The Circular Leap: AI, Business Model Innovation, and Systems Design for a Sustainable Future

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Abstract

In response to grand challenges, the linear economic model (make, use, dispose) is increasingly contested by a circular economic model. A circular economy operates on the principles of reduce, reuse, recycle, and recover, enabled by technological innovations, novel business models, and stakeholder collaboration. Positive impact the circular economy promises is often offset when circular products cannot fully replace linear products due to being inferior in quality or price, while often targeting a different market. The simultaneous production of linear and circular products leads to additional production and is widely coined "circular economy rebound". Systemic innovation in terms of products, services, business models, and ecosystems is understood as a key aspect in circular economy rebound mitigation.

However, extant literature mainly describes phenomena related to the circular economy and rebound effects, while largely neglecting descriptive and prescriptive accounts of systemic innovation and external enablement in the context of the circular economy. For instance, businesses lack guidance on how to utilize digital technologies and systems thinking to innovate for and develop a well-functioning circular economy while considering rebound effects. Additionally, current literature to a great extent remains in a descriptive mode largely focusing on circular business models, failing to apply a systemic view, including circular products, services, and ecosystems, or an external enablement view. Current literature rarely makes the leap to bridging the gap between theory and practice through dedicated research approaches such as design science research. In consequence, scholars, new ventures, and established firms lack knowledge and guidance on how to innovate within the circular economy guardrails to deliver on its impact promises.

The purpose of this dissertation is to advance knowledge of the theoretical issues linked to a circular economy and its underlying systems as well as external enablers such as artificial intelligence as a digital technology. Based on these theoretical aspects, this dissertation aims to provide prescriptive guidance on how to innovate for and develop a well-functioning circular economy by bridging the gap between theory and practice through applying design science research approaches. This is accomplished by three separate but interrelated manuscripts underlying this dissertation.

The first manuscript adopts an inductive and descriptive qualitative research approach, conducting 55 semi-structured interviews with artificial intelligence and circular economy experts, as well as new ventures that utilize AI-enabled circular economy business models. Using the Gioia-method for data analysis, the first manuscript develops a general model of the circular economy enablement through artificial intelligence as a digital technology and external enabler. Additionally, it introduces a typology of circular economy enabling artificial intelligence business models.

The second manuscript addresses the intricate but often fragmented design of circular systems, encompassing circular product design, product-service system design, circular business model design, and collaborative ecosystem design, leading to circular economy rebound. This study uses a qualitative, inductive design science research approach, including 31 semi-structured interviews and a workshop with circular design experts and entrepreneurs. Through the Gioia-method of data analysis, the manuscript presents a process blueprint of circular systems design targeted at circular economy rebound mitigation.

The third manuscript leverages 37 semi-structured interviews with entrepreneurs and experts in the domains of cascading and repurposing. Through a design science approach and structured data analysis using the Gioia-method the manuscript develops five design principles following a context, intervention, mechanism, outcome (CIMO) logic. The design principles inform entrepreneurs operating in the CE on how different key stakeholders can engage in productive partnerships to operationalize cascading and repurposing business models effectively.

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List of Abbreviations

ACERE	Australian Centre for Entrepreneurship Research Exchange
AOM	Annual Meeting of the Academy of Management
AI	Artificial Intelligence
CBM	Circular Business Model
CE	Circular Economy
CER	Circular Economy Rebound
CIMO	Context, Intervention, Mechanism, Outcome
CPD	Circular Product Design
CRBM	Cascading and Repurposing Business Model
CSD	Circular Systems Design
DESRIST	International Conference on Design Science Research in Information Systems and Technology
DSR	Design Science Research
EE	External Enablement
HICSS	Hawaii International Conference on System Sciences
IS	Information Systems
JCLP	Journal of Cleaner Production
LNCS	Lecture Notes in Computer Science
PSS	Product-Service System
RQ	Research Question
SMEs	Small and Medium-Sized Enterprises
USA	United States of America

1. Introduction

Humanity faces grand challenges, such as inequality, poverty, and climate change (Ritala, 2024). One root cause of these challenges is the linear economic paradigm that is considered prevalent in most parts of the world (Neves & Marques, 2022). A linear economy follows a "make, use, dispose logic", entailing value chains that are initiated by sourcing virgin materials, fading out at a product's end of life, and creating vast waste streams (Geissdoerfer et al., 2017). As a response to the grand challenges, linear economies are increasingly contested by an alternative economic paradigm - the circular economy (CE) (Liu et al., 2024).

The CE is understood as "*a regenerative economic system which necessitates a paradigm shift to replace the 'end of life' concept with reducing, alternatively reusing, recycling, and recovering materials throughout the supply chain, with the aim to promote value maintenance and sustainable development, creating environmental quality, economic development, and social equity, to the benefit of current and future generations*" (Kirchherr et al., 2023, p. 7). The CE is further enabled by "*an alliance of stakeholders (industry, consumers, policymakers, academia) and their technological innovations and capabilities*" (Kirchherr et al., 2023, p. 7), as well as by "*novel business models and responsible consumers*" (Kirchherr et al., 2017, p. 229).

An effective stakeholder collaboration is a key prerequisite for a well-functioning CE to enable material, knowledge, and value flows across the product life cycle phases (pre-use, use, post-use) (Millar et al., 2019; Konietzko et al., 2020; Zeiss et al., 2021). Innovative technologies hold the potential for the CE to facilitate effective stakeholder collaboration by enabling efficient value and material flows, as well as knowledge sharing (Zeiss et al., 2021).

Especially the emergence of artificial intelligence (AI) as digital technology, which yields the potential to strongly affect sustainable development in terms of environmental outcomes and productivity (Kar et al., 2022; Vinuesa et al., 2020), can support efficient stakeholder collaboration in the context of the CE (Zeiss et al., 2021; Katsikeas et al., 2023). AI is understood as "*the ability of machines to think and perform tasks simulating human behavioral patterns*" (Roberts & Candi, 2024, p. 2).

Moreover, AI as a digital technology has the potential to serve as an external enabler for new venture creation (von Briel et al., 2018; Suchek et al., 2022; Davidsson & Sufyan, 2023) and can elicit opportunity spaces that new ventures may exploit (Kornish & Ulrich, 2011; Davidsson, 2015). External enablement (EE) describes how new ventures are created through "*disequilibrating circumstances potentially facilitating a variety of entrepreneurial endeavors*" (Davidsson et al., 2020, p. 56). Opportunity spaces refer to clusters of competing ideas aiming at a specific domain of commercial success (Kornish & Ulrich, 2011). For instance, in the CE a specific domain of commercial success could be in the post-use phase of the circular product life cycle. To exploit opportunity spaces in the CE, new ventures come up with novel circular business models (CBMs), such as cycling, extending, intensifying, and dematerializing, while utilizing digital technologies, such as AI, in any of the product life cycle phases (Geissdoerfer et al., 2018; 2020; Ranta et al., 2021).

To tap into CE-related opportunity spaces and contribute to sustainable development, circular economy rebound (CER) has to be avoided. CER emerges if circular products cannot fully replace linear products due to being inferior in quality and price, while targeting a different group of consumers, thus, leading to additional production and offsetting the positive impact of circular products (Zink & Geyer, 2017).

Systems thinking in terms of circular offerings represents a key CER mitigation strategy (Siderius & Poldner, 2021) and considers the intricate interplay of processes, actors, values, as well as a wider system of technologies, resources, governance, human behavior, and market activities (Iacovidou et al., 2021). Consequently, developing novel technology-driven and systemically designed CBMs while mitigating CER yields strong potential for an economic paradigm shift as one approach of getting closer towards solving the grand challenges of our time (Siderius & Poldner, 2021; Ranta et al., 2021).

