example, a stronger focus on circular business models/PSS in the context of industrial design, and a focus on the reuse of construction waste in the context of architecture. Additionally, circular strategies and associated (similar) terminologies were understood and applied in fundamentally different ways. As the CE blurs boundaries of scale and discipline, there is a need for a universal design language and frameworks.

Within design agencies, there is also a strong need to adapt the traditional business model to enable longer client relationships. Design projects tend to remain short-term efforts, thereby, hindering the engagement of designers with the lifecycles of designed artefacts and the possibility of achieving circularity in the long term. External factors such as regulations and policies, logistics, and understandings of and attitudes towards the CE and materials seem to affect the extent to which circularity is considered and incorporated into design projects.

Accordingly, further research should focus upon the development of a common language and upon universal methods and guidelines to aid the circular design processes of different kinds of designers in practice; for example, with regard to the available circular design strategies, assessing the circular impacts within the design process and ways to facilitate effective collaborations in stakeholder networks, which would be valuable for both practitioners and design education. Investigating the practice of circular design through larger samples or longitudinal case studies would also provide deeper insights into how the design process is coordinated and adapted across different stages, how circularity is implemented across different design disciplines, and allow multiple perspectives on key factors in circular design projects to be gathered over time.

Declaration of Competing Interest

The authors declare that there are no conflicts of interest.

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