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The Circular Sprint: Circular business model innovation through design thinking

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ABSTRACT

The process of developing sustainable and circular business models is quite complex and thus hinders their wider implementation in the market. Further understanding and guidelines for firms are needed. Design thinking is a promising problem solving approach capable of facilitating the innovation process. However, design thinking does not necessarily include sustainability considerations, and it has not been sufficiently explored for application in business model innovation. Given the additional challenges posed by the need for time-efficiency and a digital environment, we have therefore developed a design thinking-based framework to guide the early development of circular business models in an online and efficient manner. We propose a new process framework called the *Circular Sprint.* This encompasses seven phases and contains twelve purposefully adapted activities. The framework development follows an Action Design Research approach, iteratively combining four streams of literature, feedback from sixteen experts and six workshops, and involved a total of 107 participants working in fourteen teams. The present paper describes the framework and its activities, together with evaluations of its usefulness and ease-of-use. The research shows that, while challenging, embedding sustainability, circularity and business model innovation within a design thinking process is indeed possible. We offer a flexible framework and a set of context-adaptable activities that can support innovators and practitioners in the complex process of circular business model innovation. These tools can also be used for training and educational purposes. We invite future researchers to build upon and modify our framework and its activities by adapting it to their required scenarios and purposes. A detailed step-by-step user guide is provided in the supplementary material.

1. Introduction

In recent years the circular economy (CE) has been promoted as a potential solution in the urgent transition to a more sustainable economic system (Schroeder et al., 2019; Velenturf and Purnell, 2021), however, in practice, the implementation of sustainable and circular business models continues to remain relatively low (Bocken et al., 2017; OECD, 2019). This is also reflected in the ongoing call for more sustainability-oriented innovation tools and comprehensive business model innovation process frameworks, which is itself a reaction to the relative complexity of operationalizing CE-based ideas and the lack of practical guidelines for firms (Blomsma and Brennan, 2017; Kalmykova et al., 2018; Pieroni et al., 2019a). Design thinking (DT) is an innovative problem solving approach with the potential for supporting sustainability-oriented processes, such as the development of circular business models (CBM) (Buhl et al., 2019). DT-based frameworks have gained popularity in recent years as they have proved useful in addressing complex challenges, where a multidisciplinary team is guided through a collaborative and iterative process of understanding, ideating and testing (T. Brown, 2008; Carlgren et al., 2016b). Even though the support of DT has been explored in the development of CE-based ideas, DT research and practice have tended to focus more on product-level innovation (IDEO and Ellen MacArthur Foundation, 2017), or on specific elements of the CBM - e.g. circular value

Abbreviations: CE, Circular Economy; DT, Design Thinking; BM, Business Model; BMI, Business Model Innovation; CBM, Circular Business Model; CBMI, Circular Business Model Innovation; SBMI, Sustainable Business Model Innovation; DSR, Design Science Research; AR, Action Research; ADR, Action Design Research; BIE, Building, Intervention and Evaluation; IM, Interpolated Median.

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proposition (P. Brown et al., 2021). Furthermore, the few frameworks that offer guidance for an end-to-end circular business model innovation process (Guldmann et al., 2019; Shapira et al., 2017) remain rather explorative, thus inviting future research on the topic. This is particularly relevant as firms are now often faced with a highly dynamic business environment in which innovation at the business model level has become a key question of competitive advantage (Verma and Bashir, 2017) – or even of survival (Breier et al., 2021), and where the degree of time efficiency may determine the success or failure of an innovation process (Eisenhardt and Brown, 1998). In addition, one also needs to consider that online collaboration and digital transformation have become key organizational capabilities in recent years, and that this ongoing trend has been accelerated as a result of the COVID-19 pandemic (Kudyba, 2020).

Given the above challenges, the present study addresses the following research question: *How can design thinking be applied to guide time-efficient, early development of CBMs within an online collaboration context?* Following an action design research approach (Sein et al., 2011), we have developed a process framework by iteratively combining DT and circular business model innovation (CBMI) literature, feedback from sixteen experts, and data from six workshops involving a total of 107 participants. The research process resulted in what can be described as a "Design Thinking Sprint for Circular Business Model Innovation", which we henceforth refer to as *Circular Sprint*. The resulting proposal includes twelve activities, purposefully adapted and combined, to be used throughout seven distinctive DT phases. The framework was developed in alignment with the eight sustainable business model innovation (SBMI) criteria synthesized by Breuer et al. (2018) and in alignment with the ten criteria for CBMI tool development compiled by Bocken et al. (2019).

The paper is structured as follows: key concepts and previous related research is presented in section 2. Section 3 details the action design research approach and the applied research process, and is then followed by section 4, in which the *Circular Sprint* and its evaluation are described. In section 5, we discuss the challenges of embedding sustainability and a BMI-orientation into a DT process. Section 6 provides final conclusions and a summary of practical and theoretical contributions.

2. Theoretical background

2.1. Design thinking

Design thinking (DT) is an approach to innovation and creative problem solving that "uses designer's sensibility and methods to match people's needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity" (T. Brown, 2008, p. 2). DT is often presented as having the potential to tackle complex or *wicked* problems (Buhl et al., 2019; Carlgren et al., 2016b), and as being well-suited for use in contexts exhibiting high levels of ambiguity or uncertainty (Liedtka, 2015). It is characterized by the themes of problem framing, user focus, visualization, experimentation and diversity (Carlgren et al., 2016b), and emphasizes observation, collaboration, fast learning, rapid concept prototyping and experimentation (Martin, 2009; Micheli et al., 2019). DT is used to guide a multidisciplinary team through a collaborative, stakeholder process and makes use of abductive reasoning, where rationality and intuition are blended (Martin, 2009; Micheli et al., 2019). It also adopts a gestalt approach, attempting to consider any problem and its possible solution as part of a wider system (Micheli et al., 2019).

Even though different DT frameworks exist, most are based on three main iterative stages, each of which entails alternating between divergent and convergent thinking. Such frameworks begin with a process of exploration, whereby the goal is to *understand* the problem to be solved. This is followed by the *ideation* stage, where potential alternatives are generated. The final stage entails an implementation and *testing* phase based on prototyping and iteration (Liedtka, 2015; Micheli et al., 2019). Most authors emphasize the use of several tools and methods in order to embed the above DT attributes throughout the DT phases (Lewrick et al., 2018). The most common of these are ethnographic methods, personas, journey maps, brainstorming, mind maps, visualization, prototypes and field experiments (Micheli et al., 2019).

Over the past decade, DT has attracted increased attention and has transitioned from merely being an innovation buzzword to becoming a widely adopted practice (Liedtka, 2015; Micheli et al., 2019). It started as an innovative product design approach and was also widely applied in process and service innovation. As its popularity grew it was tested in different areas of organizations, even at the strategic level (Kolko, 2015; Liedtka, 2015). To date, however, its application in business model innovation processes has remained rather scarce (see e.g., Bonakdar and Gassmann, 2016; He and Ortiz, 2021).

DT provides a flexible framework, and may be applied in innovation processes lasting from a few hours to a few months. However, considering the limited time available in practice, and given that time-pacing is essential for an innovation's success (Eisenhardt and Brown, 1998), a prescriptive five-day DT approach named the *Design Sprint* has gained momentum in recent years (Dell'Era et al., 2020; Mendonça de Sá Araújo et al., 2019). This detailed step-by-step approach, developed within Google Ventures, aims "to solve big problems in just five days" (Knapp et al., 2016), starting from a real problem and finishing with a user-tested prototype. This approach has lately been adopted and adapted by others, for instance, in the four-day *Design Sprint 3.0* version by Design Sprint Academy (Vetan, 2019).

2.2. Circular business model innovation

The circular economy (CE) represents an alternative to the embedded take-make-waste pattern in today's economy, which has been promoted as an effective contribution to sustainable development (Geissdoerfer et al., 2017; Schröder et al., 2020). The CE is a regenerative industrial system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops, in order to keep products, components and materials at their highest utility at all times (Geissdoerfer et al., 2017; Webster, 2015). One of the key aspects required for a transition to a CE is the development and scaling-up of business models rooted in CE strategies, i.e., circular business models (CBM) (Ellen MacArthur Foundation, 2014). The process of creating a business model which embeds, implements and capitalizes on CE practices is known as circular business model innovation (CBMI) (Bocken et al., 2019). CBMI covers the creation of a circular start-up, the transformation of a business model into a circular one, the diversification of a firm when developing an additional CBM, as well as the identification and acquisition of an external CBM (Geissdoerfer et al., 2020).