Extant literature sheds light on EE through digital technologies and its potential for new venture creation. Specifically, literature outlines mechanisms of EE (von Briel et al., 2018), analyzes the EE of AI (Davidsson & Sufyan, 2023), and highlights a broad range of CBM types as well as patterns that new ventures can choose from (Lüdeke-Freund et al., 2019; Pieroni et al., 2020). Literature also discusses systems thinking approaches as a promising measure for mitigating CER (Siderius & Poldner, 2021).

However, this dissertation identifies three notable gaps in extant literature: First, current conversations overlook the EE of new ventures in the CE through digital technologies such as AI, and fall short in exploring the combination as well as generation of novel business models beyond the well-defined CBMs. Second, prescriptive research that applies systems thinking in the context of the CE to mitigate CER is underrepresented. Third, extant research falls short in prescriptively capturing the operationalization aspect of CBMs and specifically CRBMs.

Only a few articles try to bridge the gap between theory and practice in the context of the CE by applying prescriptive research approaches, such as design science research (DSR) (e.g., Brown et al., 2021; Das et al., 2023). This dissertation mainly leverages DSR to generate practically useful artifacts in order to fill the shortcomings in extant CE-related research. DSR represents a research methodology that "*shares the values of practice (i.e., usefulness) and uses* *the methods of science (i.e., scientific method plus more specific, scrutable methods)*" (Seckler et al., 2021, p. 1).

1.1. Research Purpose and Objectives

The purpose of this dissertation is to provide guidance on how to utilize digital technologies and systems thinking to innovate for and develop a well-functioning CE while considering CER. This dissertation aims at descriptively informing the scholarly community and prescriptively guiding practitioners, hoping to valuably contribute to theory and practice in understanding and tackling the grand challenges of our time (Seckler et al., 2021). To achieve this, the dissertation has three research objectives: (1) The first research objective is to outline the challenges that are hindering the development of the CE, promises that AI brings to the CE, opportunity spaces emerging from the external enablement of the CE through AI, and novel business models new ventures adopt when tapping into the opportunity spaces. (2) The second research objective is to leverage a DSR research approach to provide guidance on how to harmonize the intricate systemic design of circular products, services, CBMs, and ecosystems to mitigate CER. (3) The third research objective is to derive design requirements and design principles for the collaborative operationalization of CRBMs between the relevant stakeholders of the CE.

These three research objectives are approached through three manuscripts that have a qualitative research design at their core and span a total of 123 interviews with experts, entrepreneurs, and designers from diverse backgrounds in the overarching domains of AI and CE. All interviews were analyzed using the data analysis method outlined by Gioia et al. (2013). While the first research objective was approached descriptively, the other two research objectives were approached by employing the prescriptive DSR methodology following the six-steps process introduced by Peffers et al. (2007).

1.2. Dissertation Outline

The structure of the present dissertation consists of four main sections. First, the theoretical background and their link to the three underlying manuscripts will be provided. Second, an overview of the three manuscripts will be presented, including the manuscripts' status with regards to publication processes in academic journals. Third, the three manuscripts are presented. The dissertation closes by outlining and contextualizing the manuscripts' findings, contributions, discussing theoretical and practical implications, as well as limitations and avenues for future research.

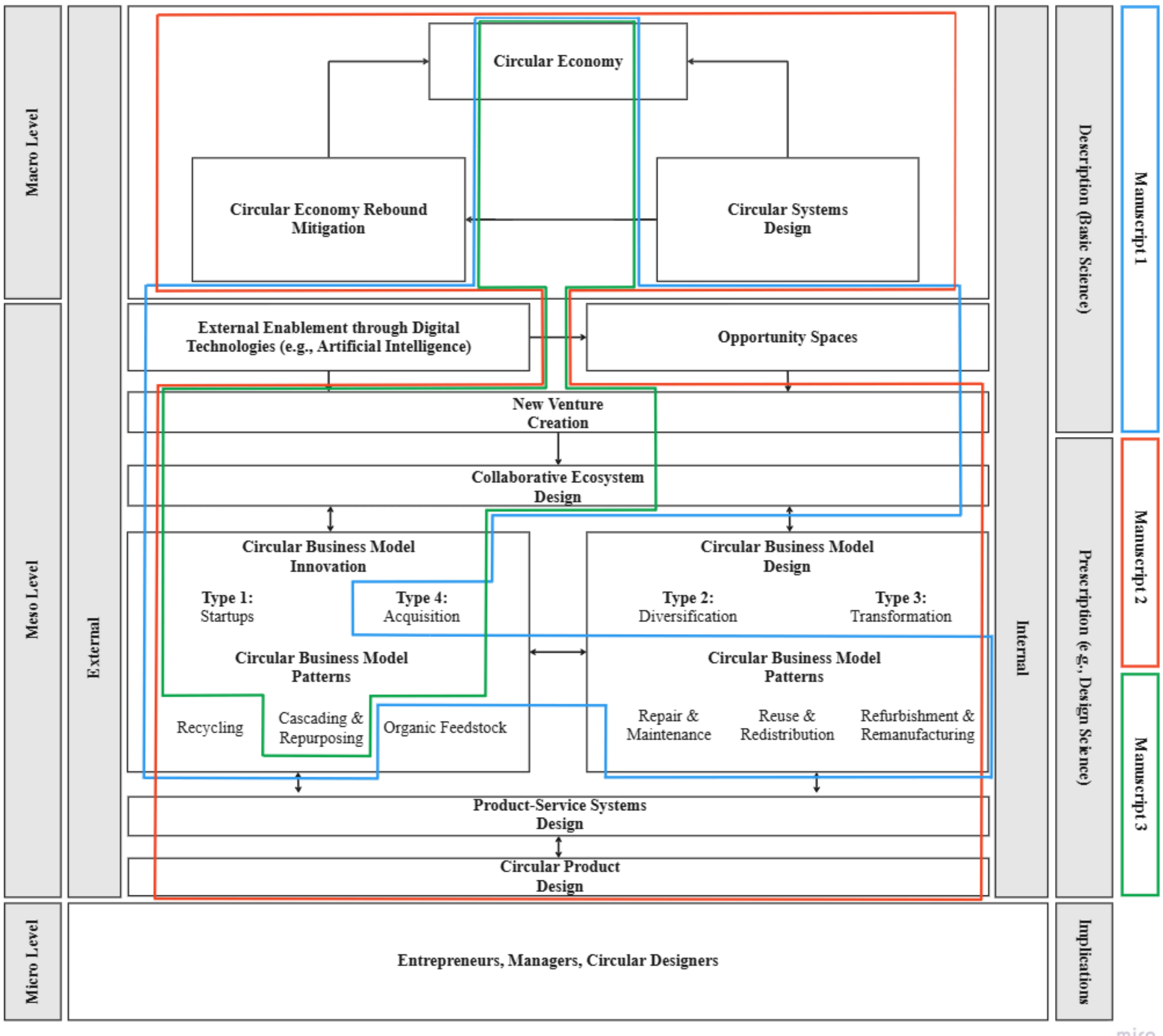
2. Theoretical Background

This dissertation is taking a macro and meso level perspective of a circular economy (CE) (Figure 1). While manuscript one applies descriptive methods of basic science, DSR is applied in manuscript two and three, shifting to a prescriptive mode of research. Design science research (DSR) in the context of this dissertation is understood as a research approach that yields the potential to develop practically useful solutions through bridging the gap between theory and practice (Hevner et al., 2004).

On a macro level, this dissertation aims to understand how a well-functioning CE (e.g., Kirchherr et al., 2017; 2023) can be enabled through circular systems design (CSD) (e.g., Iacovidou et al., 2021) while mitigating circular economy rebound (CER) (Zink & Geyer, 2017) to reach its full impact potential for solving grand challenges.

