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Simeone, Luca; van Dam, Kirsten; Morelli, Nicola

Published in:
Proceedings of Cumulus conference Rovaniemi 2019

Publication date:
2019

Document Version
Accepted author manuscript, peer reviewed version

[Link to publication from Aalborg University](#)

Citation for published version (APA):
Simeone, L., van Dam, K., & Morelli, N. (Accepted/In press). A preliminary review of the concept of circular economy in design research. In *Proceedings of Cumulus conference Rovaniemi 2019*

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A preliminary review of the concept of circular economy in design research

Luca Simeone, Kirsten van Dam, Nicola Morelli

Aalborg University, Copenhagen, Denmark

lsi@create.aau.dk, kvd@create.aau.dk, nmor@create.aau.dk

Postprint version. Suggested citation: Simeone, L., van Dam, K., Morelli, N. (2019) A preliminary review of the concept of circular economy in design research. Proceedings of Cumulus Conference, Rovaniemi (Finland), 27 May – 1 June 2019.

Abstract

Themes such as economy of materials, environmental degradation or optimization of production and consumption flows have long been discussed in design and design research. Lately, the concept of circular economy entered the stage as “an industrial economy that is restorative or regenerative by intention and design” (Ellen MacArthur Foundation, 2013). One of the reasons behind the current fascination toward circular economy is surely the (implicit or explicit) promise that circular economy yields the potential to foster environmental protection without limiting economic growth. As such, circular economy has been seen as a way to develop more sustainable business models and entrepreneurial processes but has also been criticized for its neoliberal foundation. Within design research, a good number of contributions looked into theoretical aspects or practical applications of circular economy. The aim of this paper is to survey the field by reviewing some 75 contributions ranging from books and book chapters, journal articles and conference papers. The paper presents a variety of views that not only show different ways in which design research approached circular economy, but also hint at possibilities for further investigation.

Author keywords

Circular economy, design research, literature review

Aims

Themes such as economy of materials, environmental degradation or optimization of production and consumption flows have long been discussed in design and design research from perspectives as diverse as the British Arts and Crafts movement or functionalism and modernism (Fuad-Luke, 2004). Across the 1960s and the 1970s, Richard Buckminster Fuller and Victor Papanek advocated for more sustainable design approaches and invited designers in using their skills to address socially useful ends rather than being solely oriented toward commercial interests (Fuller, 1969; Papanek, 1972). Landmark reports such as the Club of Rome's *Limits to Growth* (Meadows, Meadows, Randers, & Behrens III, 1972), the work of the Brundtland Commission (Brundtland Commission / World Commission on Environment and Development, 1987) or the documents released by the Intergovernmental Panel on Climate Change (formed in 1988) prompted reactions from parts of the design community, which responded proposing approaches such as green design¹, ecodesign², design for sustainability³ and, more recently, transition design⁴. Although some studies tried to map the evolution in the use of these terms (Ceschin & Gaziulusoy, 2016), the distinctions and the boundaries between these approaches can still be a bit blurred.

Lately, the concept of circular economy entered the stage as "an industrial economy that is restorative or regenerative by intention and design" (Ellen MacArthur Foundation, 2013). One of the reasons behind the current fascination toward circular economy is surely the (implicit or explicit) promise that circular economy yields the potential to foster environmental protection without limiting economic growth (Lieder & Rashid, 2016). As such, circular

¹ A term used "in the building, furnishings, and product industries to indicate design sensitive to environmentally-friendly, ecological issues" (Stephens & Stephens, 2009, p. 376). Green design can be characterized as "the act of mitigating environmentally destructive and excessively consumptive processes and practices associated with the creation, use and disposal of products or projects" (Flemming, 2013, p. 57).

² Ecodesign has to do with "integrating ecological awareness into design practices" (Brower, Mallory, & Ohlman, 2009, p. 7).

³ A design approach that "considers environmental (for example resource use, end of life impact) and social impact of a product (for example usability, responsible use" (Bhamra & Lofthouse, 2007, p. 39)

⁴ As put by Tonkinwise, transition design is inspired by the Transition Town movement and "is an attempt to name an ambition for an expert craft of designing that acknowledges the extent of our social crises by advancing the practices of social and sustainable designing through the incorporation of multi-stage practice-oriented transformation" (Tonkinwise, 2015, p. 91).

economy has been seen as a way to develop more sustainable business models and entrepreneurial processes (Balkenende et al., 2018).