The process of CBMI is a complex innovation challenge that may even involve changing the key building blocks of a business model (BM) and navigating against dominant business paradigms (Bocken et al., 2019). It is a process with embedded uncertainties (Linder and Williander, 2017) and for which an experimental approach has been widely recommended (Bocken et al., 2021). Furthermore, as the implementation of most CBMs requires collaboration across multiple stakeholders (Blomsma et al., 2019; P. Brown et al., 2020, 2021; Santa-Maria et al., 2021c, 2022), a boundary-spanning perspective of the BM is often called for (Breuer et al., 2018). Effective CBMI processes require firms to embrace both a life cycle and a systemic thinking perspective in order to identify potential challenges and opportunities (Centobelli et al., 2020; Santa-Maria et al., 2022). This is complemented well by the use of backcasting and the application of eco-design principles (Mendoza et al., 2017; Vergragt and Quist, 2011).

It is important to clarify that, due to the existence of trade-offs and rebound effects (Geissdoerfer et al., 2017; Zink and Geyer, 2017), increased circularity does not necessarily imply improved sustainability.

Thus, in order to generate business models that effectively improve the sustainability of a system, and to view CBMI as a subset of sustainable business model innovation (SBMI), a CBMI process still needs to be guided by sustainability criteria (Geissdoerfer et al., 2018; Guldmann and Huulgaard, 2019). In aligning the developed framework, the present paper draws on Breuer et al. (2018) who identified four guiding principles for SBMI (i.e. sustainability-orientation, extended value creation, systemic thinking and stakeholder integration), and four SBMI process-related criteria (i.e. reframing business model components, context-sensitive modelling, collaborative modelling, and managing impacts and outcomes) (Breuer et al., 2018).

Given the considerable challenges involved in conceptualizing and implementing novel business model configurations, numerous tools to facilitate the process have been proposed, such as the widely used business model canvas (Osterwalder and Pigneur, 2010). These tools can be found in both the traditional management literature and on the grey, practitioner-oriented literature (Heikkilä et al., 2016; Massa and Tucci, 2014; Täuscher and Abdelkafi, 2017). Furthermore, as in recent years sustainability and the CE have received increasing attention, a considerable number of sustainability-oriented innovation tools to support the SBMI or CBMI process have also been proposed (Bocken et al., 2019; Breuer et al., 2018; Pieroni et al., 2019a). However, many authors urge the development of approaches that address SBMI and CBMI as a continuous/holistic process, approaches which integrate CBMI, SBMI and traditional BMI, and which adapt/customize existing tools to fill the research gaps identified (Pieroni et al., 2019a). This is all addressed in the present paper. Furthermore, the present research draws on best practice and takes account of the 10 criteria for CBMI tool development compiled by Bocken et al. (2019). In their review of CBMI innovation tools Bocken et al. suggest that such tools be (i) purpose-made for CBMI, (ii) rigorously developed on the basis of research and practical insight, (iii) iteratively developed with potential users, (iv) integrate cross-disciplinary knowledge, (v) tested and assessed by practitioners. They also suggest (vi) that transparent guidance on tool use be provided, (vii) that CE and sustainability objectives be firmly integrated, (viii) that the tool be simple to use and not time-consuming, (ix) that it inspires or triggers change and (x) that it be adaptable to different contexts.

2.3. Circular business model innovation through design thinking

Based on the information provided in sections 2.1 and 2.2, DT appears to be a well-suited approach to dealing with the challenges of CBMI. It clearly facilitates the guidance of multi-stakeholder collaboration and experimentation process, is capable of collecting lifecycle or system-wide insights, and supports the ideation, testing and refinement of CE-based ideas. However, as previously mentioned, CBMI requires that (i) solutions be framed at the BM level - beyond that of product or service level innovations-, (ii) that CE strategies are embedded with the novel BM, and that (iii) SBMI principles are employed to generate positive sustainability outcomes. These three aspects are not necessarily considered in conventional DT processes (Garcia and Dacko, 2016; Shapira et al., 2017). Nevertheless, DT has still been found to be suitable in guiding sustainability-oriented innovation processes, as in Geissdoerfer et al. (2016) *Sustainable Value Ideation process*, Baldassarre et al. (2017) *Sustainable Value Proposition Design* and other studies (P. Brown et al., 2021; He and Ortiz, 2021). Furthermore, both Buhl et al. (2019) and Kagan et al. (2020) discuss how and why DT can foster sustainability-oriented innovation, for instance, by arguing how experimentation and visualization in DT support the aim of positive sustainability outcomes, how DT integrates diverse perspectives through the involvement of intra and extra-organizational stakeholders, and suggesting the use of "sustainability checkpoints" in the process, aligned with the recommendation of Hansen and Große-Dunker (2013).

There are, in particular, two previous proposals for integrating DT and SBMI/CBMI that we have taken into consideration in our approach. First, Guldmann et al. (2019) offered a *DT framework for CBMI*, and suggested modifying the user-centric DT focus such as to incorporate a systemic perspective, thus expanding the focal point from users and cross-organizational collaboration in order to cover systems and value chain collaboration. This is in fact in line with Kagan et al.'s (2020) criticism of DT. Guldmann also proposes adding an introductory stage in the DT process, in order to better present CE principles and inspire action, a proposal similar to that made by Bocken et al. (2013), in the context of their *Value Mapping Tool* for SBMI. Secondly, Shapira et al. (2017) suggested the *integrated sustainable DT process* which, in comparison to a conventional DT process, has 20 add-ins, and is guided by the framework for strategic sustainable development (FSSD) (Broman and Robèrt, 2017). However, both studies are described as explorative, and thus leave room for future refinements.

Two additional challenges not sufficiently explored in sustainability-oriented DT adaptations are also considered in this research. First, how to deal adequately with the fast-pace of industry and the limited time availability of stakeholders (Eisenhardt and Brown, 1998). There is thus a clear need to design time-efficient approaches of limited duration. And second, that previous studies did not focus adequately on adapting facilitation processes to a digital collaboration environment, which has become an increasing necessity due to the COVID-19 pandemic (Kudyba, 2020).

The framework that is developed in the present study attempts to address the above limitations by purposefully considering the following: (i) embedding sustainability and (ii) embedding circularity, (iii) aiming for outputs at the BM level, (iv) addressing the whole DT cycle, (v) considering stakeholders' time-constraints, and (vi) adapting to an online collaboration context. Table 1 provides a comparison with selected DT-based approaches.

3. Method

3.1. Research design

To answer the research question *How can design thinking be applied to guide time-efficient, early development of CBMs within an online collaboration context?,* an action design research (ADR) method was selected. ADR combines design science research (DSR) with action research (AR), two compatible research methods that aim to advance scientific understanding and solve real-world problems (Collatto et al., 2018). On the one hand, DSR stems from the design science paradigm, aiming at developing prescriptive design knowledge by creating and assessing innovative artifacts that are designed to solve a class of problems (Collatto et al., 2018; Dresch et al., 2015). On the other hand, AR originates from the natural and social sciences, and seeks to solve or explain problems of a system by iteratively involving researchers and practitioners in a cooperative and participatory way, thus generating knowledge for practice and theory (Collatto et al., 2018; Dresch et al., 2015).

In traditional DSR approaches the recognition of a problem precedes the development of the artifact and is then followed by an evaluation. This sequential approach might limit the artifact's organizational relevance, as it pays scant attention to how the artifact is (or should be) shaped by the organizational context, emerging from the interaction between design and use (Sein et al., 2011). As a response to this limitation, ADR has emerged as a "research method for generating prescriptive design knowledge through building and evaluating ensemble artifacts in an organizational setting" (Sein et al., 2011, p. 40). Thus, ADR was selected owing to its capacity to guide the rigorous development of an artifact that is organizationally relevant, e.g., the *Circular Sprint* framework and its tools, while still supporting the generation of knowledge (See section 3.2 for detailed ADR process).