On a meso level, this dissertation looks at the external enablement of new venture creation through artificial intelligence (AI) (e.g., von Briel et al., 2018) and the elicitation of opportunity spaces (Kornish & Ulrich, 2011; Davidsson, 2015). New venture creation in a well-functioning CE requires stakeholder collaboration and developing ecosystems in which materials, components, products, and services are exchanged (Kirchherr et al., 2023). The collaborative ecosystem design requires novel circular business models (CBMs) as enablers that are both externally and internally oriented (Geissdoerfer et al., 2020). This dissertation sheds light on both CBM innovation and design, covering all types of CBM innovation: (1) startups, (2) diversification, (3) transformation, and (4) acquisition (Geissdoerfer et al., 2020). The dissertation is primarily focusing on circular startups (type 1). All CBM patterns outlined by Lüdeke-Freund et al. (2019) are discussed, while the CBM pattern "cascading and repurposing " (CRBM) is thematized in more depth. Following the levels of design for sustainable innovation introduced by Baldassarre et al. (2020), collaborative ecosystem design and CBM design are complemented by product-service system (PSS) design (Tukker, 2015) and circular product design (CPD) (den Hollander et al., 2017), completing the meso-level analysis. Finally, the macro and meso level analysis has practical implications for the micro level, entailing entrepreneurs, managers, and circular designers.

Figure 1: Interrelation of Manuscripts



2.1. New Venture Creation in the Circular Economy

Digital technologies can serve as external enablers (EE) of entrepreneurial opportunities and, thus, lead to the creation of new ventures (Davidsson, 2015; von Briel et al., 2018; Davidsson et al., 2020). To exploit novel opportunities, new ventures combine existing resources to innovate existing business models, or create new ones from scratch (von Briel et al., 2018). The following section delves deeper into EE through digital technologies, elicitation of opportunity spaces, new venture creation, and the creation, as well as generation, of novel business models.

2.1.1. Digital Technologies as an External Enabler of New Venture Creation

The EE-framework explains the creation of new ventures through the EE of "*disequilibrating circumstances potentially facilitating a variety of entrepreneurial endeavors*" (Davidsson et al., 2020, p. 56). These circumstances could be either of technological, regulatory, demographic, socio-cultural, macroeconomic, political, or natural environmental nature (Davidsson et al., 2020). The EE-framework posits that new venture creation is either triggered, shaped, or enhanced when the disequilibrating circumstances externally enable stages of the venture creation process (Davidsson et al., 2020).

In the context of EE by new technological circumstances, such as the introduction of novel digital technologies, the EE-framework suggests six mechanisms for new venture creation (von Briel et al., 2018). The first mechanism - compression - brings time reductions for performing actions. The second mechanism - conservation - brings a reduction of resources required for performing certain tasks. The third mechanism - expansion - makes a certain resource more available. The fourth mechanism - substitution - makes one resource obsolete and replaces it with another. The fifth mechanism - combination - links resources to develop new ones (e.g., business models). The sixth mechanism - generation - develops new resources (e.g., business models) by changing existing ones (von Briel et al., 2018).

Thus, the introduction of a new digital technology (e.g., AI) yields the potential to externally enable the creation of new ventures (Chalmers et al., 2021). Consequently, the external enablement of new technologies triggers and shapes the combination and generation of novel business models by new ventures (von Briel et al., 2018; Davidsson & Sufyan, 2023).

2.1.2. Opportunity Spaces and External Enablement

An opportunity is widely understood as "*an idea for an innovation that may have value after further investment of resources*" (Kornish & Ulrich, 2011, p. 107). Clusters of unique ideas for innovations are understood as opportunity space (Kornish & Ulrich, 2011). Unique ideas that could potentially be profitable are considered opportunities for new ventures (Baron & Ensley, 2006). New ventures could tap into opportunity spaces to exploit the inherent value of ideas after further investment of resources (Lamine et al., 2021). This is accomplished by means of resource combinations to come up with new ends (e.g., new business models), or the generation of new resources (e.g., new business models) (Kornish & Ulrich, 2011). Thus, opportunity spaces could be understood as the trigger of new venture creation (e.g., Davidsson, 2015), while arising from the external enablement through digital technologies (von Briel et al., 2018; Davidsson & Sufyan, 2023).

Although scholars have discussed EE through digital technologies and its potential for new venture creation (von Briel et al., 2018), extant conversations overlooked the potentials of EE for new venture creation in the context of the CE. While extant literature outlines mechanisms of EE through digital technologies leading to new venture creation (von Briel et al., 2018), more in-depth discussions of the mechanisms such as combination and generation of novel business models are lacking. Davidsson and Sufyan (2023) have analyzed the EE of AI. However, no study applied the EE of AI to the CE. Lastly, although existing research outlines and defines different types and patterns of CBMs (e.g., Lüdeke-Freund et al., 2019; Pieroni et al., 2020), the conversation overlooks business models beyond these well-defined CBM types and patterns.

With manuscript one, "*Exploring the Role of Artificial Intelligence in Overcoming the Key Challenges of the Circular Economy: The Emergence of Opportunity Spaces and New Business Models*", this dissertation fills the above mentioned gaps in extant literature. The manuscript seeks to empirically understand the challenges that are hindering the development of a well-functioning CE and to outline the opportunity spaces that are elicited by the EE of AI in the context of the CE. Qualitatively, the manuscript develops a model presenting novel CE-enabling AI-business models which new ventures can adopt to tap into the opportunity spaces in the CE.

2.2. Circular Systems Design

Circular design with CBM innovation and design at its heart plays a pivotal role in developing a well-functioning CE. Intricate systemic circular design aids the mitigation of CER (Siderius & Poldner, 2021; Castro et al., 2022). The following section delves deeper into CER, circular design, and CBMs.

2.2.1. Design for Sustainable and Circular Innovation

Design for sustainable innovation, entails the design of sustainable products, services, business models, and collaborative ecosystems (Baldassarre et al., 2020). Thus, design for innovation in the context of the CE demands the integrated design of circular products, services, business models, and ecosystems.

The design of circular products entails strategies aiming to maintain a product's value and utilize materials as well as components throughout multiple life cycles while preserving physical integrity and functionality (Luttropp & Lagerstedt, 2006; Diaz et al., 2022). Circular product design follows fundamental principles such as design for repairability, recyclability, product integrity, modularity, standardization, and reconfiguration (Sassanelli et al., 2020; Franconi et al., 2022), while considering disassembly, emotional attachment and obsolescence, as well as aesthetics (Ljungberg, 2007; Chapman, 2009; van den Berg & Bakker, 2015). Since strategies for circular resource flows such as slowing and closing (Bocken et al., 2016) are enabled through services (van der Laan & Aurisicchio, 2020), the design of circular product-service systems (PSS) plays an important role in the design for sustainable and circular innovation (Baldassarre et al., 2020). Thus, circular products, in contrast to linear products, are considered to be more than physical entities, but rather intricate value-delivery systems (Moro et al., 2022). This demands that businesses offering circular products develop enabling services around the products' delivery, such as upgrades, maintenance, repair, take-back, and recycling (Tukker, 2015).

The design of CBMs combines the value logics of circular products and PSS into a sensemaking structure of value proposition, creation, delivery, and capture (Geissdoerfer et al., 2020). CBMs fundamentally rely on a well-working collaborative ecosystem of public, industrial, and civil stakeholders, extending beyond traditional linear supply chains (Konietzko et al., 2020). Consequently, circular design demands multidisciplinary teams that unify knowledge about economics, stakeholder management, ecology, supply chains, and materials (Brown et al., 2021).

2.2.2. Circular Economy Rebound

In contrast to linear design, design for sustainable and circular innovation yields the potential to reduce a number of negative externalities (Baldassarre et al., 2020). In case circular design fails to compete in quality, price, and target market with linear alternatives, the positive effects the circular design promises are offset due to additional production, instead of substitutional production, leading to CER (Zink & Geyer, 2017). Additionally, circular activities are often linked to requiring a lot of energy (e.g., recycling) and novel infrastructure (Castro et al., 2022). CER can be mitigated through price controls, environmental policy, penalization, and gamification for social and environmental causes, as well as education and empowerment of the population (Castro et al., 2022). Finally, Siderius and Poldner (2021) emphasize that a systems thinking approach towards circular design yields strong potential for CER mitigation.

