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Driving Toward Circular Business Models: Conditions and Strategies in the Built Environment

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Driving Toward Circular Business Models: Conditions and Strategies in the Built Environment

PhD Thesis

Ingvild Reine Assmann

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ABSTRACT – ENGLISH

The world is increasingly facing crises and shocks, with the climate crisis being the defining crisis of our time, affecting all facets of life on our planet: from coral reefs and species dying, weather extremes, food and water insecurity, economic disorder, international conflicts, and terrorism (United Nations, 2023b). The immeasurable costs of climate change are reaching irreparable highs. The United Nations (UN) (2023a) testify that progress toward sustainable development is underway, for instance through green energy advances and more secure food supplies. However, although progress has started, there is still a pressing need for major transformations across all aspects of society.

To assist in steering the transition, the circular economy—and particularly circular business models (CBMs) and circular business model innovation (CBMI)—has been proposed as a promising avenue to reach sustainable development through a change to business operations that profit from a circular (reduce, reuse, recycle) model instead of the outmoded linear (take, make, waste) model.

The built environment is a principal contributor to climate change, and with a rapidly growing global population, the need for housing continues to soar, catapulting the environmental, social, and economic impacts of the built environment to its peak (World Green Building Council, 2023). Considering its significant impact, it is essential that the built environment delivers transformational change to ensure sustainable built environments for the future, as it poses a crucial facet to fighting climate change, and driving economic security whilst also creating resilient societies (World Green Building Council, 2023). Resilience in the built environment has been studied at firm, industry, and society level, but the literature has not sufficiently examined resilience in the built environment across the different levels to investigate how resilience at one level can impact resilience at other levels (Kennedy & Linnenluecke, 2022),

Aiming to respond to the needs of today, this thesis seeks to answer the following research questions:

RQ 1: What conditions and strategies lead to CBM adoption and CBMI?

RQ 2: What are the resulting effects of CBMs on resilience across levels in the built environment?

This thesis comprises three core articles. Article A presents a systematic literature review and identifies 54 different determinants that drive or hinder CBM adoption, classifying them into eight macro categories: culture, regulation, market, strategy, business case, collaboration, operations, and knowledge. Article B employs a three-round Delphi method with 25 experts to categorize the drivers and barriers to CBMI in the built environment, and develops 34 strategies for practitioners in the built environment to capitalize on the drivers and overcome the barriers. These strategies are classified into four proposed categories regarding how they can assist in changing resource loops: 'Understanding the loop,' 'Facilitating the loop,' 'Promoting the loop,' and 'Regulating the loop'. Article C then cross-compares four circular and four linear startups from one entrepreneurial ecosystem, and presents how the circular startups' innate nurturing of their ecosystem has trickle-up effects to multiple levels' resilience in response to crises, using the material crisis as its crisis context.

Woven together, this thesis contributes to the literature on *circular business model innovation* and *adoption*, *the built environment*, and *resilience*. This thesis contributes to the literature by developing an in-depth review of the current literature on driving and hindering conditions to CBM adoption and CBMI, the strategies that can be used to tackle these conditions for CBMI in the built environment, and the impact of CBMs on resilience across levels.

Keywords: circular business models, circular business model adoption, circular business model innovation, built environment, construction industry, resilience, circular strategies

RESUMÉ – DANSK

Verden står i stigende grad over for kriser og chok, hvor klimakrisen er vor tids afgørende krise, der påvirker alle facetter af livet på vores planet: fra koralrev og dyrearter der dør, ekstreme vejrforhold, fødevare- og vandusikkerhed, økonomisk uorden, internationale konflikter og terrorisme (FN, 2023b). De umådelige omkostninger ved klimaændringer når uoprettelige højder. De Forenede Nationer (2023a) bevidner at fremskridt hen imod en bæredygtig udvikling er undervejs, for eksempel gennem fremskridt med grøn energi og mere sikker fødevareforsyning. Men selv om fremskridtet er begyndt, er der stadig et presserende behov for store forandringer på tværs af alle aspekter af samfundet.

For at hjælpe med at styre overgangen er den cirkulære økonomi - og især cirkulære forretningsmodeller (CBM'er) og innovation af cirkulære forretningsmodeller (CBMI) - blevet foreslået som en lovende vej til at nå bæredygtig udvikling gennem en ændring af forretningsdrift, der drager fordel af en cirkulær (’reduce, reuse, recycle’) model i stedet for den forældede lineære (’take, make, waste’) model.

Det byggede miljø er en væsentlig bidragyder til klimaændringer, og med en hastigt voksende global befolkning fortsætter behovet for boliger med at stige kraftigt, hvilket slynger de miljømæssige, sociale og økonomiske påvirkninger af det byggede miljø til sit højeste (World Green Building Council, 2023). I betragtning af dets betydelige indvirkning er det afgørende, at det byggede miljø leverer transformerende forandringer for at sikre bæredygtige byggede miljøer for fremtiden, da det er en afgørende faktor for bekæmpelse af klimaforandringer og fremme af økonomisk sikkerhed, samtidig med at der skabes modstandsdygtige samfund (World Green Building Council, 2023). Resiliens i det byggede miljø er blevet undersøgt på virksomheds-, industri- og samfundsniveau, men litteraturen har ikke tilstrækkeligt undersøgt resiliens i det byggede miljø på tværs af forskellige niveauer til at undersøge, hvordan resiliens

på ét niveau kan påvirke resiliens på andre niveauer (Kennedy & Linnenluecke, 2022), Med det formål at imødekomme nutidens behov, søger denne afhandling at besvare følgende forskningsspørgsmål:

RQ 1: Hvilke forhold og strategier fører til CBM-adoption og CBMI?

RQ 2: Hvad er de resulterende virkninger af CBM'er på modstandsdygtighed på tværs af nivåer i det byggede miljø?

Denne afhandling omfatter tre kerneartikler. Artikel A præsenterer en systematisk litteraturgennemgang og identificerer 54 forskellige determinanter for CBM-adoption, og klassificerer dem i otte makrokategorier: kultur, regulering, marked, strategi, business case, samarbejde, operationer og viden. Artikel B anvender en tredelt Delphi-metode med 25 eksperter til at kategorisere drivkræfterne og barriererne for CBMI i det byggede miljø, og udvikler 34 strategier for praktikere i det byggede miljø for at udnytte drivkræfterne og overvinde barriererne. Disse strategier er klassificeret i fire foreslåede kategorier med hensyn til hvordan de kan hjælpe med at ændre ressource ’loops’: ‘Understanding the loop,’ ‘Facilitating the loop,’ ‘Promoting the loop,’ og ‘Regulating the loop’. Artikel C krydssammenligner derefter fire cirkulære og fire lineære startups fra ét entreprenørmæssigt økosystem, og præsenterer, hvordan de cirkulære startups' iboende pleje af deres økosystem har ’trickle-up’ effekter på iværksætterøkosystemets modstandsdygtighed som reaktion på kriser, ved at bruge den materielle krise som sin krisekontekst.

Sammenlagt bidrager denne afhandling til litteraturen om innovation og adoption af cirkulære forretningsmodeller, det byggede miljø og resiliens. Denne afhandling bidrager til litteraturen ved at udvikle en dybdegående gennemgang af den aktuelle litteratur om drivende eller hæmmende forhold for CBM-adoption og CBMI, de strategier der kan bruges til at tackle disse forhold for CBMI i det byggede miljø, og virkningen af CBM'er på resiliens på tværs af nivåer.

Nøgleord: Cirkulære forretningsmodeller, vedtagelse af cirkulære forretningsmodeller, innovation af cirkulære forretningsmodeller, bygget miljø, byggeindustri, robusthed, resiliens, cirkulære strategier

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To you, dear reader, thank you for your interest in this work. It is because of people like you that care about sustainability and make an effort that we just might be able to turn this ship around.

Ingvild Reine Assmann

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LIST OF ACRONYMS

CBM – Circular business model

CBMI – Circular business model innovation

CE – Circular economy

PhD – Doctor of philosophy

RQ – Research question

UN – United Nations

1. INTRODUCTION

On November 15, 2022, the global world population reached the 8 billion mark (UNCTAD, 2022) and the UN now predicts that the world population will hit 10 billion in the 2080s (United Nations, 2022). This rapid increase in world population, matched by the ongoing trend toward urbanization, has created a severe shortage of housing globally, and by 2030, 3 billion people will be in need of new homes (UN-Habitat, 2018). Today, the built environment is one of the most resource-consuming industries, responsible for emitting 38 percent of the global energy-related greenhouse gas emissions (United Nations Environment Programme, 2020) and using 50 percent of all materials consumed across Europe (Herczeg et al., 2014). The built environment is a cornerstone for economic competitiveness and crucial for the social well-being of citizens globally (Çetin et al., 2021). Despite the high potential of the built environment's material waste for reuse and recycling, estimations show that only about 40 percent of the materials are currently reused, recycled, or sent to energy facilities, whereas 60 percent of the material waste in the construction industry is sent to landfills (US EPA, 2020). The stakeholders within the built environment therefore face a great challenge in how they respond to the global housing crisis whilst transitioning toward sustainable development (Çetin et al., 2021).