ADR is characterized by four stages. The first is a problem formulation stage, where a problem is perceived or anticipated, initial research questions are formulated, and the bases and contributions from theory and practice are identified (See sections 1 and 2). The second stage encompasses iterative cycles of *building* the artifact, *intervention* in

Table 1
Comparison of selected design thinking-based approaches. "+": characteristic is present; "(+)": characteristic may be present, depending on the use case.

	Generic DT frameworks (e.g. Brown, 2008; Liedtka, 2015)	Design Sprint (Knapp et al., 2016)	**Sustainable Value Ideation process (Geissdoerfer et al., 2016)**	**Sustainable Value Proposition design (Baldassarre et al, 2017)**	Integrated Sustainable DT process (Shapira et al., 2017)	**DT framework for CBMI (Guldmann et al, 2019)**	Circular Sprint (Present study)
(i)Sustainability embedded			+	+	+		+
(ii) Circularity embedded						+	+
(iii) BM level outputs	(+)		(+)	(+)		+	+
(iv) Full DT process	+	+	+	(+)	+	+	+
(v) Time-efficient		+					+
(vi) Online format	(+)	(+)					+

organizational settings and *evaluation* (i.e., BIE cycles), where the outcome is the resulting design of the artifact. This highly participatory stage involves researchers, practitioners and end-users (See section 3.2 for the BIE cycle and section 4 for developed artifact). The third stage of reflection and learning is undertaken continuously and in parallel to the first two stages, and calls for consciously reflecting upon how the developed solution generates learning applicable to a broader class of problems (See Section 5 for key reflections). Finally, the objective of the fourth stage is the formalization of learning, by abstracting insights into generalizable outcomes and by sharing and disseminating results (Sein et al., 2011). Guided by the ADR approach the results of the testing of the *alpha* version of the *Circular Sprint* were presented at an academic conference (Santa-Maria et al., 2021a), and reflections on the application of the *gamma* version were revealed at a second conference (Santa-Maria et al., 2021b). The final *delta* version of the framework is presented here, and is complemented by the *Circular Sprint User Guide* that can be found in the supplementary material.

3.2. Research process

The applied ADR process entailed iterating between literature review, expert feedback and a series of workshops that involved a total of 14 teams and 107 participants. The procedure is described in the next few paragraphs, and a summary of the BIE stage of the ADR process can be found in Fig. 1. The workshops are described in Table 2.

Once the initial problem and research question were formulated (see sections 1 and 2), an initial exploration of the literature was undertaken to design the first version of the framework. This involved combining four key streams of literature, namely (i) conventional DT frameworks (T. Brown, 2008; Lewrick et al., 2018; Liedtka, 2015; Micheli et al., 2019), (ii) the design sprint process (Knapp et al., 2016), (iii) selected best practices and tools from the conventional BMI field (Heikkilä et al., 2016; Massa and Tucci, 2014; Täuscher and Abdelkafi, 2017), and (iv) innovation approaches from the SBMI and CBMI literature (Bocken et al., 2019; Pieroni et al., 2019b). The initial draft framework was discussed by the present authors and feedback was requested from six experts in innovation, design thinking or circular economy (see Table 4 for list of experts). The experts were contacted through the present authors' network. This led to the design of the *alpha* version of the *Circular Sprint* framework. This was initially piloted in an internal 3-h workshop with seven academics. Soon after, the model was tested in a 6-h workshop with 39 sustainability professionals (i.e., 30 researchers, 6 private sector practitioners, 2 public sector representatives and 1 non-profit employee) working in five parallel groups within an academic conference, with the aim of generating CE-based solutions to improve the sustainability of urban mobility in the city of Graz. This session provided input for developing the *beta* version. Selected activities of the framework were then tried out in two separate 3-h workshops with master's

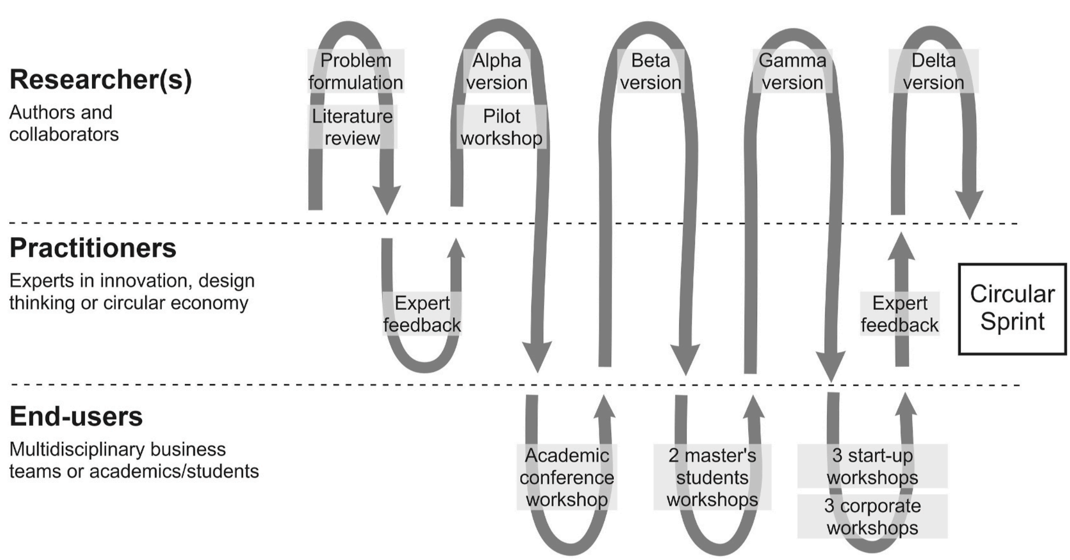

Fig. 1. The building, intervention and evaluation (BIE) stage of the action design research process applied to develop the Circular Sprint, adapted from (Sein et al., 2011).

Table 2
Description of test workshops during the Circular Sprint development cycles.

	Pilot test	Academic conference	Master's students 1	Master's students 2	Start-up	Corporate project	Total
Dates	Sep. 2020	Sep. 2020	Dec. 2020	Feb. 2021	Feb. 2021	Mar. 2021	
N° participants	7	39	29	20	4	8	**107**
N° teams	1	5	4	3	1	1	**14**
Duration	3:00	6:00	3:00	3:00	3 x 4:00	3 x 4:00	**38:50**
N° activities	5	6 + CE intro.	4 + CE intro.	5 + CE intro.	12 + CE intro.	12 + CE intro.	
N° feedback surveys		21	7	10	4	2	**44**

level students from the University of Graz (Austria) and from Han University of Applied Sciences (Netherlands). 29 and 20 students working in four and three parallel groups, respectively, collaborated in generating BMs to improve the circularity and sustainability of four, and three, real case studies. Their feedback led to the refinement of the *gamma* version. Subsequently, the two most relevant and comprehensive interventions were undertaken, each of them lasting three half-days and going through seven DT-phases and twelve sequential activities. First, a circular start-up that developed a proprietary technology to produce bio-plastics out of residual waste from the milk production process was supported in developing its initial business model. The participants were a multidisciplinary team of four persons (i.e., CEO, trainee, advisor and mentor). Second, a collaborative corporate project that aimed to develop technologies for electric-vehicle battery second-life applications was supported in the conceptualization of business model alternatives. The participants were eight employees from five consortium organizations. Finally, a practitioner-oriented user guide of the *Circular Sprint* and its 12 activities, detailing the tools and application steps, was developed and shared with thirteen selected experts on innovation, design thinking and circular economy, who were then asked to provide feedback (see Table 4 for list). The inputs for the start-up and corporate workshops, and the expert feedback allowed us to refine the process framework and the tools so as to form a *delta* version of the *Circular Sprint*. This is presented in section 4 (see supplementary material for the final version of the *Circular Sprint User Guide*).

The workshop structure was adapted to suit each use case and to match the time availability of participants. This resulted in a variety of combinations of activities, as can be seen in Table 3. Throughout the 6 workshops and expert feedback sessions data was collected via anonymous participant surveys, workshop documentation and researcher/facilitator notes. This provided the relevant input for refining and improving the framework and tools throughout the BIE stage. The participant survey employed a 5-point Likert scale, and requested feedback on the perceived usefulness and ease-of-use of each activity, described in literature as determinants of user acceptance (Davis, 1989; Venkatesh et al., 2003). This was complemented by open-ended questions. In addition, the final expert survey asked for responses on the extent to which Circular *Sprint* goals were met (see survey results in section 4.2). The first author of this study was the main facilitator of every workshop, supported by additional researchers previously trained in the method applied. All workshops were performed online, combining the use of a video platform (i.e., Zoom, MS Teams or BigBlueButton) and the online visual collaboration platform Miro, which supported the templates/canvasses for all activities. The approach described here is consistent with the 10 criteria of the CBMI tool development checklist suggested by Bocken et al. (2019).