Although the potential of a systems thinking approach towards the mitigation of CER has been discussed in extant literature (Siderius & Poldner, 2021), prescriptive studies are absent that are applying systems thinking to support actors in the CE to mitigate CER. A systems thinking perspective towards design for a CE has been neglected in the ongoing conversation about the CE. Prescriptive accounts are primarily discussing CBM innovation and design (e.g., Das et al., 2023) foregoing CPD, PSS design, and collaborating ecosystem design.

With manuscript two, "*Overcoming Rebound Effects: A Process Blueprint for Circular Systems Design*", this dissertation applies a DSR approach to prescriptively develop a tool that guides designers and circular entrepreneurs in simultaneously considering the design of circular products, services, business models, and ecosystems. The systems thinking approach applied in manuscript two aims at the mitigation of CER.

2.2.3. Circular Business Model Innovation

Business model innovation describes "*the conceptualisation and implementation of new business models. This can comprise the development of entirely new business models, the diversification into additional business models, the acquisition of new business models, or the transformation from one business model to another*" (Geissdoerfer et al., 2018, pp. 405-406). Thus, the development of entirely new business models as part of the new venture creation process is understood as a type of business model innovation. The four types of business model innovation as outlined by Geissdoerfer et al. (2018) also apply to business model innovation in the context of the CE, including circular startups (type 1), CBM diversification (type 2), CBM transformation (type 3), and CBM acquisition (type 4) (Geissdoerfer et al., 2020).

CBMs can be divided into four overarching types according to their ambition of narrowing, slowing, or closing resource loops (Bocken et al., 2016). Narrowing resource loops refers to using fewer resources per product (Bocken et al., 2016), which links back to the CBM type "Dematerializing" as defined by Geissdoerfer et al. (2020). On a more granular level, the CBM type Dematerializing can be subdivided into three CBM archetypes "Dematerialized Services", "Demand Reduction Services", and "Encourage Sufficiency" (Pieroni et al., 2020).

Slowing resource loops means the extension or intensification of a product's utilization period, focusing on product value retention (Bocken et al., 2016; Lüdeke-Freund et al., 2019), which is aligned with the CBM types "Extending" and "Intensifying" (Geissdoerfer et al., 2020). These CBM types are aligned with the CBM patterns for slowing resource loops that Lüdeke-Freund et al. (2019) outline, such as "repair and maintenance", "reuse and redistribution", as well as "refurbishment and remanufacturing". On a more detailed level, the CBM type Intensifying can be subdivided into four CBM archetypes, such as "Sharing Economy", "Sharing or Pooling Systems", "Access Models", and "Performance or Result Models" (Pieroni et al., 2020). The CBM type Extending can be subdivided into five archetypes, such as "Lifetime Products", "Premium Products with Life Extension Services", "Hybrid Models", "Direct Reuse", and "Next Life Sales" (Pieroni et al., 2020).

Finally, closing resource loops describes the resource flow between a product's end-of-life and other production, focusing on material value retention (Bocken et al., 2016; Lüdeke-Freund et al., 2019), which links back to the CBM type "Cycling" (Geissdoerfer et al., 2020). Cycling CBMs could either take the form of "recycling", "cascading and repurposing", or "organic feedstock" business model patterns (Lüdeke-Freund et al., 2019). More specifically, the circular business model type Cycling can be subdivided into two CBM archetypes, such as "Product Transformation", and "Extending Resource Value" (Pierroni et al., 2020). Consequently, new ventures can develop entirely new business models in the context of the CE by drawing on the four CBM types Dematerializing, Extending, Intensifying, and Cycling.

Although new ventures can choose from a broad range of CBM archetypes and patterns, extant literature largely overlooks their operationalization. Existing studies fall short in prescriptively capturing the operationalization aspect of CBMs. Specifically, the CBM pattern "cascading and repurposing" remains underexplored in terms of operationalization (Lüdeke-Freund et al., 2019).

With manuscript three, "*Trash to Treasure: Design Principles for Developing Cascading and Repurposing Business Models through Systemic Stakeholder Collaboration*", this dissertation closes the above mentioned gap in extant literature. The manuscript inductively develops design principles supporting relevant stakeholders in effectively and systemically collaborating and operationalizing CRBMs.

3. Research Manuscript Overview

This dissertation is based on three distinct but interrelated manuscripts that are investigating the topics highlighted in the previous sections. Table 1 outlines the three manuscripts and their research motivations, methods, samples, underlying theoretical foundations, as well as the panel of authors and publication status. All three manuscripts are investigating topics in the realm of entrepreneurial venture creation and are applying a circular economy (CE) perspective. Manuscript one is applying a basic science approach, while manuscripts two and three are applying a design science approach. In accordance with the requirements of the cumulative dissertation at ESCP Business School, the manuscripts underlying this cumulative dissertation were submitted to reputable academic journals and conferences. Submitting manuscripts to academic journals ensures scientific quality, rigor, and relevance. Presenting manuscripts at reputable academic conferences ensures early developmental feedback. The manuscripts obtained a total of 2.88 points through one Revise & Resubmit in *Journal of Product Innovation Management (JPIM)* (VHB: A; 0.8 points), a publication in *Lecture Notes in Computer Science (LNCS)* (VHB: B; 1.25 points), and an Accept at the *Hawaii International Conference on System Sciences* (*HICSS)* (VHB: B; 0.83 points). Thus, the three manuscripts reach and exceed the required 2.5 points required for the completion of the Ph.d. process at ESCP Business School.

Table 1: Overview of Manuscripts

	Manuscript 1	Manuscript 2	Manuscript 3
Title	**Exploring the Role of Artificial Intelligence in Overcoming the Key Challenges of the Circular Economy: The Emergence of Opportunity Spaces and New Business Models**	**Overcoming Rebound Effects: A Process Blueprint for Circular Systems Design**	**Trash to Treasure: Design Principles for Developing Cascading and Repurposing Business Models through Systemic Stakeholder Collaboration**
Research Question	RQ1: What challenges are hindering the development of a CE? RQ2: What AI-elicited opportunity spaces for new ventures emerge along the product life cycle through the external enablement of the CE by AI? RQ3: What CE-enabling AI-business models are adopted by new ventures aiming to exploit the opportunity spaces?	How can the design across products, services, business models and collaborations be harmonized to create circular systems?	How can different key stakeholders engage in productive partnerships to operationalize cascading and repurposing business models effectively?
Method	Qualitative Interviews (Gioia et al., 2013)	Qualitative Interviews (Gioia et al., 2013) Design Science Research (Peffers et al., 2007)	Qualitative Interviews (Gioia et al., 2013) Design Science Research (Peffers et al., 2007)
Sample	55 semi-structured interviews	31 semi-structured interviews; 1 Workshop	37 semi-structured interviews; 4 Workshops
Theory	External Enablement-Framework (Davidsson, 2015; von Briel et al., 2018; Davidsson & Sufyan, 2023) Circular Business Model Innovation (Geissdoerfer et al., 2020)	Design for Sustainable Innovation (Baldassarre et al., 2020) Systems Thinking for a Circular Economy (Iacovidou et al., 2021) Circular Economy Rebound (Zink & Geyer, 2017; Siderius & Poldner, 2021)	Cascading and Repurposing Business Model Patterns (Lüdeke-Freund et al., 2019)
Journal (Rank)	Journal of Product Innovation Management (VHB: A)	Lecture Notes in Computer Science (VHB: B)	Hawaii International Conference on System Sciences (HICSS) (VHB: B)
Authors	Konstantin Remke Sönke Mestwerdt Maximilian Tigges Matthias Mrozewski René Mauer	Konstantin Remke Henry W. Müller	Julius Trunk Konstantin Remke Christoph Seckler
Status	Revise & Resubmit	Published	Accepted
Points	0.8	1.25	0.83

3.1. Summary Manuscript One

Manuscript one "*Exploring the Role of Artificial Intelligence in Overcoming the Key Challenges of the Circular Economy: The Emergence of Opportunity Spaces and New Business Models*" analyzes the challenges that are hindering the development of a well-functioning CE and explains how the introduction of artificial intelligence (AI) as a digital technology externally enables the CE while fostering new venture creation (von Briel et al., 2018) through the emergence of opportunity spaces along the circular product life cycle (Davidsson, 2015; Kornish & Ulrich, 2011).