Within design research, a good number of contributions looked into theoretical aspects or the practical applications of circular economy. Systematic efforts to map scholarly contributions related to various aspects of circular economy already exist (e.g., Prieto-Sandoval, Jaca, & Ormazabal, 2018; Korhonen, Nuur, et al., 2018). However, only a few of these review papers more specifically looked at the role of design. Tukker, for instance, focused on the evolution of the concept of product-service system in the perspective of circular economy (Tukker, 2015). Ceschin and Gaziulusoy (2016) reviewed different approaches in design for sustainability using a framework based on different logical levels (from product innovation to systemic transformation) and following an almost chronological order (from green design to system innovation and transition). Lofthouse and Prendeville analyzed the positioning of human-centred design within circular economy by bringing together insights from various fields including economics, sociology, management and ecology and thus not limiting their review to the design field (Lofthouse & Prendeville, 2018). This article intends to complement these mapping efforts by (1) more specifically looking into the design research field and (2) narrowing the scope of the analysis and only reviewing those contributions that specifically focus on circular economy (rather than other design for sustainability approaches).

Methods

The review started with an analysis of how the construct of circular economy is used in articles published in key design journals. The selection of journals originated from an article that, in 2012, identified 40 design journals deemed as particularly relevant for design research (Gemser et al., 2012). Two new journals have been added to this list: *She Ji* and *Design Science*. Searches for the term "circular economy" (in all the text of the articles) were performed for each of these journals. Additional searches through ISI Web of Science database and Google Scholar using the words "circular economy in design" have also been carried out. From this process, 90 articles emerged. Adopting a 'snowball' approach previously used in literature (Ravasi and Stigliani, 2012; Hernández et al., 2018), these contributions have been analyzed to check whether the works they cited could be of interest, for example, because they were consistently cited or highly relevant to our research question. During the snowballing process, 17 additional publications were selected. Titles and abstracts of all these contributions were examined as to distill the most relevant publications, i.e., the ones that more closely focus on circular economy frameworks, concepts, circular design strategies or present cases, rather than just mentioning circular economy in the background of their argumentation. This left us with 75 articles, conference papers and book chapters.

These publications were then more closely analyzed according to a protocol in which bibliographic data and a brief description of the content were gathered and then independently examined by each of the authors of this review. All the publications were then grouped according to five clusters emerged by integrating the independent categorization processes carried out by the researchers: (1) design education and circular economy, (2) design and circular production processes, (3) the potential of design to intervene on the demand side, (4) the use of design to support policy and regulations oriented

towards circular economy and (5) other reflections on design theories and frameworks for circular economy. The term 'cluster' is used - rather than category - as to suggest that boundaries across the clusters were quite flexible.

By no means, this paper aims at offering an exhaustive mapping. Rather, the paper presents a variety of views that not only show different ways in which design research approached circular economy, but also hint at possibilities for further investigation. At this stage, this survey is marked as preliminary and the authors hope that the current version of the paper can gather the attention of other researchers working on this topic and interested in further jointly developing this literature review.

An introductory characterization of circular economy

The idea that the material cycles tied to production and consumption processes need to be optimized has been around since the first stages of industrialization (Desrochers, 2002; Fuad-Luke, 2004). Already starting from the 1960s, ecological and environmental economists argued that economy should be conceived as a circular system (Boulding, 1966; Pearce & Turner, 1989). While focusing on industrial economics, Stahel and Reday proposed a loop economy to refer to strategies for waste prevention and reduction, dematerialization of the industrial processes and optimization in the use of resources (Stahel & Reday, 1976). Along similar lines, industrial ecology analyzed the strict interplay between the industrial system, its environment and the related flows of material, energy and information (Erkman, 1997). More recently, the concept of circular economy brought to the table an approach that more broadly emphasizes "product, component and material reuse, remanufacturing, refurbishment, repair, cascading and upgrading" (Korhonen, Nuur, Feldmann, & Birkie, 2018, p. 545). In this sense, circular economy builds on top of related approaches ranging from cradle-to-cradle design (Braungart & McDonough, 2002), up to biomimicry (Benyus, 2002), all the way up to eco-efficiency (Huppes & Ishikawa, 2009), just to name a few.