4. Results

This section is divided into two parts. First, the final version of the *Circular Sprint* framework and the twelve activities, which were purposefully adapted and combined, are succinctly presented (a detailed step-by-step guide can be found in the supplementary material). Secondly, the empirical results of the building, intervention and evaluation (BIE) stage of the *Circular Sprint* development process are presented, including the end user results and the practitioner feedback surveys.

4.1. Developed artifact: The Circular Sprint

The action design research approach applied in the present research resulted in the development of the *Circular Sprint* framework and its twelve tools (see Fig. 2 and Table 5). This is a conceptual process model based on design thinking that can guide practitioners in the early development of a CBM, in a time-efficient manner and in an online context. It is an adaptable framework that can be applied in different situations, from supporting a start-up engaged in the initial conceptualization and testing of a CBM, to assisting a large firm aiming to diversify or transform its current business models toward the CE. This working framework may be adapted for face-to-face or hybrid contexts with limited additional effort, and the tools and activities provided are

Table 3
Activities included and tested in each workshop, shown by a "+". "*" indicates that the activity was excluded in the final version of the *Circular Sprint*.

DT Phase	Activity	Pilot test	Academic conference	Master students 1	Master students 2	Start-up	Corporate project
Prepare	Problem framing					+	+
	Background research					+	+
Inspire	CE introduction			+	+	+	+
	Vision co-creation					+	+
Understand	Expert lightning talks*		+				
	Context scan					+	+
	Actor system mapping*	+	+				
	Value chain mapping			+	+	+	+
	Customer profile					+	+
Define	How might we?	+	+			+	+
Ideate	Ideating with CBM patterns	+	+	+	+	+	+
	Simplified BM canvas		+			+	+
Decide	FSSD SWOT*	+	+				
	Sustainability scan				+	+	+
Prototype	Value exchange mapping					+	+
	CBM canvas	+		+	+	+	+
Test	Assumptions mapping					+	+
	Test cards					+	+
Present	Pitch*		+	+	+		

Table 4
List of experts that provided feedback during the development of the *Circular Sprint*.

Position	Organization	Expertise in	Initial feedback	Final feedback
Circular Economy Consultant	Land Steiermark	Innovation/ Circular Economy	+	+
Managing Partner & Senior Consultant	Puentte Design	Design Thinking/ Innovation	+	+
Innovation Manager	Green Tech Cluster	Innovation	+	
Associate Lecturer-Entrepreneurship & Design Thinking	Australian National University	Design Thinking/ Innovation	+	
PhD Student	University of Technology Troyes	Circular Economy	+	
PhD Student	University of Graz	Circular Economy	+	+
Co-Founder & CEO	Circonnact	Circular Economy/ Design Thinking		+
Program Lead Sustainability by Design	Fronius International	Circular Economy/ Design Thinking		+
Chief of Social Innovation	Universidad de los Andes	Design Thinking/ Innovation		+
Founder	Innodriven	Design Thinking/ Circular Economy		+
Founder	Innodriven	Innovation/ Circular Economy		+
Circular Economy Expert & Research Associate	Johannes Kepler Universität Linz	Circular Economy/ Innovation		+
PhD Student	University of Graz	Circular Economy/ Design Thinking		+
PhD Student	University of Graz	Circular Economy/ Design Thinking		+
PhD Student	University of Graz	Circular Economy		+
PhD Student	University of Graz	Circular Economy		+

also adaptable in order to meet specific needs. Although individual activities may be used in isolation for specific innovation purposes the strength of the *Circular Sprint* lies in its sequenced and iterative application of exercises. The present paper illustrates those activities which we found to work best. However, we invite researchers to continue with the framework refinement process in future studies.

The final framework presented here, the *Circular Sprint* - or Design Thinking Sprint for Circular Business Model Innovation - consists of a pre-workshop *prepare* phase, followed by seven distinctive DT phases i.e., *inspire, understand, define, ideate, decide, prototype* and *test*. The *prepare* phase consists of a problem framing session - recommended to be done at least two weeks before main workshop sequence -, and it is complemented by background research activities. The core of the framework begins with a CE introduction session, and it is followed by a sequence of twelve collaborative activities. The recommended order of the activities, their respective DT phases and a summary description (including key references) can be found in Fig. 2 and Table 5. Please see the supplementary material for a detailed practitioner-oriented step-by-step guide, including a copy of the exercise canvases supported in the online visual collaboration platform Miro. The activities were selected based on a review of the relevant literature (see Section 2) and were customized to comply with our objectives and the need for online execution. The activities selected, as well as their combinations and details, were refined iteratively using the ADR process described in section 3.

4.2. Artifact evaluation: feedback survey results

Throughout the BIE cycles of the *Circular Sprint* development process, the framework and its exercises were repeatedly evaluated, thus providing input for refinement and user acceptance assessment. The qualitative content collected in feedback surveys and facilitator notes supported the modifications made to each activity. As an example, the improvements made to the *Value chain mapping* activity and their rationale can be found in Table 6. Explaining in detail how each activity evolved throughout the process, and complete itemization of feedback inputs is beyond the scope of the present paper. However, the following paragraphs present a summary of the most relevant quantitative feedback results, focusing on the overall framework evaluation.

The user acceptance of each activity was assessed in terms of its perceived usefulness and ease-of-use (Davis, 1989; Venkatesh et al., 2003), and was evaluated through close-ended survey questions sent to all workshop participants using a 5-point Likert scale. Cumulative results for each activity are presented in Figs. 3 and 4 and show the percentage of answers per category (from "1 = strongly disagree" to "5 = strongly agree"). Central tendency is indicated by the interpolated median value (IM), a descriptive statistic that adjusts the value of the median (up to ±0,5 in this case) in the direction in which the data are more heavily weighted, and is suitable for presenting the results of ordinal data with few alternatives, such as those depicted on Likert scales (Gallego et al., 2008; Schweiger et al., 2019).

The usefulness of activities received a positive evaluation overall with 89% of answers being "agree" or "strongly agree", and a total IM of 4.36 (see Fig. 3). The activities that were perceived as being more useful were "Assumptions Mapping", "CBM canvas", "Context scan" and "Value exchange mapping"; and those deemed less useful were "Customer profile", "Simplified BM canvas", "Sustainability scan" and "Vision co-creation". Similarly, the ease-of-use of activities was positively evaluated overall with 90% of answers being "agree" or "strongly agree" and a total IM of 4.35 (see Fig. 4). Those activities receiving an evaluation of 'more easy-to-use' were the "Ideating with CBM patterns", "Sustainability scan" and "CBM canvas"; and those appraised as less easy-to-use were "How might we", "Simplified BM canvas" and "Test cards".

The comparison of the feedback results from individual workshops (see detail in Table A1 in Appendix) points to the relevance of adapting the combination of activities to each use case. For instance, "Customer profile", "Simplified BM canvas" and "Sustainability scan" received low usefulness evaluations for the corporate project case (IM of 2.0, 2.5 and 3.5, respectively), while they were high for the start-up case (IM of 4.5, 4.83 and 4.83, respectively). This may be explained by the fact that the corporate project case pertained to refining an initial BM concept with existing customer prospects, and was related more to profitability than to sustainability. In contrast, the start-up BM concept had no clearly identified customers and placed a strong focus on sustainability issues.

As an indication of overall satisfaction with the structure of the framework, the feedback survey also asked whether participants agreed that "activities were complementary, non-redundant and presented in the best possible order". This resulted in a positive evaluation (IM = 4.68) (Table 7). In addition, participants were asked about their level of agreement with the statement "virtual setting improved outcomes compared to a face-to-face workshop". The responses here were almost neutral overall (IM = 3.09), though they exhibited considerable variability (range = 4).