The study involves 55 semi-structured interviews that are analyzed through the Gioia-method (Gioia et al., 2013). Data collection was performed by utilizing the video-call platform Zoom and the transcription software "trint". For data analysis and synthesis, the software "atlas.ti" was used. By following the Gioia-method, 10 second-order themes and five aggregate dimensions were identified that describe the challenges hindering the development of a well-functioning CE and AI-benefits the technology brings to the CE. The extracted data was then used to come up with a general model of external enablement of the CE through AI, and a typology of CE-enabling AI-business models along the circular product life cycle.

Manuscript one builds on the external enablement-framework (EE) introduced by Davidsson (2015) and its extension to digital technologies (Briel et al., 2018) and AI (Davidsson & Sufyan, 2023). In addition, the theoretical foundations outlined by Geissdoerfer et al. (2020) are used to inform the study in terms of circular business models (CBM).

Manuscript one was submitted to the *Journal of Cleaner Production (JCLP)* (VHB: B) special issue on "Sustainable Servitization" on June 30th 2023 and received a Desk Reject on July 9th due to not fitting the scope of the journal and the special issue. After revising the manuscript, it was submitted to *JPIM* (VHB: A) special issue on "Innovation Management for a Circular Economy" on July 30th 2023. On February 16th 2024, the paper received a "Revise and Resubmit". For the revision, two additional authors, Sönke Mestwerdt and Matthias Mrozewski, were added to the panel of authors. The revised manuscript has been resubmitted to JPIM on May 31st 2024 and has been under review since. Prior to the first journal submission, the manuscript was presented at the G-Forum conference in Dresden on September 22nd 2022.

In terms of theoretical contributions, manuscript one advances the scholarly understanding of the role that digital technologies, such as AI, can play in overcoming the challenges of the CE (e.g., Zeiss et al., 2021). Additionally, this dissertation advances the EE-framework (Davidsson, 2015; von Briel et al., 2018; Davidsson & Sufyan, 2023) by linking the EE-framework with the CE literature and explaining the EE of the CE through AI as a digital technology, as well as the creation of new ventures as a consequence. In addition, the manuscript contributes by pointing out that AI yields the potential to enable the CE through increased efficiency as well as effective knowledge creation and diffusion.

Furthermore, the manuscript contributes to the literature around CBMs (e.g., Lüdeke-Freund et al., 2019; Geissdoerfer et al., 2020; Pieroni et al., 2020) by identifying a novel type of business model enabling the CE through the employment of AI, which is coined "CE-enabling AI-business model". Moreover, manuscript one identifies four opportunity spaces along the circular product life cycle where AI promises unique benefits, and defines four sub-types of CE-enabling AI-business models for each opportunity space. The sub-types are coined "Circular Design AI-Business Model", "Use Expansion AI-Business Model", "Recirculation AI-Business Model", and "Revaluation AI-Business Model".

In terms of empirical contributions, manuscript one represents the first study inductively approaching the topic of new venture creation in the CE from an EE angle. This is accomplished through a total of 55 qualitative empirical semi-structured interviews with entrepreneurs and experts from the CE and AI fields.

In terms of practical contributions, manuscript one provides entrepreneurs and businesses that are operating in the CE and aiming to leverage AI with guidance on opportunity spaces that are arising from the EE of the CE through AI, and startup-collaborations along the circular product life cycle. Departing from the target group, entrepreneurs can identify the relevant phases in the circular product life cycle, identify the right opportunity space in the pre-use, use, as well as post-use phases, and choose the respective CE-enabling AI-business model type to create their circular startup (Geissdoerfer et al., 2020). Established businesses, in contrast, can use the outcome of manuscript one to transform their business models, or identify the right startup partners for business model acquisition and diversification according to the respective opportunity spaces (Geissdoerfer et al., 2020). On top of that, manuscript one provides guidance on the CE-enabling AI-benefits businesses can offer as part of their CE-enabling AI-business models. These CE-enabling AI-benefits range from knowledge creation and diffusion to efficiency gains.

3.2. Summary Manuscript Two

Manuscript two "*Overcoming Rebound Effects: A Process Blueprint for Circular Systems Design"* harmonizes the various spheres and literature streams of circular design such as circular product design (CPD) (den Hollander et al., 2017), product-service system (PSS) (Tukker, 2015; Franconi et al., 2022), CBM (Geissdoerfer et al., 2020), and collaborative ecosystem design (Konietzko et al., 2020) to develop a practically useful artifact guiding circular designers, businesses, and entrepreneurs in the holistic design of circular systems (CSD) (Iacovidou et al., 2021) aiming to mitigate circular economy rebound (CER) (Zink & Geyer, 2017; Siderius & Poldner, 2021).

The study entails 31 semi-structured interviews and one workshop. All data was analyzed using the Gioia-method (Gioia et al., 2013). Data was collected via the video-call platform Zoom and transcribed using the transcription software "trint". For data analysis and synthesis, the software "atlas.ti" was used. 27 second-order themes and five aggregate dimensions were identified. While the five aggregate dimensions resemble the phases of CSD, the 27 second-order themes mirror the different steps of the CSD process. Manuscript two follows the six-step design science research (DSR) methodology outlined by Peffers et al. (2007), starting with the problem identification, followed by the definition of objectives of a solution, artifact design and development, demonstration, evaluation, and communication.

In terms of theoretical foundations, manuscript two departs from the four levels of design for sustainable innovation introduced by Baldassarre et al. (2020), comprising eco design, PSS design, sustainable business model design, and collaborative ecosystem design. It additionally builds on a systems thinking approach for the CE (Iacovidou et al., 2021) and the CER theory by Zink & Geyer (2017), as well as CER mitigation strategies highlighted by Siderius and Poldner (2021).

Manuscript two was submitted to the *19th International Conference on Design Science Research in Information Systems and Technology (DESRIST-19)* on January 16th 2024. On March 22nd 2024 the manuscript was accepted for publication and conference attendance. An acceptance for the conference is linked to a publication in the outlet *Lecture Notes in Computer Science* (LNCS; VHB: B), which is a reputable journal in the research field of Information

Systems (IS). The manuscript was finally published in LNCS after one round of revision on May 27th 2024. Consequently, the manuscript was presented at the DESRIST-19 conference in Trollhaettan, Sweden, on June 4th 2024. The manuscript was nominated for the Best Paper Award at the DESRIST-19 conference. Additionally, manuscript two was accepted at the Australian Centre for Entrepreneurship Research Exchange (ACERE) conference in Sydney, Australia (date of acceptance: October 18th 2023), but was not presented due to the geographical distance and high costs involved. The manuscript was, furthermore, accepted at the Annual Meeting of the Academy of Management (AOM) (date of acceptance: March 28th 2024) in Chicago (United States of America (USA) and was presented at the conference on August 13th 2024.