A circular economy has been proposed as an avenue to sustainable development (Guldmann & Huulgaard, 2017). As such, the built environment is, according to several scholars, a particularly beneficial context for applying circular economy practices and strategies to achieve both economic and environmental gains (Ellen MacArthur Foundation, 2015; ING, 2017; Koutamanis et al., 2018; Nußholz et al., 2020). Scholars define the 'circular economy' differently based on their differing schools of thought (Ellen MacArthur Foundation, 2015; Kirchherr et al., 2017; Nobre & Tavares, 2021). For example, different definitions portray the circular economy as either a model, a concept (Bocken et al., 2017), or a strategy (Galvão et al., 2018), aiming to address the challenges of resource scarcity and material disposal whilst winning financially (Galvão et al., 2018). Yet all definitions share the notion that the circular economy is concerned with extending the lifetime of materials to retain materials and resources circulating at their highest value within planetary boundaries at all times (Blomsma & Brennan, 2017; Bocken et al., 2017; Ellen MacArthur Foundation, 2015; Guerra et al., 2021). For continued societal prosperity, the ability of the built environment to rise up and meet the urgent needs of the twenty-first century is fundamental (Ghaffar et al., 2022). However, to arrive at a circular economy, it’s imperative that companies transform the way they currently operate (Bocken et al., 2016; Guldmann & Huulgaard, 2020), and circular business models (CBMs) stand out as a means to do so (Nußholz & Milios, 2017). Nevertheless, despite being promising, to transition from a traditional linear business model to a CBM constitutes a complex innovation challenge (Bocken et al., 2018; Guldmann & Huulgaard., 2017); hence, the adoption of CBMs in companies remains slow (Guldmann & Huulgaard, 2020).

1.1 Research context

The research in this PhD thesis applies the CBM literature stream to the built environment context. CBMs may be defined as how a firm or an ecosystem of firms creates, delivers, and captures value by (i) slowing, (ii) closing, (iii) narrowing, or iv) regenerating resource loops (Bocken et al., 2016; Çetin et al., 2021; McDonough & Braungart, 2013; Nußholz et al., 2023; Oghazi & Mostaghel, 2018; Pieroni, 2020; Stahel, 1994). This research stream is still in its conceptualization phase and is distinguished by fragmented and sometimes disparate literature (Merli et al., 2018; Nußholz, 2017; Pieroni et al., 2019; Pieroni, 2020). While scholarly studies on CBMs have grown exponentially over the last decade (Bigliardi & Filippelli, 2021; Geissdoerfer et al., 2020), there is a misalignment between the academic interest in CBMs and the various industries’ belief in their potential, and hence a limited uptake of CBMs in practice.

However, some companies (e.g., Renault, Nudie Jeans, Apple, and Phillips) are adopting circular solutions—for instance, to position themselves as frontrunners, or to deal with market and public procurement requirements (Guldmann, 2016). Research has, however, primarily focused on understanding and describing the theoretical advances toward CBMs (Kirchherr et al., 2017; Pieroni et al., 2019, 2020). Kirchherr and van Santen (2019) found that in over 160 articles about circular economy (indexed in Scopus from 2006 to 2019), less than 40 percent of the literature includes strong empirical demonstrations, and merely 20 percent of the literature involves recommendations to firms (Kircherr & van Santen, 2019; Pieroni, 2020). Moreover, the literature on CBMs can be separated into two streams: CBM adoption and circular business model innovation (CBMI). The CBM adoption literature stream focuses on the incorporation of CBMs into firms' business models and operations, whereas the CBMI literature concentrates on the innovation activities needed in order to develop CBMs. To date, the CBMI research stream has fostered seminal studies arguing the topic's significance or outlining the concept (Lewandowski, 2016; Linder & Willander, 2017; Nußholz & Milios, 2017; Pieroni, 2020). A few scholars have concentrated on developing methods and tools to support the companies wanting to adopt CBMs (Bocken et al., 2019; Rosa et al., 2019), while other scholars have focused on developing or examining CE standards (Flynn & Hacking, 2019; Homrich et al., 2018). Thus far, academic research on CBMI approaches has remained conceptual and descriptive, with limited empirical evidence, constraining the usefulness of such research to practitioners (Bocken et al., 2019; Kirchherr & van Santen, 2019; Lieder & Rashid, 2016; Pieroni et al., 2019).

This thesis applies the CBM and CBMI literature to the built environment context. The term 'built environment' is fairly recent and was coined by social scientists attempting to explain, in one holistic and integrated concept, the consequences of human activities (Haigh & Amaratunga, 2010; Hassler & Kohler, 2014; Rapoport, 1976). The built environment encompasses the construction industry and the 'man-made building and infrastructure stocks that constitute the physical, natural, economic, social, and cultural capital' (Hassler & Kohler, 2014. p.120). Furthermore, the 'built environment' term has been adjusted to confront the connection between the built and unbuilt elements of the environment (Hassler & Kohler, 2014), which correlates with the characterization of a social-ecological system where the built environment may be regarded as an artifact in a coinciding zone between nature and culture wherein causation transpires in both directions (Hassler & Kohler, 2014). The built environment plays a vital role in our societies as it serves human endeavors, and, if damaged or challenged, a society's ability to thrive or function—both economically and socially—can be massively disrupted (Haigh & Amaratunga, 2010). The built environment also possesses protective characteristics that reduce the risks to humanity posed by hazards and crises. However, extreme events and exogenous shocks can cause significant disruption to the built environment, for instance its enclosed buildings, infrastructure, and distribution systems (Al-Humaiqani & Al-Ghamdi, 2022; Crick et al., 2018; Howe, 2011; Marks & Thomalla, 2017; US EPA, 2020). The sustainability debate, climate change, and the increasing cognizance of risks are all factors that are currently narrowing the attention to fragility and the need for resilience, particularly in the resource-consuming industries such as the built environment.

1.2 Research aim

Despite the apparent benefits of adapting to the circular economy by implementing and innovating toward CBMs, the uptake of CBMs remains limited (De Angelis, 2021; Stål & Corvellec, 2018). Moreover, although the built environment has been proposed as a particularly well-suited context for exploring CBMI, the industry remains conservative and unwilling to innovate (Çetin et al., 2021; Ghaffar et al., 2022; Nußholz, 2018a). Prior research has advanced the theoretical knowledge on CBM adoption and CBMI (see Antikainen et al., 2016; Bigliardi & Filippelli, 2021; Bocken et al., 2019; Bocken & Konietzko, 2022; Geissdoerfer et al., 2022;

Guldmann & Huulgaard, 2020; Lieder & Rashid, 2016; Linder & Williander, 2017; Pieroni et al., 2021; Santa-Maria et al., 2021). Scholars have also discussed the application of a circular economy to the built environment (Carra & Nitesh, 2017; Çetin et al., 2021; Eberhardt et al., 2019; Nußholz & Milios, 2017). However, few studies have examined the adoption of CBMs and CBMI in the built environment, and even fewer studies have provided targeted strategies that allow practitioners to advance the transition to CBMs in their built environment firms. Building on the existing literature on CBMs and adopting it to the particular context of the built environment, this thesis has two core aims. The first aim is to translate the theoretical advancements within the field of CBMs into practical knowledge and strategies that practitioners in the built environment can employ. The second aim is to convey the experiences of the built environment practitioners, to expand the academic understanding of the conditions and strategies toward CBMI, and the effect of CBMs on resilience across levels. With these aims, this thesis will attempt to answer the following research questions:

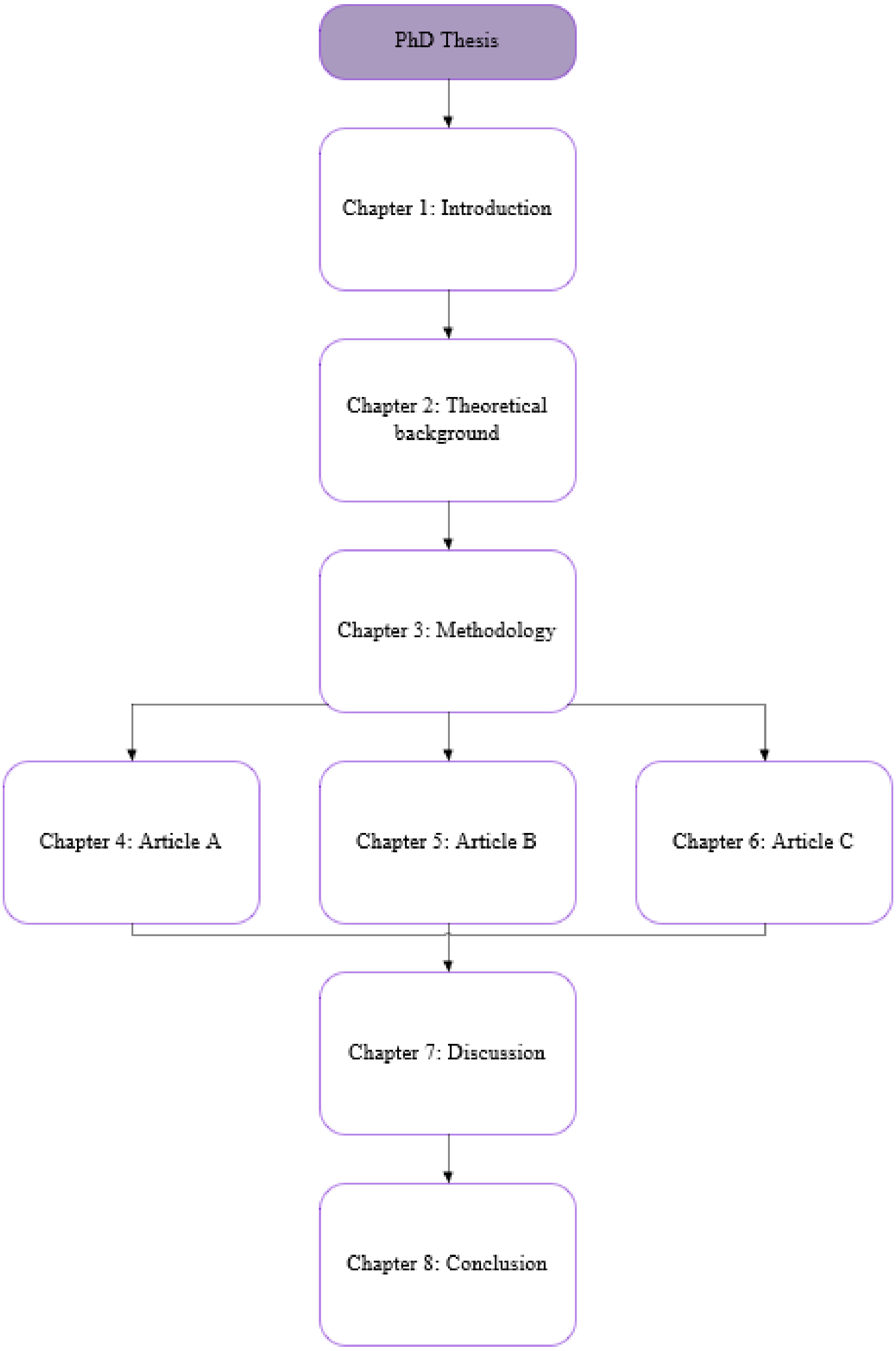
RQ 1: What conditions and strategies lead to CBM adoption and CBMI?