The final expert feedback survey (n = 9) was designed to obtain an

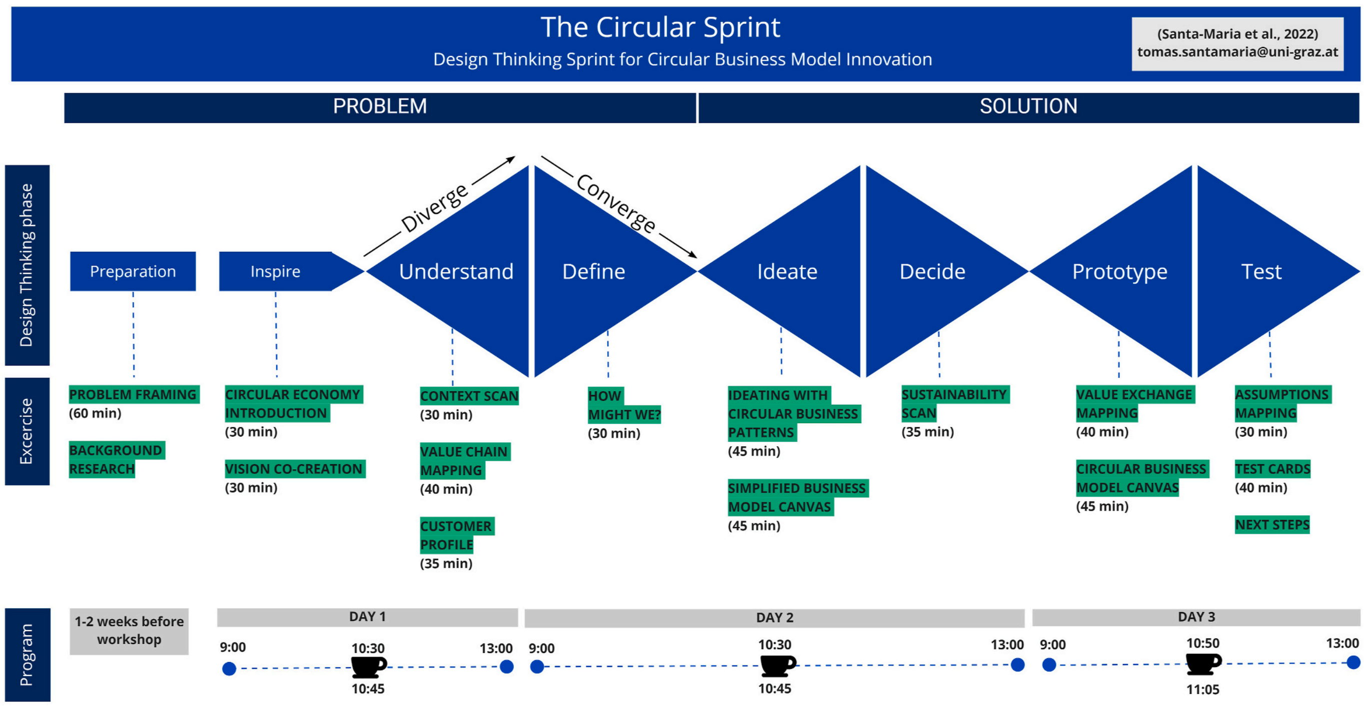

Fig. 2. The Circular Sprint framework. The figure contains the process phases, the activities, and a proposed timeline, which may be adapted according to the use case.

indication of the extent to which the *Circular Sprint* complied with its main objective (i.e., supporting early-stage CBM development) and its six desired key characteristics (see Table 1). The results are presented in Table 8. The results suggest that, according to expert opinion, the main objective of the framework is strongly supported (IM = 4.4), and indicates a positive evaluation of the six key characteristics. Experts considered that the characteristic best achieved was the adaptation to an online environment, followed by that of effectively addressing all stages of a DT process, and that of successfully embedding sustainability and circularity in the process. Nevertheless, the characteristics that according to expert opinion were less achieved are the effective generation of outputs at the business model level and time efficiency, although opinions diverged considerably on the latter (Range = 3).

5. Discussion

Following the ADR approach, and in parallel with the BIE development phase of the *Circular Sprint,* a continuous reflection and learning phase was undertaken, reflecting on how the developed solution generated learning applicable to a broader class of problems. The key reflections are now presented below.

5.1. Sustainability-oriented innovation through design thinking

Prior to the present study, one of the key criticisms made of conventional DT frameworks was that they only embed sustainability when the user deliberately chooses to do so (Garcia and Dacko, 2016; Shapira et al., 2017). Thus, throughout the development of the *Circular Sprint* framework, we concluded that this aspect needed to be made the basis of our DT approach if it were to be of any use in guiding a sustainability-oriented innovation process. This required augmenting the three conventional innovation lenses guiding DT innovation processes, i.e., desirability, feasibility and viability (T. Brown, 2008), by a fourth lens of sustainability (see Fig. 5).

Furthermore, we argue that sustainability should be considered as a guiding principle throughout the whole process, rather than merely being expressed in some form in the outcome. In other words, instead of merely being perceived as an additional constraint, sustainability considerations need to be viewed as an opportunity throughout the innovation process. Such an approach enables sustainability to drive innovation by opening up space for new ideas - during divergent thinking phases – or by directing the filtering of proposed solutions - during convergent thinking phases (Shapira et al., 2017; Thompson et al., 2011).

Embedding sustainability and circularity in a DT innovation process has proven to be possible but challenging, as attested through our research and by previous experiences (Baldassarre et al., 2017; P. Brown et al., 2021; Geissdoerfer et al., 2016; He and Ortiz, 2021). We argue that the most relevant difference between conventional DT approaches and those entailing a sustainability orientation (or circular economy orientation) is the shift away from a user-centric focus to a more systemic/holistic perspective. The latter approach expands the focal point from end customers to systems and from cross-organizational collaboration to value chain collaboration, aligned with Guldmann et al. (2019) and Kagan et al. (2020) proposals. In addition, it complies with the Breuer et al. (2018) SBMI requirements for systemic thinking and stakeholder integration.

As mentioned in section 2, the *Circular Sprint* approach outlined here aims to fulfil each of the eight SBMI criteria proposed by Breuer et al. (2018). An indication of how each activity contributed to this goal is presented in Table 9. The most relevant aspects are: Systems-thinking is aimed for by replacing a conventional “customer journey map” (usually combined with a “persona” or “empathy map” activities) (Knapp et al., 2016; Lewrick et al., 2018) with a “value chain map” activity which facilitates understanding from a systemic and lifecycle perspective. Sustainability-oriented thinking is also supported by the inclusion of a “vision co-creation” exercise and the related backcasting logic (Broman and Robèrt, 2017; Vergragt and Quist, 2011), by the addition of an inspiring CE introduction session (Bocken et al., 2013; Guldmann et al., 2019), by the support of the ideation activity with CBM pattern cards (Lüdeke-Freund et al., 2019), by aiding the key decision moment with sustainability-oriented criteria in the “sustainability scan” - which also

Table 5
Description of activities tested and included in the *Circular Sprint*. "*" indicates that the activity was excluded in the final version. Activities are flexible, thus the times stated are merely indicative.