In terms of theoretical contributions, manuscript two represents the first study connecting the isolated literature streams on circular product design (CPD) (den Hollander et al., 2017; Diaz et al., 2022), product-service system (PSS) (Franconi et al., 2022), CBM (Geissdoerfer et al., 2020), and collaborative ecosystem design (Konietzko et al., 2020) by outlining interactions between these design spheres, as well as navigation strategies. Additionally, this dissertation advances scholarly understanding on how CSD aids CER mitigation (Siderius & Poldner, 2021; Zink & Geyer, 2017). In terms of empirical contributions, manuscript two represents the first study to inductively approach CSD and CER mitigation. This is accomplished by 31 qualitative semi-structured interviews.

In terms of practical contributions, manuscript two develops a practically useful process blueprint for circular designers, entrepreneurs, and businesses operating in the CE. The process blueprint represents a comprehensive framework to facilitate the holistic design of circular systems, simultaneously considering CPD, PSS design, CBM design, and collaborative ecosystem design. Using the process blueprint prevents the isolated design of the individual elements of a circular system. For instance, in the case of eScooters the isolated design led to a final product design that appears to mismatch the CBM (sharing/intensifying), consequently offsetting the positive environmental effects the concept was promising. Increased street congestion, misuse of inexperienced riders, insufficient charging infrastructure, and bans from cities (e.g., Paris), stand as a testament for the isolated design of the single elements of the circular system around eScooters and mirror potential CER effects that fragmented CSD can yield. The process blueprint helps circular designers, entrepreneurs, and circular businesses to understand the complexities and interdependencies between the different circular design spheres, and to effectively navigate through these, thereby contributing to CER mitigation.

3.3. Summary Manuscript Three

Manuscript three "*Trash to Treasure: Design Principles for Developing Cascading and Repurposing Business Models through Systemic Stakeholder Collaboration"* develops design requirements and design principles for collaborative, systemic, and effective stakeholder collaboration to operationalize cascading and repurposing business models (CRBMs) (Lüdeke-Freund et al., 2019).

The study inductively develops design principles by leveraging 37 semi-structured interviews and a data analysis guided by the Gioia-method (Gioia et al., 2013). The collected data was transcribed using the software "trint" and coded using "atlas.ti". The 30 initially identified first-order codes were distilled into 13 second-order themes and nine aggregate dimensions. The manuscript follows the DSR structure as outlined by Peffers et al. (2007). To develop design principles, manuscript three derives design requirements from the data analysis and finally distills five design principles that serve as mechanisms and outcomes within the overarching logic of context, intervention, mechanism, and outcome (CIMO) (Denyer et al., 2008) that is used to formulate structured design principles (e.g., Maesschalck, 2022).

The theoretical foundations of manuscript three are grounded in the CBM patterns of cascading and repurposing as outlined by Lüdeke-Freund et al. (2019).

Manuscript three was submitted to the *58th Hawaii International Conference on System Sciences (HICSS-58)* on June 14th 2024. The HICSS conference proceedings represent a B-publication according to the VHB 2024 journal ranking. The manuscript received conditional acceptance on August 18th 2024. After resubmission of the revised version, the manuscript was accepted for publication and conference attendance on September 12th 2024. The publication is expected for January 2025.

In terms of theoretical contributions, manuscript three makes significant contributions to the literature on CBMs (Lüdeke-Freund et al., 2019). Departing from the lack of actionable frameworks for the operationalization of CRBMs in terms of stakeholder roles and the coordination of material flows, as identified by Lüdeke-Freund et al. (2019), the present study identifies entrepreneurs as a promising collaboration partner for small and medium sized enterprises (SMEs) in operationalizing CRBMs. Additionally, manuscript three introduces the DSR methodology (Peffers et al., 2007) to the literature stream on CRBMs and is the first to derive actionable design principles for the collaborative operationalization of CRBMs.

In terms of empirical contributions, manuscript three represents the first study to inductively approach stakeholder collaboration and CRBM development in the context of the CE. The study consists of 37 semi-structured interviews with entrepreneurs and experts from the domain of CE and more specifically cascading and repurposing.

In terms of practical contributions, manuscript three offers entrepreneurs and managers a set of design principles that are intended to aid the process of collaborative CRBM development and guides effective stakeholder collaboration for the operationalization of CRBMs. Entrepreneurs and managers can use the design principles to develop and operationalize CRBMs by finding the right partners for an effective collaboration optimizing the sequenced use of materials.

4. Manuscripts

4.1. Manuscript 1: Exploring the Role of Artificial Intelligence in Overcoming the Key Challenges of the Circular Economy: The Emergence of Opportunity Spaces and New Business Models

Authors	Konstantin Remke, Sönke Mestwerdt, Maximilian Tigges, Matthias Mrozewski, René Mauer
Journal	Journal of Product Innovation Management (A)
Status	R&R
Citation	Remke, K., Tigges, M., Mauer, R. (Under Review in *Journal of Product Innovation Management*). Exploring the Role of Artificial Intelligence in Overcoming the Key Challenges of the Circular Economy: The Emergence of Opportunity Spaces and New Business Models.

4.2. Manuscript 2: Overcoming Rebound Effects: A Process Blueprint for Circular Systems Design

Authors	Konstantin Remke & Henry Willem Müller
Journal	Lecture Notes in Computer Science (DESRIST) (B)
Status	Published
Citation	Remke, K., & Müller, H. W. (2024, May). Overcoming Rebound Effects: A Process Blueprint for Circular Systems Design. In *International Conference on Design Science Research in Information Systems and Technology* (pp. 33-47). Cham: Springer Nature Switzerland.

4.3. Manuscript 3: Trash to Treasure: Design Principles for Developing Cascading and Repurposing Business Models through Systemic Stakeholder Collaboration

Authors	Julius Trunk, Konstantin Remke, Christoph Seckler
Journal	Hawaii International Conference on System Sciences (HICSS) (B)
Status	Accepted
Citation	Trunk, J., Remke, K., Seckler, C. (Accepted in *HICSS-58*, 2025). Trash to Treasure: Design Principles for Developing Cascading and Repurposing Business Models through Systemic Stakeholder Collaboration.

5. Conclusion

Concluding this dissertation, a synthesis of findings is provided, followed by overarching theoretical contributions as well as practical implications. Finally, limitations, and avenues for future research are highlighted.

5.1. Summary and Synthesis of Findings

Generally, the findings of the present dissertation deepen the scholarly understanding of the enabling components of the circular economy (CE) as well as its design and guide practitioners in innovating for and developing a well-functioning CE.

By investigating the impact that digital technologies can have on the CE and the emergence of novel business models, this dissertation contributes to the literature stream on the external enablement-framework (EE) (von Briel et al., 2018; Davidsson & Sufyan, 2023) and circular business model (CBM) innovation (Geissdoerfer et al., 2020).

In answering the research question: "*what challenges are hindering the development of a CE?*", manuscript one finds that the primary challenges the CE is facing are information deficiencies as well as competitive disadvantages (e.g., efficiency) of the CE in comparison to linear models on systems and organizational levels. These findings correspond with the research by Zeiss et al. (2021) highlighting the need to respond to CE challenges such as where is a resource that I need right now?, who has data that can help me?, or how can I design something as circular as possible?

The second research question: "*what AI-elicited opportunity spaces for new ventures emerge along the product life cycle through the external enablement of the CE by AI*?" is answered by highlighting artificial intelligence (AI)-benefits and defining opportunity spaces for new venture creation along the circular product life cycle. The identified benefits that AI brings to the CE are knowledge creation and analysis, knowledge diffusion, and efficiency gains on systems and organizational levels. Departing from these findings, four emerging opportunity spaces are identified along the circular product life cycle. In the pre-use phase, an opportunity space emerges for new ventures by leveraging AI to support processes around increasing circular product value to a maximum. In the use phase, an opportunity space emerges for new ventures by leveraging AI to keep products at the highest value possible. Between the use and post-use phases, an opportunity space emerges by leveraging AI to keep products with decreased value in use. Lastly, in the post-use phase, an opportunity space emerges by leveraging AI to restore minimal product value. These findings add to the theoretical foundations outlined by Davidsson (2015) as well as Kornish and Ulrich (2011) about opportunity spaces that are elicited through EE.