In the past 10 years, circular economy has received increasing attention also thanks to discussions led by policy makers (CIRAIG, 2015; European Commission, 2015; Ghisellini, Cialani, & Ulgiati, 2016) and to the work of business advocacy bodies and industry, such as the Ellen MacArthur Foundation (Ellen MacArthur Foundation, 2013, 2015), IDEO⁵, Arup (ARUP, 2016) and McKinsey (Finland's Independence Celebration Fund & McKinsey, 2014), which all published reports and toolkits that show the potential of circular economy to support a broad transition towards more sustainable business models. As both the concepts of circular economy and sustainability are gaining traction, they are, at times and uncritically, used interchangeably (Geissdoerfer, Savaget, Bocken, & Hultink, 2017)⁶.

⁵ <https://www.circulardesignguide.com> accessed 26 November 2018

⁶ Although comparing the two terms is not the main focus of the paper, we will here briefly report the definition of sustainability provided by the cited authors: "the balanced and systemic integration of intra and intergenerational economic, social and environmental performance" (Geissdoerfer, Savaget, Bocken, & Hultink, 2017, p. 759).

A few authors analyzed the current high number of characterizations of the term and proposed some integrative definitions. Jouni Korhonen and colleagues saw circular economy as:

[Circular economy - CE] is a sustainable development initiative with the objective of reducing the societal production-consumption systems' linear material and energy throughput flows by applying materials cycles, renewable and cascade-type energy flows to the linear system. CE promotes high value material cycles alongside more traditional recycling and develops systems approaches to the cooperation of producers, consumers and other societal actors in sustainable development work (Korhonen, Nuur, et al., 2018, p. 547).

In a similar attempt, Prieto-Sandoval and colleagues elaborated the following consensus definition in which they characterized:

circular economy as an economic system that represents a change of paradigm in the way that human society is interrelated with nature and aims to prevent the depletion of resources, close energy and materials loops, and facilitate sustainable development through its implementation at the micro (enterprises and consumers), meso (economic agents integrated in symbiosis) and macro (city, regions and governments) levels. Attaining this circular model requires cyclical and regenerative environmental innovations in the way society legislates, produces and consumes (Prieto-Sandoval et al., 2018, p. 613).

By stating that circular economy is not the only possible answer to the question of sustainability, these authors also looked into how different sustainable design strategies - e.g., eco-design guided by life cycle assessment processes, cradle-to-cradle (Braungart & McDonough, 2002) or biomimicry approaches (Benyus, 2002) - can be applied (as "catalyzers") to design services and goods that can be reintroduced in the system and reduced, reused and recycled within circular economy.

The work of these authors is particularly important to go beyond the widespread characterizations of circular economy as simply "depicted as a combination of reduce, reuse and recycle activities, whereas it is oftentimes not highlighted that [circular economy] necessitates a systemic shift" (Kirchherr, Reike, & Hekkert, 2017, p. 221). Along the same lines, Bocken and colleagues developed a framework to provide a rich conceptual overview of the possible design and business model strategies for circular economy (Bocken, de Pauw, Bakker, & van der Grinten, 2016). The authors acknowledged the need to take stock of the inherent complexity of remodeling current business models in relation to circular economy. To help address such complexity, while considering innovation projects and actions in relation to circular economy, Prieto-Sandoval and colleagues characterized interventions on the supply side, on the demand side and on regulation and policy (or, in other terms, on production, consumption and legislation) as three areas of particular relevance ([Prieto-Sandoval et al., 2018](#)).

Summary of the articles analyzed

Design education and circular economy

Some scholars provided their considerations on how circular economy is (or could / should be) taught in design schools. In general, a good number of authors seem to converge on the need to change the current curricula of design schools as to more broadly include key circular economy approaches and appropriate related processes for product design, co-creation, management and marketing (Leube & Walcher, 2017). To this extent, design education should more closely embrace open design and distributed production paradigms, which can support circular economy (Collina, Galluzzo, Maffei, & Monna, 2017). Virtanen and colleagues analyzed how a Circular Material Library - i.e., a library containing a selection of available recycled materials - can favor circular re-thinking and re-designing of products (Virtanen, Manskinen, & Eerola, 2017). The authors argued that in the future, such material libraries can be linked to online material shops through which students, designers and companies can directly buy and sell resources. Some other papers look into those particular skill sets oriented to collaboration, facilitation and negotiation that designers need in order to address complex challenges such as circular economy (Bianchini & Arquilla, 2019; Papalambros, 2015; Pedersen & Clausen, 2018; Vermaas, 2016). Haemmerle and colleagues argued that there is a gap between the expert knowledge needed to operate in the field of sustainability and what is taught and practiced in current design education (Haemmerle, Shekar, & Walker, 2012).