RQ 2: What are the resulting effects of CBMs on resilience across levels in the built environment?

1.3 Thesis structure

To answer these research questions, this thesis has been structured as follows. Chapter 1 introduces the topic of this thesis, the research context, and the research aim; Chapter 2 presents the theoretical background; Chapter 3 describes the methods applied in this thesis; Chapters 3 to 6 present Articles A, B, and C; and Chapters 7 and 8 provide the main contributions, limitations, and conclusion of this thesis.

Figure 1. PhD thesis chapter overview



2. THEORETICAL BACKGROUND

In this section, I discuss the concepts and frameworks underpinning the core theories of this thesis. Here, I will explore the following core areas of literature: (a) the conditions and strategies that drive or hinder CBM adoption and CBMI, and (b) resilience in the built environment. While I discuss these overarching theories, in this section I narrow the focus to exploring the gaps and underdeveloped elements in the literature. These gaps relate to the conditions underlying CBM adoption and CBMI, the need for strategies that guide practitioners through CBMI, and the effect of CBM implementation on resilience across levels in the built environment.

2.1 Conditions and strategies to CBM adoption and CBMI

Since 2014, there has been a call for European policymakers to construct the right conditions for the circular economy, circular practices, and CBMs to prosper (Laubscher & Marinelli, 2014). To advance knowledge on the topic, the academic literature has primarily investigated the progress toward the uptake of CBMs at country, industry, and firm level. While this is important, there are two core theoretical weaknesses that are limiting the implementation of CBMs in practice: first, research in this area is lacking an overarching framework that firms can use, irrespective of their industry. This lack of an overarching framework is limiting the widespread adoption of CBMs in practice, with scholars arguing that this is due to the need to change the key building blocks of the firm, and the need to act in disregard of dominant business paradigms (Bocken et al., 2019; Bocken et al., 2017; Ritala et al., 2018). Second, there is a lack of research focusing on firm-level implementation of CBMs and the challenges that are impacting the transition to CBMs (Blomsma & Brennan, 2017; Franco, 2017; Ghisellini et al., 2016; Guldmann & Huulgaard, 2020; Lieder & Rashid, 2016; Urbinati et al., 2017). There is also a lack of scholarly guidance for firms and practitioners on how to implement such models (Galvão et al., 2022). The shortage of research on the topic has led to a lack of tools and operational frameworks that can help facilitate the adoption of CBMs, and also a dearth of the knowledge needed to assist firms in their transition toward CBM adoption (Urbinati et al., 2017). Hence, expanding our knowledge on the topic is essential to empower practitioners, policymakers, and researchers to foster the implementation of CBMs in the built environment (de Jesus et al., 2019; Hölzl & Janger, 2011; Oghazi & Mostaghel, 2018).

As the interest in CBM literature has matured, a growing body of literature has focused on the conditions that impact how firms design, develop, and implement CBMs; specifically, more than 30 publications were published on this topic between 2014 and 2021 (Geissdoerfer et al., 2022; Santa-Maria et al., 2021). However, this prior research has primarily focused on identifying the conditions that hinder CBM adoption or implementation, and the barriers related to the reluctance in firms to adopt CBMs (Aid et al., 2017; Geissdoerfer et al., 2022; Kazançoğlu et al., 2020; Singh & Giacosa, 2018). Moreover, the previous studies have principally made use of the case study approach to investigate the barriers to CBM adoption and implementation (Tura et al., 2019; van Loon & Van Wassenhove, 2020; Werning & Spinler, 2019). Therefore, these theoretical shortcomings create a pressing need for scholars to advance the knowledge on the institutional, organizational, and individual conditions that drive or hinder the adoption of CBMs.

One such precondition to a more widespread adoption of CBMs is CBMI. Scholars argue that to arrive at a CBM, firms must first undertake CBMI, which is a concept that is substantially less covered in the literature than CBMs, and fewer definitions have been proposed for the CBMI concept (Bigliardi & Filippelli, 2021). The concept of CBMI goes hand in hand with CBMs and is defined by Geissdoerfer et al. (2020) as 'the conceptualisation and implementation of circular business models' (p. 7). Geissdoerfer et al. (2020) propose that there are four different types of CBMI acknowledged in the literature: i) circular startups, ii) CBM diversification, iii) CBM transformation, and iv) CBM acquisition (Geissdoerfer et al., 2020). While academic attention on innovation for CBMs has grown rapidly during the past five years, leading to increased research on CBMI, its theorization is relatively recent, and many aspects are yet to be explored (Bigliardi & Filippelli, 2021).

In the literature, CBMI is explained as a complex organizational challenge that faces multidimensional barriers (Geissdoerfer et al., 2022; Guldmann & Huulgaard, 2019; Tura et al., 2019). Given the theoretical and practical importance of the topic, there is therefore a need to examine the conditions that predispose to CBMI (Geissdoerfer et al., 2022). Establishing the conditions that constrain CBMI activities in firms can empower practitioners, policymakers, and researchers to tackle the hindering conditions and to enhance the adoption of CBMs (de Jesus et al., 2019; Guldmann & Huulgaard, 2019; Hölzl & Janger, 2011; Oghazi & Mostaghel, 2018). To date, the literature on CBMI has primarily focused on business-to-business contexts, efficiency, and recycling (Bocken & Konietzko, 2022). Studies have also been focused on the underlying notion of CBMI (Geissdoerfer et al., 2020; Lüdeke-Freund et al., 2019; Pieroni et al., 2019; Santa-Maria et al., 2021), and scholars have investigated the drivers of, and barriers to, CBMI (Geissdoerfer et al., 2022; Tura et al., 2019; Vermunt et al., 2019). In spite of this development in literature, there is still a lack of empirical research providing actionable managerial perspectives on how transitions to CBMs should be accomplished (Geissdoerfer et al., 2022a), and a limited number of studies have investigated the drivers and barriers and connected these to the strategies required to tackle them from an actionable managerial perspective in order to support firms in the CBMI process (Geissdoerfer et al., 2022a). Particularly as the uptake of CBMs remains slow (Heldt, 2021) and more research is needed to guide practitioners toward CBM adoption and CBMI, this thesis sets out to provide actionable strategies that practitioners can employ, and to advance the literature on the conditions that promote CBM adoption and CBMI.

Taken together, there has been an increasing focus on both CBM adoption and CBMI from practitioners, policymakers, and academics. Nevertheless, these pressing needs to understand the conditions—both those driving and hindering the uptake of CBMs and CBMI in the context of the built environment, and the strategies that practitioners can use to tackle these conditions—need to be further explored in order to accelerate the transition toward CBMs.

2.2 Resilience in the built environment

Considering today's growing trepidations regarding climate change, biodiversity loss, global temperature increases, and the pressing need for sustainable development, there has been rising interest in scholarly studies examining resilience. The term 'resilience' has become widely approved by scholars and policymakers in an effort to express the way to reduce society's susceptibility to the dangers caused by human, technical, and natural hazards (Haigh & Amaratunga, 2010). Unsurprisingly, resilience is defined differently depending on which context it is applied to, and when examining the literature, it is apparent that profound variations exist in how scholars construe the concept of resilience (Haigh & Amaratunga, 2010).