Departing from these findings, manuscript one further answers the question: "*what CE-enabling AI-business models are adopted by new ventures aiming to exploit the opportunity spaces?*". The CE-enabling AI-business models defined in manuscript one resemble the four opportunity spaces. For opportunity space one, the "Circular Design AI-Business Model" should be adopted by new ventures, benefitting retailers, assemblers, and manufacturers. The primary AI-benefits this business model offers are productivity and cost reduction (efficiency). For opportunity space two, the "Use Expansion AI-Business Model" can be employed by new ventures, benefitting users as well as repair and maintenance providers. This business model is primarily offering AI-generated benefits of decision support and circular product monitoring (information analysis and knowledge creation). For opportunity space three, the "Recirculation AI-Business Model" can be adopted, benefitting users as well as reuse and redistribution providers. This business model offers the primary AI-benefit of creating interlinkages and enhanced information dispersion (knowledge diffusion). Lastly, for opportunity space four, the "Revaluation AI-Business Model" can be employed by new ventures, mainly benefitting refurbishers, remanufacturers, and recyclers, while offering decision support and circular product monitoring as a main AI-generated benefit.

Manuscript two answers the research question: "*how can the design across products, services, business models and collaborations be harmonized to create circular systems?*". The manuscript finds a design process to harmonize the different circular design spheres -products, services, business models, collaborating ecosystems- in order to create circular systems. The design process consists of five phases: System Research, Life Cycle Thinking, System Creation, System Fit, and System Evaluation. The five phases resemble the design process of the various design spheres. For example "Life Cycle Thinking" which entails the design of CBMs, "System Creation", which involves the design of collaborative ecosystems as well as product-service systems (PSSs), and "System Fit", which involves circular product design (CPD). These findings add to the research by Baldassarre et al. (2020) and Iacovidou et al. (2021) describing levels of design for sustainable innovation and circular systems thinking by applying the respective levels to circular design. Additionally, the process developed in manuscript two adds a prescriptive account to the works of Zink and Geyer (2017) describing the phenomenon of circular economy rebound (CER), as well as Siderius and Poldner (2021) who are descriptively highlighting the need for systems thinking for CER mitigation.

Manuscript three answers the research question "*how can different key stakeholders engage in productive partnerships to operationalize cascading and repurposing business models effectively?*" The manuscript finds five design principles that serve as mechanisms and outcomes within the context, intervention, mechanism, and outcome (CIMO) logic. Additionally, the manuscript identifies small and medium-sized enterprises (SMEs) as promising partners for entrepreneurs in setting up and operationalizing cascading and repurposing business models (CRBMs). These findings add to the research by Lüdeke-Freund et al. (2019) calling for actionable frameworks for the operationalization of CRBMs in terms of stakeholder roles and the coordination of material flows.

The findings of this dissertation can be synthesized into three overarching findings. First, the dissertation highlights the potential of new venture creation and systems thinking for a well-functioning CE. This is underscored by all three manuscripts, advancing the scholarly understanding of the promises that systems thinking brings to the CE (e.g., De Angelis & Ianulardo, 2024). Second, the findings suggest that CSD, including CBM innovation and design, can serve as a way for new ventures to respond to EE and maximize impact through the mitigation of CER. This advances the scholarly understanding of EE and potential responses by new ventures in the context of the CE while considering CER, as underscored by manuscript one and two (e.g., von Briel et al., 2018; Siderius & Poldner, 2021; Castro et al., 2022; Nielsen & Hakala, 2023; Das et al., 2023). Third, all three manuscripts highlight the importance of an effective and systemic stakeholder collaboration for the operationalization of CBMs, enabled through knowledge diffusion throughout the circular ecosystem. This advances scholarly understanding in terms of the importance that systemic and effective stakeholder collaboration through digital technologies and the identification of relevant stakeholders (e.g., SMEs and new ventures) can have for a well-functioning CE (e.g., Salvador et al., 2021; Tapaninaho & Heikkinen, 2022; Schultz et al., 2024).

Taken together, this dissertation finds that digital technologies, such as AI, systemic design, and collaborative operationalization of CBMs yields interesting pathways to enable a well-functioning CE, informing new venture creation, and mitigating CER. The findings of the three manuscripts advance the current discourses about the EE of the CE through digital technologies, such as AI (von Briel et al., 2018; Davidsson & Sufyan, 2023; Nielsen & Hakala, 2023), CBM innovation (Geissdoerfer et al., 2020), CBM patterns and types (Lüdeke-Freund et al., 2019; Pieroni et al., 2020), CRBM operationalization (Lüdeke-Freund et al., 2019), as well as design for sustainable and circular innovation and systems thinking for CER mitigation (Zink & Geyer, 2017; Baldassarre et al., 2020; Iacovidou et al., 2021; Siderius & Poldner, 2021).

5.2. Theoretical Contributions

This dissertation contributes to the CE literature in important ways. Kirchherr et al. (2023, p. 7) posit that the CE is "*enabled by an alliance of stakeholders (industry, consumers, policymakers, academia) and their technological innovations and capabilities*". Additionally, a CE is "*enabled by novel business models and responsible consumers*" (Kirchherr et al., 2017, p. 229). Transitioning from a definition of the CE to its interlinkage with new venture creation, Geissdoerfer et al. (2020) argue that the creation of novel business models corresponds to the first type of circular business model innovation, coined "circular startup". The role that design plays in enabling the CE and new venture creation becomes evident when referring to the highly published articles "*Crafting Business Architecture: The Antecedents of Business Model Design*" by Amit & Zott, 2015, "*Product Design in a Circular Economy: Development of a Typology of Key Concepts And Terms*" by den Hollander et al. (2017), or "*Opportunities as Artifacts and Entrepreneurship as Design*" by Berglund et al. (2020).

This dissertation departs from the previously mentioned perspectives, contributing and presenting a first approach to advance scholarly understanding of technology-driven EE of the CE and corresponding business model innovation, as well as design science research (DSR) methodology considering novel CBMs and CSD. Taken together, the present dissertation contributes to advancing the scholarly understanding of the enabling elements outlined in the Kirchherr et al. (2017; 2023) definition by applying an EE perspective, systems thinking, and DSR.

By investigating the challenges of the CE and potential benefits that AI as a digital technology can bring to the field as an EE in manuscript one, the present dissertation contributes by shedding light on the CE-enabling element "technological innovation and capabilities" that is outlined as a central enabler of the CE (Kirchherr et al., 2023). By defining novel types of CE-enabling AI-business models for opportunity spaces along the circular product life cycle in manuscript one, this dissertation further contributes by advancing scholarly understanding of the second central enabling element of the CE, which Kirchherr et al. (2017) coin "novel business models". Through manuscript one, this dissertation further contributes to better understanding the role of new ventures in the CE by identifying CE-enabling AI-business models new ventures can adopt to tap into externally enabled opportunity spaces.

Consequently, manuscript one stands as a testament to the importance of business model innovation, new venture creation, and technology-driven EE for the CE, mirroring this dissertation's strong theoretical contribution to the literature on EE (Davidsson, 2015; von Briel et al., 2018; Davidsson & Sufyan, 2023) and CBM innovation (Geissdoerfer et al., 2020).

Through manuscript two, this dissertation contributes to advancing scholarly understanding of the CE-enabling element "responsible consumers" (Kirchherr et al., 2017) and its theoretical underpinnings by integrating consumer behavior as an important part of the CSD artifact that has been developed throughout manuscript two. Another contribution this dissertation makes is linked to the CE-enabling component "alliance of stakeholders" (Kirchherr et al., 2023) and its theoretical implications by operationalizing and integrating the design sphere of collaborative ecosystems into the artifact (Konietzko et al., 2020). The enabling component of "technological innovations and capabilities" (Kirchherr et al., 2023) is covered by manuscript two integrating technologies as an important component of the "System Research" phase of the artifact. In addition, the manuscript contributes to the enabling component "novel business models" (Kirchherr et al., 2017) by integrating CBMs into the "Life Cycle Thinking" phase of the process blueprint, while leaving room for the development of novel business models that are building on established ones (type 3: transformation) (e.g., Pieroni et al., 2020).