Past and current experiences of education programmes that clearly oriented their activities taking into consideration circular economy can provide insights (Yekta, Muireann, Adam, & Manon, 2018), like in the case of the Textiles Environment Design research group at University of the Arts London. Earley chronicled the last two decades of this research group and showed how circular design informed a variety of their projects at the intersection of educational, research and design / practice-oriented activities (Earley, 2017).

Design and circular production processes

Other authors looked into how design can support and streamline production and manufacturing processes as to implement circularity, reduction of waste and optimization of resources. This is an area that design researchers seem to consider of particular relevance. By far, in our review, this is the category with the highest number of contributions.

Some contributions mention the need to take into consideration the development of products, institutions, and systems appropriate to recycling, re-manufacture, and re-use as one of the key themes for design innovation (Mortati, 2015) and design-driven manufacturing processes (Roos, 2016). To this end, digitally-enhanced and distributed production models - e.g., the ones behind the makers movement (D'Elia, 2018; Petruilaityte, Ceschin, Pei, & Harrison, 2017; Smith, 2017) - are examined in light of their potential to support light, locally grounded and more circular supply chains. As such, the need for the adoption of more open and collaborative production processes that also include the use of maker spaces is highlighted (Smith, Baille, &

McHattie, 2017). Such analyses look at various geographic contexts (D'Elia, 2018; Fleischmann, Hielscher, & Merritt, 2016), but there seems to be a high concentration of studies focusing on the UK (Coulson & Woods, 2016; Gallagher, Coughlan, Williams, & McNabola, 2018; Johnson, Champion, McHattie, & White, 2016; Smith, 2017; Smith, Baille, & McHattie, 2017).

Some other authors more critically looked at some possible limitations of these maker-based distributed production models. Unterfrauner and Voigt studied the makers' movement in relation to their ambition to do socially valuable things - including their environmental awareness (Unterfrauner & Voigt, 2017). The authors stated that "there is a visible risk that the innovative momentum of 'making' gets lost in response to market pressures, lacking awareness of customers and makers not yet able to capitalize on their collective powers, missing the chance of innovating their own ways of collaborating in interdisciplinary teams" (Unterfrauner & Voigt, 2017, p. S3324). Kohtala analyzed a design school's Fab Lab in a university in northern Europe and noted how those fab labs and makerspaces with "strong ecology-oriented visions and programmes [...] provide important role models, and they prove that open-design, digital-craft processes can serve sustainability-oriented priorities" (Kohtala, 2017, p. 389) but, at the same time, she argued that "maker communities are divided in their sustainability orientations and knowledge" (p.388) and that in some cases "very real, potentially far-reaching consequences of personal fabrication often seem to be invisible in Fab Labs in the global North: the reality of the supply chains outside the Labs, the reality of electronic component manufacturing and the toxic reality of e-waste" (p. 388). Fleischmann and colleagues suggested that, in order to live up to the potential of Fab Labs towards sustainable design ideas, Fab Labs should lead to the development of sustainability guidelines and replicable processes that facilitate co-creation (Fleischmann et al., 2016).

Some of the analyzed papers map and critically examine existing efforts towards circularity in the design industry. Moorhouse and Moorhouse looked at sustainable design practices in relation to zero waste fashion by briefly reviewing a series of initiatives currently implemented by large multinational companies, smaller niche brands or more experimental educational projects (Moorhouse & Moorhouse, 2017). The textile industry is also the focus of various studies (Mazzarella, Mitchell, May, & Escobar-Tello, 2018), including Valentine and colleagues' analysis of the recent transformations in relation to globalisation, sustainability and technological progress (Valentine, Ballie, Bletcher, Robertson, & Stevenson, 2017). The authors advocated that there is the need to more openly share ideas, knowledge, skills, resources and experiences and to more fully reconsider the ethical aspects textile production. This is a position echoed by Markou and colleagues, who pointed out that openly sharing knowledge improves environmental considerations in the early design stages (Markou, Segonds, Rio, & Perry, 2017). Fashion and textile design in the UK and Scotland is also analyzed by the already cited Smith and colleagues and by Coulson and Woods (Coulson & Woods, 2016; Smith et al., 2017).