The word 'resilience' was first proposed by Holling (1973) in relation to ecological literature—to understand the non-linear dynamics detected in ecosystems (Haigh & Amaratunga, 2010). Ecological resilience was defined as 'the amount of disturbance that an ecosystem could withstand without changing self-organized processes and structures' (Haigh & Amaratanga, 2010. p.10). The resilience concept has also been defined as the ability of social-ecological systems (and their entities, e.g., firms, communities) 'to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks' (Walker et al., 2004, p. 7). Consequently, resilience is thus understood as a multi-scale concept to measure interrelated entities (such as firms) and systems (such as supply chains, industrial systems, and social-ecological systems) (Holling et al., 2002; Kennedy & Linnenluecke, 2022). When examining resilience on various levels, the literature has, for instance, focused on how firms, industries, and societies can maintain resilience whilst preventing destruction of the life-supporting basis that is provided by ecosystem resilience (Dentoni et al., 2021; Kennedy & Linnenluecke, 2022; Williams et al., 2021). The resilience term is in growing use and is increasingly employed in built environment–related research, planning, governance, and politics (Hassler & Kohler, 2014). In the built environment literature, certain context-specific definitions of the resilience concept have particularly been employed (e.g., organizational resilience, resilience engineering, economic resilience) (Hassler & Kohler, 2014). However, following growing concerns regarding climate change, biodiversity loss, and sustainable development, resilience should also be examined across different levels to investigate how resilience at one level can impact resilience at other levels (Kennedy & Linnenluecke, 2022). This aspect has been underexplored in the resilience literature within the built environment context.

Scholars argue that the built environment plays a significant role in contributing to society's improved resilience (Bosher, 2008; Dainty & Bosher, Haigh & Amaratunga, 2010; Hassler & Kohler; 2014; Lloyd-Jones, 2006). At present, firms and ecosystems within the built environment are navigating an atmosphere of uncertainty and crises; thus, fostering resilience has become increasingly necessary for firms to function effectively and for ecosystems and society to be equipped to adapt and prosper in the long term (Lopes de Sousa Jabbour et al., 2023). The built environment hosts a multitude of ecosystems, including entrepreneurial ecosystems working to attain a sustainable urban future. For the survival of these ecosystems, there is now an increasing need for resilience in order to overcome the growing number of crises. Scholars have argued that applying the resilience concept to entrepreneurial ecosystems is fitting as both ecological ecosystems and entrepreneurial ecosystems in essence are systems of interrelated yet distinct agents that display self-sustaining behavior and share the properties of coherence and diversity (Roundy et al., 2017). The declining state of the natural environment raises considerable concern about how current industrial systems—including those in the built environment—are eroding the resilience of the social-ecological system, and the ability of ecosystems and society to endure the distresses and shocks that can lead to non-linear and transformative change (Folke et al., 2010; Kennedy & Linnenluecke, 2022).

As a possible means to gain resilience, the circular economy has transpired as an alternative way to organize industrial systems, aiming to ensure that social-ecological systems remain within the limits of what the environment can handle by reducing the exploitation of raw materials and lowering industrial waste and emissions (Kennedy & Linnenluecke, 2022). Yet, the exact channels in which the circular economy assists social-ecological system resilience are typically not further conceptualized (Kennedy & Linnenluecke, 2022). Scholars have declared that a circular economy supports social-ecological system resilience and sustainable development more broadly (Geissdoerfer et al., 2017; Ishii & van Houten, 2020). However, to date, the two literature streams on circular economy and resilience have mostly evolved separately (Kennedy & Linnenluecke, 2022). There is therefore an emergent gap in the theory, and an advance in empirical studies investigating the nexus between circular economy and resilience has been summoned (Chari et al., 2022; Kennedy & Linnenluecke, 2022).

Furthermore, management studies bridging circular economy and resilience theories have remained sparse and left critical questions unanswered. For instance, how can the circular economy influence firm, industry, and social-ecological system resilience? How can principles of resilience be incorporated into circular business practices (Kennedy & Linnenluecke, 2022)?

Moreover, scholars disagree on whether circular economy goes hand in hand with sustainability, and Roostaie et al. (2019) argue that there are disparities between the concepts of sustainability and resilience. Some scholars assert that resilience encourages redundancy and flexibility to respond to external disturbances, whereas sustainability—and particularly CBMs—targets the efficient management of resources, which conflicts with the idea of surplus or redundancy (Kennedy & Linnenluecke, 2022; Roostaie et al., 2019). To depict how minimizing resource utilization and waste can assist in restoring ecological resilience, Aguiñaga et al. (2018) proposed a visualization of a circular value ecosystem, but not many others have attempted to do the same (Kennedy & Linnenluecke, 2022). Multiple scholars have, however, argued that it is necessary to change from the currently prevalent linear systems of consumption and production in order to escape societal decline and the collapse of ecosystems at a global scale (Esposito et al., 2018; Kennedy & Linnenluecke, 2022; Pla-Julián & Guevara, 2019; Stahel, 2016; Webster, 2017). Some studies have also examined the overall effects of a circular economy on firm- and industry-level resilience, contending that resilience can be fostered by espousing dynamic capabilities, increasing access to exchange partners within a circular economy, and decreasing dependence on raw materials (Kennedy & Linnenluecke, 2022). In recent years, scholarly studies on resilience have escalated in light of the COVID-19 pandemic. Blériot (2020) described how a circular economy may benefit resilience, and although the study examined circular economy practices within the context of global supply systems, the findings are also relevant to the context of the built environment. The study suggests that circular principles—for instance, reusability and design improvements for prolonged use—could assist in developing resilience, and that firms should design with repurposing in mind to building flexibility, which in turn can boost resilience, and enhance future value creation (Blériot, 2020).

Considering this growing need for resilience to contend with the increasing incidence of disasters and crises, and the potential of the built environment to participate in boosting resilience, the need for advancing scholarly knowledge on the topic is sorely needed. Scholars argue that the circular economy offers a possible avenue to gain social-ecological system resilience as it works to reduce raw material exploitation, industrial waste, and emissions (Kennedy & Linnenluecke, 2022). According to numerous studies, the built environment holds exceptionally strong potential for realizing circular economy strategies and creating both environmental and economic advances (Ellen MacArthur Foundation, 2017; ING, 2017; Koutamanis et al., 2018; Nußholz et al., 2020). However, few scholarly studies have examined the application of CBMs and CBMI to the built environment, particularly presenting how CBMs in the built environment can lead to increased resilience. Therefore, this thesis intends to fill this gap in literature and examine how resilience in the built environment industry can be gained through CBMs. Moreover, as scholars argue a need for studies examining resilience across different levels to gain understanding on how resilience at one level can impact resilience at other levels, this thesis addresses this gap by examining how CBMs can offer trickle-up effects on resilience across levels (startup, subsystem, entrepreneurial ecosystem and industry level).

3. METHODOLOGY

This chapter presents the methodological approach adopted in this thesis. First, I discuss the philosophical assumptions that have been used to steer this work; next, I describe the research design and research approach; and finally, I present the strategies employed to improve research validity and reliability.

3.1 Philosophical assumptions

Research philosophy is a term that represents a system of beliefs and assumptions regarding the development of knowledge, in which the assumptions unescapably shape how a researcher understands their research questions, the methods they select, and how they interpret their findings (Crotty, 1998; Saunders et al., 2019). The research philosophy entails the ontology (the individual views of the nature of the phenomenon), the epistemology (the methods used to understand the phenomenon), and the axiology (the function of ethical principles and values in the research process) (Saunders et al., 2019). Through combining the ontological and epistemological assumptions that support the context of the examined phenomena, this thesis has adopted a pragmatist approach (Saunders et al., 2019). The pragmatist research approach is a philosophical stance that sits between relativism and positivism and considers research so as to contribute to both theoretical advancement whilst providing practical solutions that can inform future scholars and practice (Saunders et al., 2019). For pragmatists, research begins with a problem and continues with one or more research questions that tend to incorporate the pragmatist emphasis of practical outcomes (Saunders et al., 2019). Further, the pragmatist philosophy acknowledges that there are multiple different ways to interpret the world and conduct research, and that one single viewpoint will never be able to depict the full picture and that multiple realities may exist (Saunders et al., 2019). However, this does not signify that pragmatists always use multiple methods—but it does mean that they employ methods that allow credible, reliable, relevant, and well-founded data that advances research (Kelemen, 2008; Saunders et al., 2019).

In research, there are three main approaches to theory development: deduction, induction, and abduction: i) a deductive approach is used to develop theories and hypotheses and to design a research strategy to test the hypothesis; ii) an inductive approach is used to gather the data and develop a theory based on the data analysis; and iii) an abductive research approach uses data to study the phenomenon, recognize the themes, and rationalize the patterns in order to foster new or adapt existing theory, which is then tried—often through supplementary data collection (Saunders et al., 2019). Charles Peirce utilized an abductive research approach and argued that the logic of the abductive approach is the basis of pragmatism, founded on the premise that knowing and doing are inseparable parts of the same process (Campbell, 2011; Trischler, 2022). This thesis has adopted the abductive approach and employed pragmatist thinking when considering the research problem, the context of knowledge, and the anticipated contribution to theory and practice. This approach was selected for two reasons: first, for the rapidly growing literature in the field of CBMs, and second, for the real-world context of this project. A pragmatist, abductive approach was considered the most fitting approach as it permits an iterative process that switches between literature review, data collection, and idea development (Trischler, 2022).

3.2 Research design

Guided by the abductive, pragmatist approach employed in this thesis, I conducted a systematic literature review and two qualitative studies in which I implemented distinct methods and techniques for data analysis. In Table 1, I present the research approach and the research design that was employed in this thesis, and then present the different research articles and data analysis approaches used in each article.