Manuscript two stands as a testament to the importance of design for the CE and new venture creation, as it presents a practically useful artifact for entrepreneurs (and incumbent firms) operating in a CE. The artifact emerged from the application of the DSR methodology. Manuscript two mirrors this dissertation's strong theoretical contribution to the literature streams on circular product design (CPD) (e.g., den Hollander et al., 2017), PSS (e.g., Franconi et al., 2022), CBM design (e.g., Das et al., 2023), and collaborative ecosystem design (e.g., Konietzko et al., 2020). Furthermore, this dissertation advances the scholarly understanding of design for sustainable innovation (Baldassarre et al., 2020) by applying the theoretical approach to the CE.

Through manuscript three, this dissertation contributes to the "alliance of stakeholders" theme (Kirchherr et al., 2023) by identifying SMEs as promising partners for entrepreneurs in terms of operationalizing CRBMs. Furthermore, through manuscript three, this dissertation contributes to advancing scholarly understanding of the notion of "novel business models" in the CE context (Kirchherr et al., 2017). By developing design principles for the development of CRBMs through effective stakeholder collaboration, manuscript three marks the first study shedding light on the design elements of CRBMs.

Manuscript three stands as a testament to the importance of collaborations between startups and incumbent firms (e.g., SMEs) in the context of CBM operationalization. This mirrors this dissertation's contribution to the literature stream on business model patterns as well as actionable frameworks for their operationalization (Lüdeke-Freund et al., 2019).

5.3. Practical Implications

Apart from theoretical contributions, the present dissertation yields various practical implications for entrepreneurs, managers of incumbent firms (e.g., SMEs), and circular designers.

5.3.1. Implications for Entrepreneurs

The findings of this dissertation aid entrepreneurs in identifying opportunity spaces along the circular product life cycle and in better understanding the benefits that digital technologies such as AI can bring to the CE. In addition, entrepreneurs can use the findings of this dissertation to create new ventures using AI to shape novel CE-enabling AI-business models to tap into the identified opportunity spaces.

Entrepreneurs benefit from this dissertation's findings by being able to draw from the artifacts developed throughout manuscript two and three. The artifact developed in manuscript two specifically aids entrepreneurs in harmonizing the design of business models with collaborative ecosystems, PSS, and CPD. This systemic design approach supports entrepreneurs in coming up with new circular systems and circularly optimizing existing portfolios of products, services, business models, and ecosystems. Simultaneously, the artifact developed in manuscript two supports entrepreneurs in mitigating or reducing CER effects through systemic design.

The artifact developed in manuscript three aids entrepreneurs in collaboratively operationalizing CRBMs and shaping novel and more informed business models for a CE.

Entrepreneurs can utilize the design principles developed in manuscript three to find the relevant partnerships and CRBM configurations based on a CIMO-logic (Denyer et al., 2008).

Thus, entrepreneurs can leverage this dissertation to develop novel business models complemented by intricate and holistic circular systems aiming to mitigate CER by designing circular products that are comparable with linear alternatives in quality, price, and target market (Zink & Geyer, 2017; Siderius & Poldner, 2021).

5.3.2. Implications for Managers

This dissertation helps managers in better understanding the challenges of the CE and how they can innovate by either transforming their business model towards a CE-enabling AI-business model, diversifying through partnerships, or acquiring new ventures employing CE-enabling AI-business models (Geissdoerfer et al., 2020). Moreover, for managers, the identified opportunity spaces can be interesting to take as a starting point for the consideration of transformation, diversification, and acquisition (Geissdoerfer et al., 2020) of novel CE-enabling AI-business models.

Managers can further leverage the artifacts developed in this dissertation to better shape and understand their CBMs, as well as to harmonize CBM design with the overarching CSD while simultaneously considering the design of circular products, services, and collaborative ecosystems. For managers, the CER implications of CSD can also be interesting when offering circular products. The findings of this dissertation can help managers in developing circular products that are comparable with linear products in quality, price, and target market to mitigate CER (Zink & Geyer, 2017; Siderius & Poldner, 2022).

5.3.3. Implications for Circular Designers

For circular designers the findings of this dissertation have important implications. While circular designers are mainly concerned with the design of circular products, they rarely have an overview of the circular system around the circular product. Thus, the findings of this dissertation provide circular designers with an overview of the circular system around circular products, aiding an intricate design of products that have functioning PSS around it, while being embedded in a matching CBM and collaborative ecosystem.

On top of that, circular designers can benefit from the findings of this dissertation in understanding the impact of digital technologies on the CE and the opportunity spaces arising from it to develop circular systems that are tapping into these opportunity spaces, while leveraging digital and innovative technologies. Circular designers can further benefit from design knowledge created through DSR studies and the DSR process itself. This dissertation can aid circular designers in leveraging scientifically sound solutions to prescriptive problems, complementing the daily work of circular designers.

5.4. Limitations and Avenues for Future Research

Despite this dissertation making important theoretical and practical contributions, it is acknowledged that this study faces limitations that naturally translate into an agenda for future research.

First, the qualitative nature of the research conducted in the context of this dissertation leaves room for quantitative testing of its findings. Testing the findings of this dissertation would enhance the relevance and strengthen the rigor of this research. Thus, future research could quantitatively test the findings outlined in the underlying manuscripts. Especially the theoretical argumentation about CER mitigation and impact maximization could be an interesting angle for future quantitative studies.

Second, the new venture perspective the present dissertation takes on can be understood as a limiting aspect, especially considering the remaining three types of CBM innovation: diversification, transformation, and acquisition (Geissdoerfer et al., 2020). Studying the remaining types of CBM innovation from an incumbent firm perspective could uncover other and different types of CE-enabling business models, require a different circular system configuration, and yield different stakeholder considerations. Future research could, thus, take on an incumbent firm perspective to study the phenomena examined in the present dissertation.

Third, due to time constraints in terms of special issues and conference deadlines, the evaluations of the artifacts developed in manuscript two and three remained on a rather superficial level. In-depth testing of the artifacts (also by applying quantitative methods) could optimize the artifacts' usefulness, scientific rigor, and further evaluate the artifacts' relevance for solving the problems to be tackled. Future research should evaluate the usefulness and other evaluation parameters by potentially dedicating an entire study to the evaluation of the artifacts (Tuunanen et al., 2024).

Lastly, despite contributing to the relevant discourses as for instance CBM innovation, CER, and CPD, the manuscripts underlying this dissertation have not been submitted or published in the outlets covering the relevant discourses. Instead, primarily outlets from the information systems (IS) and innovation field have been selected. Future research that is building on this dissertation and connecting to the relevant discourses, thus, should target journals such as Journal of Cleaner Production, Business Strategy and Environment, and Industrial Ecology to reach the relevant audience.

6. Concluding Remarks

In light of the grand challenges that humanity faces, hopefully the findings of this dissertation not only contribute to the relevant academic discourses, but also add real-world value to entrepreneurial as well as managerial practice. Especially the artifacts that were developed throughout this dissertation through rigorous application of the design science research (DSR) methodology may yield great potential to contribute to tackling grand challenges such as climate change (Seckler et al., 2021; Ritala, 2024). The findings of this dissertation will be utilized in the form of university lectures (electives in specialized Master programs) at ESCP Business School in 2025, and research advisory services in collaboration with the Centre for Sustainability Transformation Applied Research (STAR). These use cases mirror the practical relevance of the research conducted in the context of this dissertation, and may contribute to further bridging the gap between theory and practice.

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