Scholarly works that look at other industry sectors are more sparse. Some chapters of the book *Designing for the Circular Economy* (Charter, 2018) study circularity in relation to the industry of electrical and electronic equipment (Hilton, 2018; McIntyre, 2018; Wiens, 2018). Gallagher and colleagues

examined the innovation journey of a conservation charity (i.e., the largest landowner in the UK) while transitioning toward low-carbon energy. The paper particularly focuses on the systematic approach to the management of innovation adopted by the charity while combining open and design-driven innovation (Gallagher et al., 2018). Along the same lines, Morel and colleagues presented the case of an automotive company, in which an innovation community and its collective action to enable eco-innovation is leveraged (Morel, Unger, & Buet, 2016). The collaborative aspects of circular models are also the main area of focus of the literature review carried out by Watson and colleagues (Watson, Wilson, Smart, & Macdonald, 2018). The authors are interested in defining the capabilities needed to engage external stakeholders in environmental innovation and they identify three levels: specific operational capabilities (e.g., scientific expertise, manufacturing, technological and marketing capabilities); first-order dynamic capabilities to manage the engagement; and second-order dynamic capabilities “to make use of contrasting ways of seeing the world to reframe problems, combine competencies in new ways, and co-create innovative solutions (value framing), and to learn from stakeholder engagement activities (systematized learning)” (Watson et al., 2018, p. 254). Mont reflected upon product durability and looked into design strategies for increasing product life span (e.g., design for reuse and upgrading, for easy maintenance and easy replacement; design for remanufacturing; design for upgrading; mass-customisation; timeless design) and into concepts for increasing value of durables (e.g., shift from consumer ownership to producer ownership; shift from supply chain to value chain actor-networks) and optimising utilisation rate of consumer durables (Mont, 2008). The construct of product biographies is particularly helpful to look at servitization and at how to qualify - within a circular economy perspective - products for exchange or service value creation (Spring & Araujo, 2017). Haug specified the notion of ‘resilient design’ by offering a fine-grained classification of both causes of product replacement and organizing means to extend the longevity of products (Haug, 2018).

A quite ample number of papers focus on the need to explore and use different materials or use waste as a core development material (Appels et al., 2019; Gujel et al., 2014; Lilley, Smalley, Bridgens, Wilson, & Balasundaram, 2016; Ordoñez & Rexfelt, 2017; Peck, Kandachar, & Tempelman, 2015; Simões, Simoes, Carvalho, Pontes, & Bernardo, 2013; Tenhunen et al., 2018). As an example, Turrini looked at the tradition of using cardboard to make objects and furnishing as a way of activating short and circular production chains (Turrini, 2017).

The potential of design to intervene on the demand side

Some other authors more closely focused on how design interventions can affect the demand side, e.g., by nudging toward more circular behaviour (reduce, reuse, recycle) (Bofylatos, 2018) or by leveraging Design for Behaviour Change⁷ as a way to promote the transition to a circular economy

⁷ Design for Behaviour Change is concerned with how design can shape or influence human behaviour and sustainable innovation (Lockton, Harrison, & Stanton, 2010; Niederer et al., 2014).

(Piscicelli & Ludden, 2016). O'Connor pointed out that "a widespread behavioural change is required. Citizens need to act now and influence through their purchasing decisions, while educational institutes and governments need to immediately put the right mechanisms in place to enable a truly responsible, fair and just economy to be created" (O'Connor, 2018, p. 87).

Ackermann identified some factors that might influence customer behavior as regards repair and maintenance activities: the customers' ability to take care of the product (if they see it as easy or hard) and their motivations as linked to nine areas that are related to "the product itself (financial aspects, pleasure, functionality, aesthetics), the consumer (intrinsic motivation, rebellion against the brand policy) or the relationship between the consumer and the product (fit with the participant's identity, irreplaceability, shared ownership" (Ackermann, 2018, p. 5). In a similar vein, various authors explored how the dimensions of caring for one's possessions (e.g., affection, responsibility, commitment) play an important role in understanding the attitudes of end-users as regards ownership, disposal and reuse and, as such, can be taken into consideration by designers to extend the lifespan of objects (Baxter, Auricchio, & Childs, 2016; Bosserez & Verbeeck, 2018; Choi, Stevens, & Brass, 2018; Lilley, Smalley, Bridgens, Wilson, & Balasundaram, 2016). Vogt and Nunes reviewed some motivational factors for environmental behaviour, particularly examining a case study on recycling disposable plastics in six German hospitals (Vogt & Nunes, 2014). Results show that interventions that make it easier for everybody to efficiently handle waste at work (e.g., information from and feedback to staff, clear labelling and space for several waste bins, and eco-audits) are probable success factors that can drive toward more sustainable staff behavior.