DT Phase	Activity	Brief description	Note	Time
Prepare	Problem framing	Facilitated discussion to understand context, the problem, and to frame the a priori workshop goal (Vetan, 2019)	Perform 1–2 weeks before the workshop.	30–60 min
	Background research	Conduct research and prepare workshop material (e.g., interview key stakeholders and synthesize data) (Vetan, 2019)		
Inspire	CE introduction	Introduction to CE and BMs. Present inspiring examples and background research (Bocken et al., 2013; Guldmann et al., 2019)	Levels knowledge and inspires action. Adapt to use case.	20–40 min
	Vision co-creation	Short backcasting exercise to create a future-oriented change toward a desired sustainable vision (Broman and Robèrt, 2017; Vergragt and Quist, 2011)		30 min
Understand	Expert lightning talks*	Listen to 2–3 experts (5–10 min each) to get a deeper understanding of the challenge and find key insights (Knapp et al., 2016)	Inclusion is recommended. Time-consuming preparation.	20 min
	Context scan	Collaboratively identify context threats and opportunities through an adapted PESTEL (Aguilar, 1965)	Optional activity. Not a priority but provides good insights.	30 min
	Actor system mapping*	Visualization of the key actors of a system, the flow of different values and the sustainability issues within. Adaptation from (Desai et al., 2017; Schiffer and Hauck, 2010)	Replaced and simplified as the Value Chain Mapping activity.	40 min
	Value chain mapping	Generate a shared understanding of the current value chain, identifying key actors, challenges, sustainability hotspots, current implementation of CE practices and a priori opportunities. Combines of Value chain analysis (Taylor, 2005) with a Sprint Mapping activity (Knapp et al., 2016)	Highly useful activity to later develop CE-based solutions. The canvas provided went through many refinements in the development process.	40 min
	Customer profile	Identify the most relevant customer segment and describe key characteristics through a simplified Persona (Lewrick et al., 2018)	Added in later tests. The usefulness of its inclusion depends on the use case.	35 min
Define	How might we?	Rephrase insights into "How might we … ?" questions to turn problems into opportunities and re-define workshop goal (Knapp et al., 2016; Lewrick et al., 2018)		30 min
Ideate	Ideating with CBM patterns	Brainstorming session to propose solutions, finding inspiration in CE strategies and a set of seven CBM pattern cards, developed from the literature (Lüdeke-Freund et al., 2019)	Could be combined with additional ideation activities (Lewrick et al., 2018).	45 min
	Simplified BM canvas	Refine the 4 best ideas intro rough BM concepts by defining the *who, what, how* and *why* (Gassmann et al., 2014)	Added after 1st pilot to facilitate early-stage BM-level conceptualization.	45 min
Decide	FSSD SWOT*	Qualitative assessment of 16 ad hoc sustainability indicators, related to the sustainability principles of the Framework for Strategic Sustainable Development (FSSD; Broman and Robèrt, 2017), followed by a SWOT exercise.	Requires longer preparation and expert facilitation. It was replaced by the sustainability scan activity.	35 min
	Sustainability scan	Facilitates selection of best idea through a simplified assessment of 7 criteria for successful sustainable innovation (i.e. desirability, feasibility, viability and 4 indicators of sustainability). Inspired by (Brown, 2008; Shapira et al., 2017).		35 min
Prototype	Value exchange mapping	Detail winning BM idea by visualizing the key actors and the exchange of different tangible and intangible forms of value (Brillinger, 2018; Pynnonen et al., 2008)		40 min
	CBM canvas	Description of the 11 key building blocks of a sustainable/circular BM (Mentink, 2014; Bocken, 2015).		45 min
Test	Assumptions mapping	Identify BM assumptions and define priority for testing (Bland and Osterwalder, 2020)		30 min
	Test cards	Turn assumptions into testable hypotheses and plan experiments to validate them (Bland and Osterwalder, 2020)		40 min
Present	Pitch*	Presentation of solutions to the whole group.	Used when working in parallel groups.	10–30 min

serves as a sustainability checkpoint - (Buhl et al., 2019; Hansen and Große-Dunker, 2013), and by using a sustainability-oriented modification of the BM canvas (Bocken, 2015; Mentink, 2014) in the prototype stage.

However, based on our experience with the *Circular Sprint* framework, there are two aspects which may have a strong influence upon the level of sustainability and the circularity of outcomes. First, expert facilitation might be required to break *business-as-usual* thinking patterns and to ensure that all the proposed activities are correctly implemented. Secondly, the mix of participant profiles also exerts an influence on outcome characteristics, both in terms of sustainability/circularity and in terms of viability/feasibility/desirability. One of the strengths of DT is the fact that it involves a multidisciplinary and diverse team (Carlgren et al., 2016b; Micheli et al., 2019). This supports the inclusion of a diversity of perspectives, as is commonly recommended for sustainability-oriented processes (Buhl et al., 2019). We found evidence of this in our research. For instance, the winning ideas arrived at in the academic conference workshop, were - in comparison to the other workshops – those which were most ambitious in terms of sustainability - probably due to the high share of sustainability researchers -, but tended to be relatively low in terms of economic viability. In contrast, the ideas revealed during the corporate project workshop were higher in terms of technical feasibility and economic viability, but relatively low with respect to their sustainability potential. The best ideas generated during the start-up workshop were, in contrast, more balanced with respect to sustainability potential and economic viability/technical feasibility/social desirability. This was probably due to the relatively high level of diversity among participants, as well as to their high level of commitment.

5.2. Adapting design thinking for business model innovation and an online environment

DT was originally developed with a focus on product development, and though its applications have now expanded to cover a wide array of problem-solving contexts (Liedtka, 2015), its use in business model innovation processes has only recently been explored (Bonakdar and Gassmann, 2016; He and Ortiz, 2021). Our experience has shown that aiming for outputs at the BM level in a DT-innovation process is challenging, though possible. Initial problem formulation and participant background knowledge are relevant here since, as one workshop participant stated, "thinking in business models is not a skill that comes naturally". Adapting a DT process for BM level outcomes presents a relevant trade-off that needs to be managed. We argue that while designing an innovation process which pushes too early on for BM concepts limits the ideation and creativity potential, the use of BM frameworks may quickly help arrange the best ideas into a feasible, viable and desirable proposal. In order to address this dilemma, the *Circular Sprint* takes account of BM-related input in the introductory session and then aims to inspire ideation activities by making use of circular BM patterns. In addition, in order to ease the potential burden on inexperienced participants, the framework described here incorporates a light version of the BM canvas (Gassmann et al., 2014) and a value exchange mapping activity (Brillinger, 2018; Pynnonen et al., 2008) before attempting to fill up the full (circular) BM canvas (Bocken, 2015; Mentink, 2014; Osterwalder and Pigneur, 2010).

The Covid-19 pandemic forced us to adapt our DT process to a digital environment. This provided us with an opportunity to embed specific characteristics into our artifact and also motivated us to explore the challenges of doing such activities within the context of online collaboration. Expert opinion (Table 8) suggests that our adaptation was effective, and user opinion indicates that the online version had no adverse impact on the DT experience (Table 7). Based on user comments and facilitator discussion, we believe that the online collaboration format was particularly positive with respect to supporting effective time management and enabling a balanced number of contributions between participants. However, it constrained overall user engagement and the in-depth exploration of ideas. In dealing with the challenges of the online context, some aspects that proved particularly valuable were the use of silent brainwriting, idea clustering and note-and-vote techniques (Knapp et al., 2016; Lewrick et al., 2018), combined with the use of a visible online timer.

5.3. Limitations and future research

The present research is explorative, and thus subject to certain methodological limitations which limit its generalizability. Concerning the developed artifact, the *Circular Sprint*, it must be acknowledged that even though we followed an ADR approach with four iterative cycles within the BIE stage, we cannot be certain that we reached a feedback saturation point. Due to the complexity of the framework proposed - containing 12 activities - we invite future researchers to adapt and build upon our proposal by exploring other combinations of activities, and by further refining activity specifications. Future research could also be used to examine how different case contexts (e.g., industry, previous knowledge of participants, the maturity level of CBM concept, online vs offline) affect the usefulness of each activity in the framework. Furthermore, we welcome larger scale testing on usefulness and ease-of-use, as well as adoption intention by industry.

While the framework is presented linearly, by its very nature, DT is iterative and cyclical. We thus invite future researchers to apply longitudinal studies, in order to build upon the CBM early-stage development process described here. It would also be desirable if case studies could be undertaken so as to follow the BM concept up to effective implementation in the market. Some aspects of the framework that could be further developed are (i) the level of external stakeholder involvement, for example, by integrating open innovation practices; (ii), the consideration of the measurement (and management) of sustainability impacts, beyond potentially biased qualitative criteria; and (iii) the focus on the design-implementation gap of CBMI (Baldassarre et al., 2020), for example, by enhancing the iterative prototyping and testing phases of the framework.

Concerning the feedback survey results reported in Tables 7 and 8, one limitation that needs to be acknowledged is that the positive wording of the questions may have inadvertently led to biases in response. The adoption of a more neutral tone is thus recommended for future research.

Finally, it is also worth mentioning that design thinking has been subject to both theoretical and practical criticism (Badke-Schaub et al., 2010; Carlgren et al., 2016a; Hernández-Ramírez, 2018; Laursen and Haase, 2019; Woudhuysen, 2011). This also needs to be taken into

Table 6
List of improvements made to *Value chain mapping* activity during BIE cycles.