Table 1. Article overview

	Article A	Article B	Article C
Research approach	Pragmatist, abductive		
Research design	Multi-method research design		
Research studies	Literature review study	Qualitative study	Qualitative study
Research methods	Systematic literature review	Three-round Delphi study	Multiple case study
Data collection	• Data extraction from research databases	• Semi-structured interviews • Written accounts	• Semi-structured interviews • Secondary data (firms' websites, site visits, videos, pitch decks, social media posts)
Data analysis	Qualitative data analysis using the 'qualitative content analysis process' (Elo & Kyngäs, 2008)	Gioia method to develop first order concepts, second order themes and aggregate dimensions (Gioia et al., 2013).	Thematic coding guided by the four phases of the conceptual model 'the adaptive cycle' to analyze the thematic categories and cross-compare eight cases through the lens of each category (Eisenhardt, 1989, Kiger & Varpio, 2020; Williams & Moser, 2019)

3.3 Research approach

3.3.1 Data collection

Since this thesis followed pragmatist assumptions, which aim to employ methods that allow credible, reliable, relevant, and well-founded data that advances research, I deemed a qualitative research method to be the most fitting for the purpose of this thesis. This method was selected both to gain deep insight into the phenomena of the conditions that drive or hinder CBM adoption and CBMI in the built environment (Kelemen, 2008; Saunders et al., 2019), and also to take into account the explorative nature of this research. Thus, this thesis has followed a multi-method research design, which was defined by Creswell (2015) as research that utilizes a combination of various qualitative methods (e.g., interviews and observations), or multiple forms of quantitative data (survey data and experimental data) (Creswell, 2015; Silverman, 2020). In a multi-method design study, the aim is to use different qualitative methods that are all founded on the same epistemological perspective (Justesen & Mik-Meyer, 2012; Mik-Meyer, 2020); this can fortify the research quality since these different qualitative methods can allow for the emergence of different perspectives and nuances (Essén & Sauder, 2017; Krølner et al., 2014; Tierney et al., 2019; Mik-Meyer, 2020). Some scholars reason for the benefits of a multi-method qualitative design. They assert that such a design generates information and knowledge that would otherwise be unreachable for the researcher (Frederiksen et al., 2014) and therefore argue that research designs using multiple research strategies are the strongest (Esterberg, 2002), even though the multi-method qualitative design is considered a particularly arduous undertaking (McDonnell et al., 2017; Pratesi, 2012). A multi-method qualitative research design was therefore selected for the purpose of this thesis as a means to examine the vast multiplicity and contingency of the social world (Moran-Ellis et al., 2006; Mik-Meyer, 2020). Selecting qualitative research methods for this thesis does, however, present obstacles, particularly as qualitative research continues to be regarded by some scholars as the bottom of the hierarchy when considering evidence for informing (Galdas, 2017). Thorne (2009) expounds on the shortcomings and complexities of the evidence-founded movement for understanding the potential contributions of qualitative research. Predominantly, Thorne (2009) argues that the challenge of qualitative researchers is not to attempt to convince skeptics that qualitative studies exhibit objective, opinion-free neutrality, but instead articulate the unique value that can be gathered from qualitatively derived knowledge and the role it can play in a system that assesses impact using an evidence-based decision-making perspective (Galdas, 2017). Galdas (2017) argues that even though it may be more strenuous to quantify the impact of the qualitative research, scholars should refrain from reaching for a positivist tape measure to resolve this issue as this will leave scholars to become apologists for the subjectivity that stands as the very strength of interpretative research (Galdas, 2017). Employing qualitative data methods can allow researchers to attain rich, detailed descriptions of actions occurring in real-life contexts which uphold the meanings that actors attribute to these actions and settings (Gephart, 2004).

Systematic literature review

The first article in this multi-method research design is a systematic literature review (Article A). There are numerous forms of literature reviews, which vary from purely systematic to less systematic (Post et al., 2020). These can be seen as either integrative or systematic literature reviews; integrative literature reviews are best employed to inform the development of conceptual frameworks, whereas systematic literature reviews are better suited for synthesizing and comparing evidence (Snyder, 2019). A systematic literature review is presented as a repeatable process that documents all the available studies that are relevant to a particular topic area or a distinct research question (Kitchenham, 2007). For Article A, we therefore selected the systematic literature review approach to construct an updated overview of the latest state-of-the-art literature in the field of determinants to CBM adoption.

Qualitative data collection

Furthering the multi-method qualitative design in this thesis, both semi-structured interviews and written account approaches were employed.

Interviews are the most frequently employed form of data collection, and within qualitative research the semi-structured interview constitutes the most commonly used data collection method (DiCicco-Bloom & Crabtree, 2006; Taylor, 2005). In this thesis, semi-structured interviews were employed in both Article B and C. Semi-structured interviews offer a wide repertoire of possibilities, as they are sufficiently structured to tackle the specific topics associated with the study's phenomenon, whilst leaving room for participants to propose new meanings to the focus of the study (Galetta, 2013). The reasoning behind selecting semi-structured interviews for two of the articles was because it allowed us to ask each interviewee the same set of questions whilst also allowing us to collect in-depth insights and use follow-up questions and clarifications when necessary (Bryman & Bell, 2015). First, the semi-structured interview approach was employed in Article B to conduct the first-round and third-round interviews with the Delphi study experts. Next, the semi-structured interview approach was again used for Article C, for conducting the interviews with the representatives from the four circular and four linear startups that functioned as our cases for the comparative multiple case study. Moreover, in both Article B and C we employed the following seven practical steps of interviewing proposed by Kvale (1996): (1) thematizing the interview project, (2) designing the interview guide, (3) interviewing, (4) transcribing, (5) analyzing, (6) verifying, and (7) reporting.

Another qualitative approach utilized in this thesis was the 'written accounts technique,' used in Article B. This is a time-efficient method for gathering high-quality and descriptively rich data by posing participants questions that they must respond to with written text responses (Handy & Ross, 2005). The relative permanency of the written word leads to written accounts, offering a higher level of temporal ordering, coherence, and self-reflection than what oral accounts can offer (Ong, 1982). Considering that a significant part of the qualitative research includes transcribing verbal interviews into written text from which key themes are abstracted, written accounts can produce data that is simpler to analyze and easier to engage with (Letherby & Zdrodowski, 1995). In Article B, the qualitative data was collected through three rounds: one initial semi-structured interview round, one written accounts round and a final semi-structured interview round. As a result, in round two, each of the 25 Delphi study experts responded to questions considering the data collected from the first round of interviews through written accounts by email. Thus, this written account round was crucial to seek consensus among the experts before embarking on the third and final interview round.

3.3.2 Data analysis

Systematic literature review

For the data in the systematic literature review in Article A, we employed a shared spreadsheet for gathering all the drivers and barriers that we retrieved from each of the relevant articles. This led to a collection of 966 individual codes of drivers and barriers in which we used the coding technique ‘qualitative content analysis process’ described by Elo and Kyngäs (2008) to unify the drivers and barriers since the original authors used different terms for describing drivers and barriers with the same meaning. We then performed a second data analysis round in which each of the drivers and barriers gathered were discussed thoroughly among the research team, and we further narrowed down the drivers and barriers into 54 categories and classified them into eight macro categories.

Qualitative data analysis

An important feature of qualitative research is identifying patterns that arise from the data. These patterns will serve as the foundation for later theory development and further empirical examination (Bettis et al., 2015), and several approaches for qualitative data analysis exist (Gehman et al., 2018). In this thesis, we applied the Gioia method developed by Gioia et al. (2013) to codify the data in Article B. We therefore interpreted the collected data through the coding steps of first-order concepts, second-order themes, and aggregate dimensions. The coding of the ‘first order concepts’ was completed once the coding structure was considered stable, at which we had reached 74 first-order concepts (Gioia et al., 2013). Then, the ‘second-order themes’ were developed by clustering the 74 first-order concepts and was finalized once we reached theoretical saturation via the concept and theme development process, with 20 second-order themes (Glaser and Strauss, 1967; Gioia et al. (2013). Finally, the second-order themes were reduced into ‘aggregate dimensions’ and the analysis resulted in three overarching conceptual dimensions.

Moreover, Article C provided insights on how startups in the built environment with CBMs affect resilience across levels. Article C was conducted as a qualitative multiple case study based on 34 semi-structured interviews with representatives from four circular and four linear startups, all belonging to one entrepreneurial ecosystem.

The analysis of the data collected in Article C consisted of abductive thematic coding guided by the knowledge from existing literature and the scholarly insights from the theory of Panarchy. Panarchy theory explains the dynamics of complex adaptive systems and their resilience in a rapidly changing world. Stemming from the theory of Panarchy, a conceptual model has been presented, titled: ‘The adaptive cycle’. The adaptive cycle was conceptualized by Holling (1986, 2001) to construe the dynamics of complex ecosystems in response to change and is structured in four phases that complex adaptive systems move through, namely: ‘exploitation’, ‘conservation’, ‘release’, and ‘reorganization’. Article C was abductively analyzed, building on this existing conceptual model’s specific four phases to derive the thematic categories and cross-compare our cases through the lens of each category (Eisenhardt, 1989; Williams & Moser, 2019). To code the data, we followed the six-step process presented by Kiger and Larpio (2020) who recommend to thematically code the data by first familiarizing with the data, in which we observed appearing patterns and took notes. Then, the second step which Kiger and Larpio (2020) recommends is to generate the initial codes. In this step we coded the transcripts in NVivo and developed 163 individual initial codes. Then, the third step suggests to start the search for themes of broader significance, in which we grouped the codes into 80 themes. Step 4, then entailed iteratively reviewing these themes, and due to the abductive nature of Article C, in this step we analyzed the thematic codes in relation to the existing theory on the phases of the conceptual model of the adaptive cycle. Followingly, the fifth step involved further narrowing down the themes in which we thematically grouped the data into each of the four phases and ended up with 68 thematic codes, each belonging to one of the four phases of the adaptive cycle. Lastly, the sixth step of the process as proposed by Kiger and Larpio (2020) was to produce the manuscript using the elements from the analysis including the notes, codes and themes, and using representative data extracts such as interview quotes to argument for why the study responds to the research question.