Educational and communicational aspects are the central focus of other authors. Fassio described a website aimed at providing fine-grained information on food supply chains (Fassio, 2017). Such website provides a gamified environment in which end-users play the role of an entrepreneur and have to make choices as regards the supply chain (e.g., what kind of irrigation system to implement for their farm or what kind of ingredients to use when producing jam). Each of these choices potentially has consequences concerning the sustainability and circularity of the final product distributed to the market. Mugge and colleagues examined how visual information about prior use (e.g., signs of wear and tear and textual descriptions) has a negative effect on consumers' evaluations of refurbished electronics (Mugge, de Jong, Person, & Hultink, 2018). Vanhamäki and colleagues explored the opportunities of using information design to process and produce more understandable information about rural renewable energy possibilities and, consequently, to better meet the information needs of rural actors (Vanhamäki, Heinonen, Manskinen, & Kälviäinen, 2017).

The use of design to support policy and regulations oriented towards circular economy

Some other authors examined how design can support public administrations in creating policy actions and legislation that implement circular economy (e.g., D'Elia, 2018). Charter pointed that an important area of focus to develop more circular economies is in relation to "maximising materials value in the system for the longest time period, where waste is 'designed out' from the

beginning. This will mean that radical new policy frameworks will need to be developed to enable the extension of the life cycle of product-services and packaging and the components and materials within them" (Charter, 2018, p. 2).

Benoy and Lehne provided an overview of emerging developments in circular economy policy worldwide, showing the variety of policy tools across entire material and product value chains and life cycles (Benoy & Lehne, 2018). Keiller and Charter looked at how bottom-up community repair organisations - such as the repair cafes in the UK - have influenced policy-makers to design more repairable products (Keiller & Charter, 2018). Cooper explored some key components of economic infrastructure for sustainable product design (Cooper, 1999). Such infrastructure should take into account areas such as the way in which economic progress is measured, the potential of fiscal reform to change the relative cost of manufacturing and after-sales services, the environmental objections to industrial concentration and free trade, and the need to increase products designed for the least possible environmental impact.

Barbero and Bicocca reported on an Italian circular economy project that aims at fostering a design-driven and collaborative engagement of universities, local authorities, government offices, associations, public bodies in a joint attempt to adopt a more systemic view and a broader approach in territorial development (Barbero & Bicocca, 2017).

Other reflections on design theories and frameworks for circular economy

Last but not least, some other authors more broadly looked at the theoretical aspects of design for circular economy and proposed some general frameworks (i.e., not specifically related to the supply side, to the demand side or to regulation and policy). The already cited work of Ceschin and Gaziulusoy (2016) is a good entry point for theoretical considerations on how the various design for sustainability concepts refer to circular economy. Similarly, the work of Madge gives an extensive and historiographical review on design and its environment in all its definitions (Madge, 1993).

Coulson and Woods proposed a Circular by Design Canvas tool, developed to help SMEs think strategically about the application of circular approaches to their business (Coulson & Woods, 2016). Munthe-Kaas & Hoffmann (2017) looked at compositionist design as a way to create "things" - collectives of humans and non-humans (Telier et al., 2011) - and at how compositionist design can support public participation and inclusion of citizens in urban planning. One of the cases analyzed by the authors is a two-year experiment staged to develop knowledge, skills and practices for the management of a 'resource centre' based on the concept of circular economy. Cong and colleagues proposed a design method to improve end-of-use product recyclability through a sequence of steps that evaluate various end-of-use scenarios and then analytically define which components of a product are more suitable to be disassembled, recycled and reused (Cong, Zhao, & Sutherland, 2018). Mestre and Cooper presented a conceptual framework to identify various life cycle strategies in circular product design (Mestre & Cooper, 2017). Particularly, the framework is a way to look at technical cycles - i.e., "technical and/or technological use and transformation of material and energy

resources, and their design optimisation to the highest possible levels of efficiency" (p. S1624) - and at biological cycles - i.e., "the biological design solutions occurring in (or inspired) by the natural ecosystems, in which materials are cycled in nature over time" (p. S1624). The paper provides some examples on how this conceptual framework can be productively used to frame circular economy design interventions. Reitsma and colleagues explored the use of stories from the Climate Fiction genre as a dialogical tool to engage experts and various other stakeholders in the discussion of moral, ethical and societal issues in the transition towards a low emission society (Reitsma, Wessman, & Örnevall, 2017). Goldsworthy presented a framework that helps designers to better design circular fashion products while considering multiple rhythms and speeds within a product's entire lifecycle (e.g., slow and fast fashion speed) (Goldsworthy, 2017).