Improvement	Rationale	Modification phase	Supporting evidence
Modified canvas from a rigid table of value chain steps (columns) and elements (rows) to a flexible open canvas with easy-to-modify pre-filled value chain steps and sets of colour-coded post-its.	Improve usefulness by adding flexibility to map the value chain as complexly as needed, potentially connecting value chains of several material streams.	From Beta to Gamma to Delta.	Master's students spent too much time discussing value chain steps and adapting to their use case context. Start-up members suggested enabling mapping and connecting different value chains.
In the Beta version, the elements to be identified in each value chain step were: main actors, comes in, comes out, inefficiencies and sustainability issues, opportunities. Modified to identify: main actors, sustainability issues and value chain inefficiencies, challenges and barriers.	Improve usefulness by shifting focus from the time-consuming specification of resource movements to the identification of sustainability/value chain issues to be solved. Also allowing more space to explore problems before thinking of opportunities/ solutions.	From Beta to Gamma.	Master's students spent too much time discussing what comes in and out of each step, leaving little time for identified issues to be potentially solved. This modification also answers to user suggestions to explore the problem more in-depth.
Revised and improved the wording of the pre-filled value chain steps.	Improve ease-of-use with the use of self-explanatory word choice which is adaptable to several value chain settings.	From Beta to Gamma to Delta.	Suggestions from master's students, corporate project participants and expert feedback
Revised and improved the self-explanatory instructions.	Improve ease-of-use by improving exercise replicability, increasing flexibility of activity and reducing dependency on expert facilitation.	From Gamma to Delta.	Facilitator notes and suggestions from start-up and corporate project workshops.
Added a pre-filled example to explain the activity.	Improve ease-of-use by making the activity easier to understand and triggering earlier participant engagement.	From Gamma to Delta.	Suggestions from start-up and corporate project workshops.
Added a curated list of value chain sustainability issues and a figure with linear value chain inefficiencies as activity support documents.	Improve usefulness by supporting a faster and holistic identification of value chain issues.	From Beta to Gamma.	Master's students struggled to identify value chain issues, keeping narrow focus or biasing opinions.
Revised and improved the graphical representation of canvas, instructions, support content and example.	Improve ease-of-use with a more suggestive and clearer graphical representation.	From Beta to Gamma to Delta.	Facilitator notes and suggestions from students, start-up and corporate project workshops.

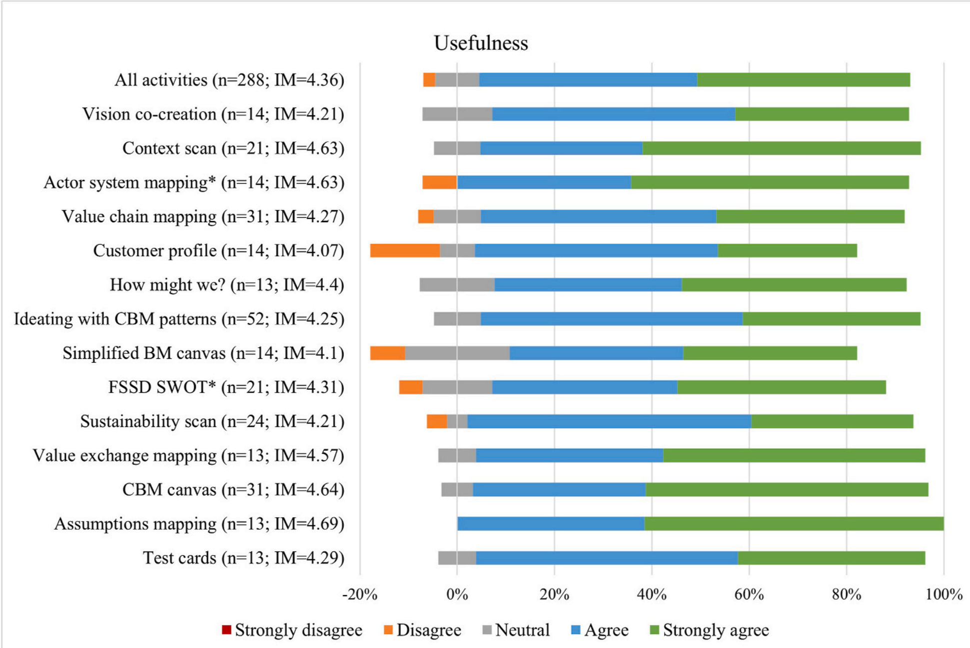

Fig. 3. Activity usefulness survey results, using a 5-point Likert scale (1 = strongly disagree; 5 = strongly agree). The diverging stacked bar chart presents the percentage of answers per category (n = number of answers; IM = interpolated median; * = activity excluded in the final version of the *Circular Sprint)*.

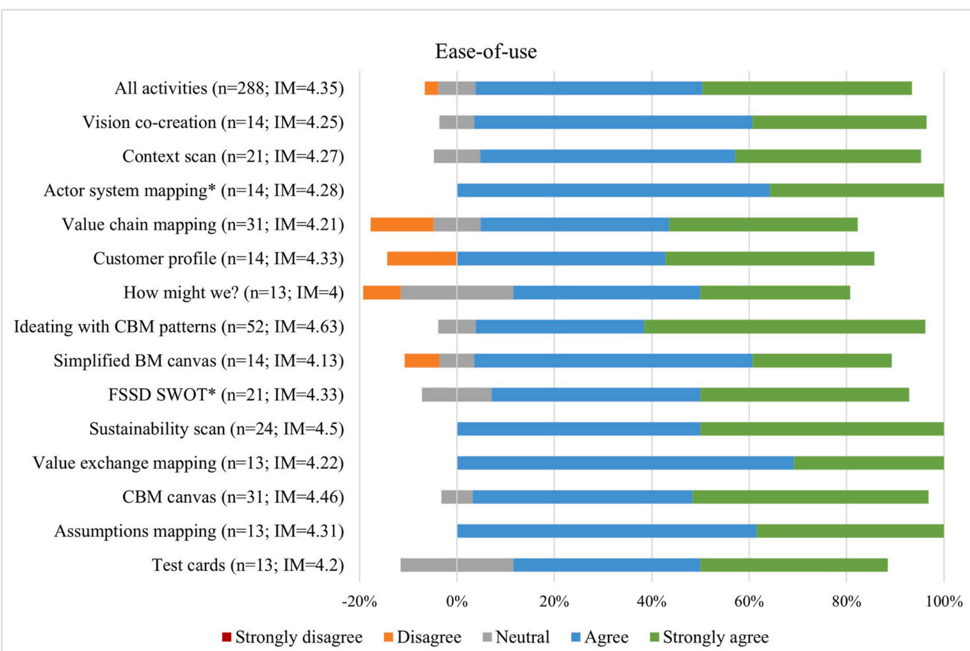

Fig. 4. Activity ease-of-use survey results, using a 5-point Likert scale (1 = strongly disagree; 5 = strongly agree). The diverging stacked bar chart presents the percentage of answers per alternative (n = number of answers; IM = interpolated median; * = activity excluded in the final version of the *Circular Sprint)*.

Table 7
User appreciation of virtual setting and activity complementarity. The table indicates the interpolated median values of responses, using a 5-point Likert scale (1 = strong disagreement; 5 = strong agreement).

	Academic conference	Master's students 1	Master's students 2	Start-up	Corpo-rate project	Total count	Total interpolated median	Total range
Activities were complementary, non-redundant and in the best possible order	4.84	4.08	4.50	4.83	4.75	49	4.68	3
Virtual setting improved outcomes versus physical workshop	2.92	3.00	3.00	4.50	3.00	49	3.09	4

Table 8
Final expert feedback survey answers (n = 9) on the overall goal and key characteristics of the Circular Sprint. The table indicates interpolated median values and range of agreement level using a 5-point Likert scale (1 = strong disagreement; 5 = strong agreement).