3.4 Research validity and reliability

Qualitative research has often been criticized for lacking scientific rigor, with scarce justification of the employed methods, dearth of transparency of the analytical techniques, and findings that are at risk of being a compilation of personal views subject to researcher bias (Noble & Smith, 2015; Rolfe, 2006; Sandelowski, 1993). Therefore, demonstrating rigor in qualitative research is important, and although there are no universally accepted terminology and criteria by which to evaluate qualitative research, qualitative researchers should adopt strategies to strengthen the credibility of their research (Noble & Smith, 2015). Often, research quality is evaluated on its validity, which considers the research accuracy, and the reliability, which is concerned with the consistency of the research. To ensure the highest-possible degree of research validity and reliability, this thesis set out to incorporate multiple measures that would allow this.

To avoid bias in Article A, which employed the systematic literature review design, we first set out to perform a preliminary evaluation of only the titles and abstracts of the review results. This step is performed to efficiently eliminate all the obviously ineligible publications and direct the reviewers' attention toward reading thoroughly the full articles of the relevant publications (McDonagh et al., 2013). In this stage, all the abstracts were read by at least two of our researchers. This approach is known as a dual review and is included as a method for reducing the potential for random errors and bias (McDonagh et al., 2013). During the dual review, the researchers compare their decisions and resolve differences through discussions, and consult with a third-party researched whenever consensus is not reached (McDonagh et al., 2013). Further, to train the team and test for disagreements and misconceptions regarding the review protocol and coding criteria, the first 30 articles were examined by all three researchers and discussed subsequently. This strategy is described by McDonagh et al. (2013) as a pilot phase, in which the reviewers first screen 10 to 20 percent of the review articles, then go on to discuss the inclusion criteria and resolve possible disagreements early on to ensure reliability of the reviewers' assessments.

Second, to ensure research validity and reliability in the semi-structured interviews (Article B and C), the various interview guides were tested by conducting pilot interviews. A pilot test should be conducted in all research studies in which the aim is to make certain that the required validity is achieved (Gani et al., 2020), and is defined as the pre-test version of a research instrument before the actual research study is conducted (Majid et al., 2017; van Teijlingen & Hundley, 2002). Pilot interviews are crucial for the researcher to test the questions and gain interview practice before undertaking the actual research interviews (Majid et al., 2017). Moreover, Castillo-Montoya (2016) argues that interview protocols are strengthened after conducting pilot interviews and implementing changes thereafter. Pilot interviews indicate whether a semi-structured interview guide is reliable and can be used for a real study—or will need modifications (Aung et al., 2021). Also, to increase the reliability of the research, each of the interviews were video-recorded and transcribed verbatim within 24 hours. Transcription is considered an integral component of the quality process of interview-based qualitative research (Bell et al., 2022; Point & Baruch, 2023; Saunders et al., 2019).

Third, the qualitative data in Article B and C were gathered until a theoretical saturation point was reached. Saturation originates from grounded theory (Glaser & Strauss, 1967) and has gained general acceptance as a methodological principle in qualitative research which is used to verify rigor and validity in a research study (Daher, 2023; Sebele-Mpofu, 2020). It is used to indicate that owing to the data that have been collected thus far, further data collection and analysis are redundant (Saunders et al., 2018). Therefore, in both Article B and C, the saturation point was acknowledged when the interview responses were becoming chiefly repetitive.

4. ARTICLE A

Title: Determinants of Circular Business Model Adoption – A Systematic Literature Review

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Abstract

Although the circular economy is considered an avenue to sustainable development, the transition toward circularity is moving slowly. Academic literature has examined how various factors can affect the adoption of circular business models in specific industries and organizational types. However, no research has systematically reviewed the determinants of circular business model adoption. Through a systematic literature review, this study provides a holistic overview of the determining drivers of and barriers to the adoption of circular business models. Building on a sample of 67 journal articles, this study identifies 54 different determinants and classifies them into eight macro categories: culture, regulation, market, strategy, business case, collaboration, operations, and knowledge. The findings can guide policy-makers, researchers, and decision makers across industries in understanding what obstacles to avoid and drivers to employ when they wish to increase circular business model adoption.

Keywords: Barriers, circular business models; circular economy; determinants; drivers; systematic literature review.

1. Introduction

As a significant proportion of non-renewable resources is rapidly diminishing, the need for a circular economy is increasingly evident (Antikainen et al.,2016; Ellen MacArthur Foundation,2015). The Ellen MacArthur Foundation (2015, p. 2) defines a circular economy as "one that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles". A circular economy can thus offer environmental benefits to global eco-systems, by reducing harmful emissions and decreasing the loss of resources (Rizos et al., 2016). In literature, the concepts of circularity and circular economy date back to pre-industrial times and are widely studied in both practitioner and scholarly writings (Kirchherr et al., 2018; Lieder & Rashid, 2016). During the last two decades, the concept of the circular economy has been increasingly used in research and industry as (a) an alternative to the linear economy (Adams et al., 2017; Guldmann & Huulgaard, 2020) and (b) an approach to resolving the contradiction between economic growth and environmental sustainability (Ronholt et al., 2019).

Although, theoretically the circular economy is considered an avenue to sustainable development, governmental and private transitions toward circularity are moving slowly in practice, and implementation of circular economy activities remains relatively rare (García-Quevedo et al., 2020). A recent report published by Circle Economy (2020) shows that the world in 2020 was only 8.6% circular and that progress in this transition has stalled. Interestingly, in 2018, the world was more circular, as the global population cycled 9.1% of everything that was used, showing a negative development in which global circularity decreased between 2018 and 2020. This slow uptake of circularity indicates that either the ability to transition toward circularity or the business model for doing so is not yet in place.

Nevertheless, as firms using circularity in their business models report more resilient supply chains, cost reductions, increased reporting accuracy, and market differentiation (Circle Economy & Ecofys., 2016), the notion of circular business models (CBMs) has gained momentum in the academic literature. Moreover, the approach is gaining popularity among firms wishing to help achieve local, national, and global sustainability (Schroeder et al., 2019). Still, industry-wide adoption of CBMs seems hard to reach as many companies are failing to implement them successfully and are still not able to reap their full potential (Achtenhagen et al., 2013; Reim et al., 2021). Galvão et al. (2022) argue that a main barrier to CBMs is that in practice, companies are not yet being guided on how to actually implement CBMs.

To facilitate the transition from linear business models to CBMs, new knowledge on the institutional, organizational, and individual factors that can either foster or hinder CBM adoption is critical. Although a number of studies have explored the effect of various factors on the adoption of CBMs (Kirchherr et al., 2018; Salvador et al., 2020; Vermunt et al., 2019), this literature still lacks systematic reviews of the determinants of CBM adoption. This study conducts a systematic review of the drivers of and barriers to CBM adoption, defining CBM drivers as factors that enable and encourage the transition toward a CBM, and barriers as factors that obstruct the transition toward it (de Jesus & Mendonça., 2018). Both drivers and barriers can occur at institutional (e.g., regulatory and market factors), organizational (e.g., strategic and operational factors), and individual levels (e.g., employees' awareness and knowledge of the circular economy).

This study thus provides a holistic overview of determinants that can serve as either drivers of or barriers to CBM adoption. After systematically collecting and analyzing the literature on determinants of CBM adoption, it formulates a syncretic categorization of the driving and hindering factors—an approach that offers scholars working on CBMs potential avenues for further qualitative and quantitative research. Moreover, the findings of this study can assist practitioners across industries in identifying the determinants that are likely to impact their firms' CBM adoption processes. In addition, the insights that this study yields will also be useful for policy-makers at both national and European Union (EU) levels in creating circular economy policy frameworks and support mechanisms.

This study is structured as follows. Section 2 presents the research methods and dataset. Section 3 reviews and discusses the applicable literature and illustrates the findings. Section 4 presents the study discussions along with the key takeaways for academia, practice, and policy. Finally, Section 5 discusses the study's limitations and conclusions and offers suggestions for future research.

2. Research method

A systematic literature review was selected for this study and is defined by Kitchenham (2007) as a repeatable process that documents all available studies that are relevant to a specific topic area or a distinct research question (Kitchenham,2007). The research topic of this systematic literature review is the determinants of CBM adoption.

To ensure that the systematic literature review would be con-ducted properly and rigorously, Okoli's eight-step guide to conducting a systematic literature review was followed. The eight steps comprise (1) identifying the purpose, (2) drafting protocol and training the team, (3) applying a practical screen, (4) searching for literature, (5) extracting data, (6) appraising quality, (7) synthesizing studies, and (8) writing the review (Okoli,2015).

A search criterion in this study was for only English-language peer-reviewed journal articles to be included. Books and conference proceedings were deselected, as they were not considered relevant for this study. We decided not to limit the time frame of the search; the oldest reference in the sample was from 1960, although the vast majority of the articles were published after 2010. SCOPUS, Web of Science, and EBSCO were selected as the databases from which articles would be collected. These databases were selected as they were considered the most relevant and provided the highest impact journals in this topic area.