Siemieniuch and colleagues looked at how some global drivers (population demographics, food and energy security, resource depletion, emissions and global climate) are going to affect sustainability in manufacturing (Siemieniuch, Sinclair, & Henshaw, 2015). These drivers are going to push towards more circular models that will place higher demands on the workforce and their ability to manage complexity, large-scale and cross-disciplinary approaches and an increasing high number of virtual work platforms and extensive human-machine and human-system interactions. As such, a significant input from the fields of ergonomics and human factors is expected.

Discussion and final remarks

At this stage, we consider this survey of design research contributions that specifically focus on circular economy as preliminary and we hope that our effort might prompt other researchers in pointing to some of its shortcomings and, possibly, in working together with us on further versions of the review. In the meantime, we can share some considerations as emerged from the current review process and highlight some areas of interest.

The need to integrate different disciplinary fields while academic research is still at an emerging phase

While current discussions on the circular economy concept are prevalent in the policy and business development debate, academic research is still emerging and fragmented (Korhonen, Honkasalo, & Seppälä, 2018). Key concepts, frameworks and approaches of circular economy still need more in-depth and critical discussions as the "basic assumptions concerning the values, societal structures, cultures, underlying worldviews and the paradigmatic potential of circular economy remain largely unexplored" (Korhonen, Nuur, et al., 2018, p. 544). The literature in design research proposes a variety of studies surveying existing cases and proposing frameworks and methods, but it often lacks deeper theoretical considerations elaborated by closely linking research across as diverse domains as natural and social sciences. As such, the risk is that within design research the concept of circular economy becomes "reified" (Lane, Koka, & Pathak, 2006), i.e., taken for granted and used without taking in consideration the critique that circular economy has received in other disciplinary fields. As an alternative, we suggest a deeper investigation of circular economy across disciplinary domains as a way to introduce a richer - and, possibly, more shared - vocabulary to look at the phenomenon.

Beyond the simplistic idea of circular economy as a holy grail

Various authors pointed to the links between some of the current approaches toward circular economy and the dominant neoliberal political and economic landscape (Ceschin & Gaziulusoy, 2016). As such, circular economy has been seen as a way to develop more sustainable business models and entrepreneurial processes, possibly laying the foundations for renewed growth-driven economic strategies (Valenzuela & Böhm, 2017). Circular economy, in other terms, can be seen as a way to decouple economic growth from environmental impact (Ghisellini et al., 2016). Design researchers should more clearly acknowledge such critique and position their work against this political background.

Underexplored areas in current research

Our review showed that current research has some preferred areas of investigation. A good number of contributions explore how design can optimize the supply side and the demand side. However, fewer contributions look into how design can contribute to better policies and regulations. In addition, there seems to be a higher number of contributions studying specific geographic areas (e.g., the UK) or industry sectors (textile and fashion or consumer electronics). Future research might want to look into currently underexplored areas.

Harmonization of frameworks and methods

A number of authors proposed theoretical frameworks or methods to support more circular design. A deeper review of such frameworks and methods will probably help design researchers and practitioners in assessing their potential and limitations and possibly improving the existing frameworks and methods rather than always proposing new ones. A more harmonized theoretical and methodological array of possibilities could be of great support for those education programmes that want to embed circular economy in their curricula.

Going beyond the construct of circular economy

An obvious limitation of this article is that it only reviewed those contributions that contain the words 'circular economy'. Readers who are familiar with the past decades of design studies broadly related to environmental sustainability might feel that some of the more recent scholarly contributions use the construct of circular economy to re-state what has been already said in past literature using different constructs. By acknowledging this limitation, we invite future research in extending the gaze and looking at the rich scholarly heritage in this area as to put in a wider context the novelty and the relevance of some current contributions exploring the notion of circular economy.

Acknowledgments

We would like to thank the reviewers for their insightful comments and the entire DESIGNSCAPES consortium for their support and collaboration. The research leading to this contribution has received funding from the European Union's H2020 Programme under Grant Agreement No. 763784. This article

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