		Interpolated median	Range
Overall goal	It is very effective in guiding the early-stage development of a circular business model	4.40	1
Characteristic (i) and (ii)	It is very effective in embedding sustainability and circularity throughout the innovation process	4.06	1
Characteristic (iii)	It is very effective in generating outputs at the business model level (beyond product)	3.80	2
Characteristic (iv)	It effectively addresses all stages of the design thinking process	4.50	2
Characteristic (v)	It is very time efficient (i.e., generates very valuable outputs in a limited time)	3.83	3
Characteristic (vi)	It is very well adapted to an online environment	4.60	3

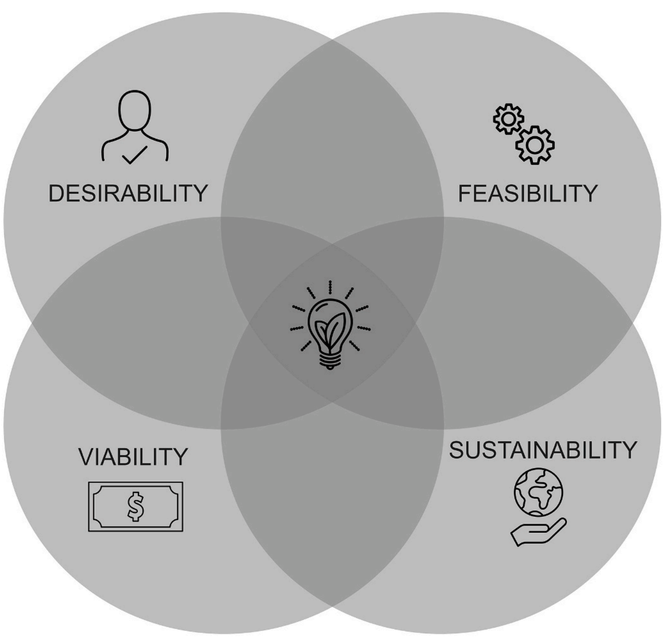

Fig. 5. The four lenses of sustainable innovation. Own elaboration, inspired by Brown (2008) and Shapira et al. (2017).

account in future research.

6. Conclusion

The process of developing a sustainable and circular BM is quite challenging, hindering its wider implementation in the market. By combining DT-based frameworks with best practices from the BMI, SBMI and CBMI literature we have developed, tested and iteratively refined a process framework for guiding the early-stage development of a CBM, in a digital and time-efficient manner. The framework entails the adaptation and combination of 12 exercises to be used through seven distinctive DT phases.

The present study is a response to the increasing demand for comprehensive operational guidelines that may be used by firms engaged in CBM development. The proposed framework answers calls to address CBMI as a holistic process, to integrate SBMI and conventional BMI approaches and to customize existing tools (Blomsma and Brennan, 2017; Pieroni et al., 2019a). This research strengthens previous approaches to adapt DT for sustainability (Guldmann et al., 2019; Shapira et al., 2017) and offers an empirical application of the SBMI criteria proposed by Breuer et al. (2018) and of the CBMI tool-development checklist proposed by Bocken et al. (2019). In addition, this study also integrates and explores the principles for adapting DT to sustainability-oriented innovation, as developed theoretically by Buhl et al. (2019), and in a single-case study by Kagan et al. (2020). In doing so, the present study manages to embed a sustainability and a CE-oriented lens within conventional innovation, DT and BM management practices, and supports the integration and enhancement of these related fields. The study has also contributed to theory by expanding the understanding of DT as a sustainability-oriented innovation process that is strengthened by integrating the four lenses of desirability, feasibility, viability and sustainability.

This study has also provided deeper insight into the artifact development process, offering a practical application of the ADR approach (Sein et al., 2011). Furthermore, this research discusses the challenges and opportunities arising when adapting a DT process to embed a sustainability orientation, when aiming at BM-level outputs, and when attempting to adapt it to an online and time-limited context.

In terms of its practical contributions, we believe we have developed an actionable framework capable of supporting the complex innovation process of developing, improving, transforming, or adapting a CE-oriented BM. The research output includes a step-by-step guide containing 12 exercises and their canvasses. This may be used and adapted by practitioners and innovators. The artifact developed here may also be used for student or company educational purposes as it can be applied in the teaching and training of CE-thinking, CBM development and DT.

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CRediT authorship contribution statement

Tomas Santa-Maria: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Visualization. **Walter J. V. Vermeulen:** Writing – review & editing, Supervision, Funding acquisition. **Rupert J. Baumgartner:** Resources, Writing – review & editing, Supervision, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Table 9
Indication of how each Circular Sprint activity contributed to the fulfilment of the eight SBMI criteria synthesized by Breuer et al. (2018).

Activity	SBMI Criteria							
	sustainability orientation	extended value creation	systemic thinking	stakeholder integration	reframing BM components	context-sensitive modelling	collaborative modelling	managing impacts and outcomes
CE introduction	+		+					
Vision co-creation	+	+	+				+	
Context scan						+	+	
Value chain mapping	+	+	+	+		+	+	+
Customer Profile							+	
How might we?					+		+	
Ideating with CBM patterns	+	+					+	
Simplified BM canvas		+			+		+	
Sustainability Scan	+		+			+	+	
Value exchange mapping		+	+	+			+	
CBM canvas	+	+	+	+	+		+	
Assumptions mapping							+	+
Test cards							+	+

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Appendix A. Supplementary data

Supplementary data to this article include the *Circular Sprint User Guide* and can be found online at https://doi.org/10.1016/j.jclepro.2022.132323.

Appendix

Table A.1
Feedback survey results by workshop type, presenting interpolated median values for responses on usefulness and ease-of-use, applying a 5-point Likert scale (1 = strongly disagree; 5 strongly agree). Blank spaces indicate that the activity was either not undertaken, or that such information was not requested.

Activity	Evaluation criteria	Academic conference	Master students 1	Master students 2	Start-up	Corporate project	Expert feedback	Total answer count	Total interpolated median	Total answer range
CE introduction	Usefulness	–	–	–	–	3.00	–	2	3,00	4
Vision co-creation	Usefulness	–	–	–	4.83	4.50	3.90	14	4.21	2
	Ease-of-use	–	–	–	4.83	4.50	4.00	14	4.25	2
Context scan	Usefulness	4.63	–	–	–	–	–	21	4.63	2
	Ease-of-use	4.27	–	–	–	–	–	21	4.27	2
Actor system mapping*	Usefulness	–	–	–	4.50	3.50	4.70	14	4.63	3
	Ease-of-use	–	–	–	4.50	4.50	4.17	14	4.28	1
Value chain mapping	Usefulness	–	4.00	4.25	4.50	5.00	4.25	31	4.27	3
	Ease-of-use	–	4.00	4.10	4.83	3.50	4.10	31	4.21	3
Customer Profile	Usefulness	–	–	–	4.50	2.00	4.10	14	4.07	3
	Ease-of-use	–	–	–	4.50	2.00	4.50	14	4.33	3
How might we?	Usefulness	–	–	–	4.50	5.00	4.00	13	4.40	2
	Ease-of-use	–	–	–	4.50	4.50	3.33	13	4.00	3
Ideating with CBM patterns	Usefulness	4.25	3.92	4.50	4.50	4.50	4.25	52	4.25	2
	Ease-of-use	4.80	4.33	4.50	4.83	5.00	4.10	52	4.63	2
Simplified BM canvas	Usefulness	–	–	–	4.83	2.50	4.00	14	4.10	3
	Ease-of-use	–	–	–	4.83	3.00	4.00	14	4.13	3
FSSD SWOT*	Usefulness	4.31	–	–	–	–	–	21	4.31	3
	Ease-of-use	4.33	–	–	–	–	–	21	4.33	2
Sustainability Scan	Usefulness	–	–	4.13	4.83	3.50	4.10	24	4.21	3
	Ease-of-use	–	–	4.79	4.83	5.00	4.00	24	4.50	1
Value exchange mapping	Usefulness	–	–	–	5.00	5.00	4.10	13	4.57	2
	Ease-of-use	–	–	–	4.83	4.00	4.07	13	4.22	1
CBM canvas	Usefulness	–	4.00	4.79	4.83	5.00	4.75	31	4.64	2
	Ease-of-use	–	4.38	4.79	4.00	5.00	4.20	31	4.46	2
Assumptions mapping	Usefulness	–	–	–	4.50	5.00	4.70	13	4.69	1
	Ease-of-use	–	–	–	4.50	5.00	4.17	13	4.31	1
Test cards	Usefulness	–	–	–	4.50	5.00	4.10	13	4.29	2
	Ease-of-use	–	–	–	4.83	5.00	3.75	13	4.20	2

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