To gather the existing literature in the field of CBM adoption, we developed a search query through discussions within the team of researchers and by drawing on our previous knowledge of the CBM literature. Multiple searches for alternative search strings were per-formed; however, ultimately, the elected search string was set to yield the largest number of studies, which broadened the review's scope. Following recommendations from Kitchenham (2007), multiple trial searches were undertaken with search terms that could be derived from the research questions, in order to ensure that the search string would capture a useful number of papers (Kitchenham, 2007). The final search query that was used was:

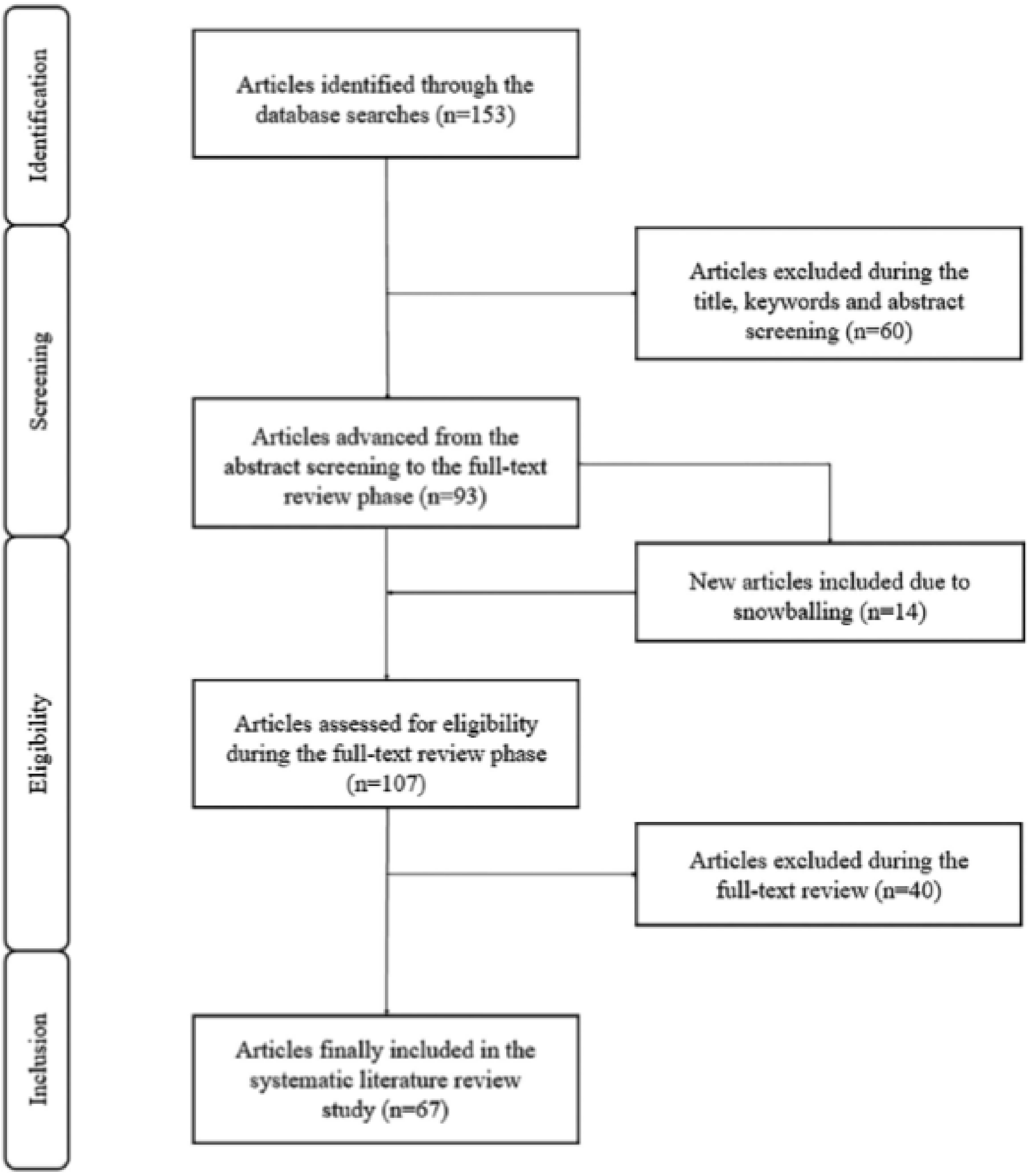
> TITLE-ABS-KEY (driv* OR trigger* OR enabl* OR ante-cedent* OR determin* OR influenc* OR foster* ORmotivati* OR reason* OR promot* OR factor* OR opportunit* OR risk* OR threat* OR challeng* OR bar-rier* OR inhibit* OR limit* OR constrain* OR hurdl* OR hindranc* OR hinder* OR hamper* OR imped* OR pre-vent* OR obstacl*) AND TITLE-ABS-KEY (circular* OR circle* OR “closed-loop” OR “closed loop*”) ANDTITLE (“business model*”) AND (LIMIT-TO (DOCTYPE,“ar”) OR LIMIT-TO (DOCTYPE, “re”)) AND (LIMIT-TO (LANGUAGE,“English”)).

This approach allowed the highest number of articles to be assembled, which ultimately resulted in 153 individual articles (excluding duplicates extracted from the three databases). These articles were screened based on their keywords and abstracts and thus narrowed down to the articles that were relevant to the research theme.

The inclusion criterion was that the article used at least one of the following core aspects in terms of literature background, research objective, or results: (1) CBMs and (2) determinants for CBM adoption (represented by drivers, barriers, enablers, obstacles, etc.). Consequently, we excluded those articles that only mentioned CBMs as a general context for their research and not as a core aspect of the research design (e.g., Todeschini et al., 2017), those that addressed CBM as a determinant (e.g., Di Tullio et al., 2018), and papers that investigated circular economy transitions in general (thus not having CBMs as the unit of analysis) (e.g., Chiappetta Jabbour et al., 2020).

To decrease the risk of bias, all abstracts were read by a minimum of two researchers and all disagreements were discussed by the research team. To train the team, the first 30 articles were assessed by all three researchers in order to test for disagreements or misunderstandings about the review protocol and criteria. After conducting the test, the results were debated among the researchers to discuss inconsistencies and ensure agreement before resuming the review of the remaining articles. As a result, the list was narrowed down to 93articles that were considered to correlate with the research theme. These articles were all read in full to examine the inclusion of determinants of CBMs. During the full-text reading, 14 new articles were added to the sample through the snowballing method, resulting in a total of 107 articles that were assessed for eligibility during the full-text review phase. On the basis of the full-text reading, 40 articles were excluded from the sample, as they were found to not be focused on determinants of CBMs. Therefore, the final sample of this systematic review study consisted of 67 articles (see Figure 1).

Figure 1. Flow diagram of the systematic literature review

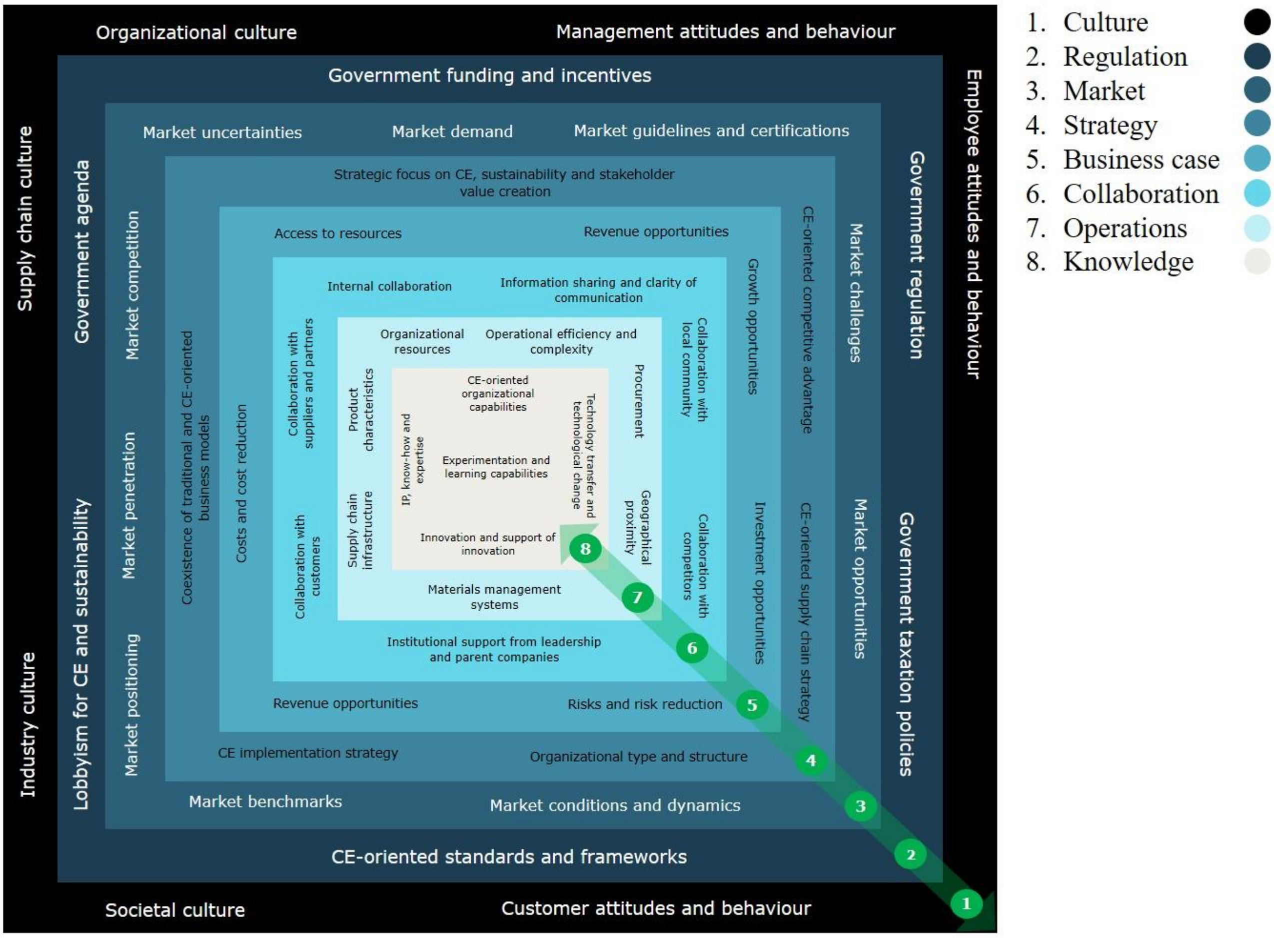


The research team made use of a shared spreadsheet to gather qualitative information about the articles. Throughout the reading process, the determinants found in the text were recorded in the shared file. A list of 966 codes related to determinants of CBM adoption was originally extracted from the accumulated articles. Building upon this list, the research team performed a qualitative data analysis using the coding technique proposed by Elo and Kyngäs (2008) to merge determinants for which the original authors used different terms, but which had convergent meaning. In a second round of data analysis, all the determinants were discussed by the research team, grouped into 54 categories, and subsequently classified into eight macro categories: culture, regulation, market, strategy, business case, collaboration, operations, and knowledge.

3. Results

Through the systematic review process, we derived 54 main determinants of CBM adoption, which were classified into eight separate macro categories: culture, regulation, market, strategy, business case, collaboration, operations, knowledge. The categories and macro-categories are illustrated in Figure 2, in which they range from the most external to the most internal determinants of CBM adoption.

Figure 2. Category map of the determinants of circular business model adoption, ranging from most external to most internal category



3.1 Cultural determinants

Various cultural determinants are highlighted by the reviewed articles as important influencers of CBM adoption (Table1). For instance, Customer attitudes and behavior can determine the adoption rate of CBMs, as customers may reject CBMs due to their reluctance to change, their desire to own, or the novel and uncertain practices related to CBMs (Bianchini et al., 2019; Cantú et al., 2021; Guldmann & Huulgaard, 2020; Huerta Morales, 2020; Lewandowski, 2016; Sattari et al., 2020; Vermunt et al., 2019). Not unexpectedly, customers are instead more likely to purchase circular products when linear products have higher prices (Cantú et al.,2021). As products' life cycles are extended with more durable products, customer loyalty may also be increased (Marke et al., 2020) and there-fore also their willingness to engage with CBM-oriented companies.

Employee attitudes and resistance to change can also impact their employers' adoption of CBMs (Cantú et al., 2021; Ingemarsdotter et al., 2020). The team motivation to switch to a CBM is crucial for accelerating the adoption process (Lehtimäki et al., 2020). Managers' attitudes is ultimately a deciding factor due to managers' role in incentivizing broad participation of employees in the transition toward CBMs (Cantú et al., 2021; Rizos et al., 2016).

On a higher level, the company's overall philosophy, habits, sustainability awareness, history, and level of commitment all determine an organization's cultural approach to CBM adoption (Cantú et al., 2021; Pieroni et al., 2021; Rizos et al., 2016; Ünal et al., 2019). Having a common shared vision within the organization can drive the transition, in addition to the organization's flexibility to change, which can vary greatly depending on company size, cognitive barriers, path dependence, and resistance to abandoning the current business model for a new one (Carraresi & Bröring, 2021; Guldmann & Huulgaard, 2020; Ünal et al., 2019; Zucchella &

Previtali, 2019). The reviewed literature also shows that sustainability reporting practices can affect consumers' decisions and push companies to stand accountable for their actions and commitment to circularity (Stål & Corvellec, 2018).

However, companies operating in different industries are also impacted differently, due to different levels of awareness concerning CE (circular economy) and sustainability across industries (Cantú et al., 2021; Carraresi & Bröring, 2021; Ingemarsdotter et al., 2020; Levänen et al., 2018; Pieroni et al., 2020; Stål & Corvellec, 2018; Vermunt et al., 2019). Lack of system thinking and awareness about how to integrate practices in the industry will also be an important obstacle in the integration of circular economy in business models (Cantú et al., 2021; De Angelis, 2021; Fraccascia et al., 2016; Palmié et al., 2021).

Finally, lack of trust and compatibility between partners in the supply chain can make it difficult for companies wanting to develop industrial symbioses to aid in transitioning to CBMs (Cantú et al., 2021; Guldmann & Huulgaard, 2020; Salvador et al., 2020; Zucchella & Previtali, 2019). On a broader, societal level, the societal culture can have a strong impact on companies and, as the importance of public opinion and pressure increases, societal culture can become a strong enabler/hindrance for CBM adoption (Cantú et al., 2021; Hofmann & Jaeger-Erben, 2020).

Table 1: Culture Determinants of CBM adoption

Determinant	**Description**	**Examples and references**
Organizational culture	The values, expectations and practices that shape the ideas and behaviour of the people within an organisation	• Sustainability awareness, philosophy, history, commitment and practices of an organization (Cantú et al., 2021; Pieroni et al., 2021; Rizos et al., 2016; Ünal et al., 2019). • Organizational orientation towards stakeholder and level of stakeholder involvement in the organizational business model (Guldmann and Huulgaard, 2020; Pedersen et al., 2019).

		• Common shared sustainability vision within the organization (Zucchella and Previtali, 2019). • Organisational structure and flexibility to change (Ünal et al., 2019; Guldmann and Huulgaard, 2020; Carraresi and Bröring, 2021a; Cantú et al., 2021). • Long-term vision and orientation of the organization (Bianchini et al., 2019; Pedersen et al., 2019; Hofmann and Jaeger-Erben, 2020; De Angelis, 2021).
Employee attitudes and behaviour	The state of mind and the way the people of an organization conducts themselves	• Employee attitudes and behaviours towards change (Ingemarsdotter et al., 2020; Cantú et al., 2021; Rizos et al., 2016) • Employee attitudes and behaviours towards expertise development (Ünal et al., 2019) • Employee motivation towards switching to a circular business model (Lehtimäki et al., 2020)
Management attitudes and behaviour	The state of mind and the way the people leading or managing an organization conducts themselves	• Management attitudes and behaviours towards sustainability and circular economy (Rizos et al., 2016; Ingemarsdotter et al., 2020; Cantú et al., 2021) • Management attitudes and behaviours towards risk (Rizos et al., 2016)
Supply chain culture	The values, behaviours and norms of the actors operating in an organization's supply chain	• Lack of trust and compatibility between partners in the supply chain (Cantú et al., 2021; Guldmann and Huulgaard, 2020; Salvador et al., 2020; Zucchella and Previtali, 2019). • Resistance to change from suppliers (Cantú et al., 2021).
Industry culture	The values, behaviours and norms of the actors operating in an industry	• Lack of CE and sustainability awareness in the industry (Cantú et al., 2021; Carraresi and Bröring, 2021; Ingemarsdotter et al., 2020; Levänen et al., 2018; Pieroni et al., 2020; Stål and Corvellec, 2018; Vermunt et al., 2019). • Lack of promotion and communication of the circular economy agenda in the industry (Cantú et al., 2021; Donner et al., 2021; Guldmann and Huulgaard, 2020; Hopkinson et al., 2018; Reim et al., 2019). • Lack of system thinking culture in the industry (Cantú et al., 2021; De Angelis, 2021; Fraccascia et al., 2016; Palmié et al., 2021)

		• Conservatism and reluctance of the industry when it comes to the green transition (Rizos et al., 2016).
Customer attitudes and behaviour	People's feelings, beliefs and intensions towards a business or organisation	• Customers' expectations, trust and acceptance (Bianchini et al., 2019; Bocken et al., 2017; Calvo-Porral and Lévy-Mangin, 2020; Elzinga et al., 2020; Hankammer et al., 2019; Ingemarsdotter et al., 2020; Lieder and Rashid, 2016). • Costumers rigidity, irrationality, scepticism inertia, and reluctance to change (Bianchini et al., 2019; Cantú et al., 2021; Lewandowski, 2016; Planing, 2015). • Customers' resistance towards the novelty and uncertainty related to circular business models (Guldmann and Huulgaard, 2020; Huerta Morales, 2020; Vermunt et al., 2019). • Customers' price sensitivity (Cantú et al., 2021). • Customer loyalty (Marke et al., 2020), triggered by the extension of product life cycle. • Customers' desire to own (Sattari et al., 2020). • Customer types and characteristics (personal, cultural, social, and psychological characteristics) (Guldmann and Huulgaard, 2020).
Societal culture	The values, behaviours and norms of a society	• Societal perception of the quality of reused, remanufactured or recycled products (Cantú et al., 2021; Guldmann and Huulgaard, 2020; Shao et al., 2020; Vermunt et al., 2019). • Public opinion and pressure to adopt circularity practices (Cantú et al., 2021; Hofmann and Jaeger-Erben, 2020) • Sustainability reporting frameworks and practices (Stål and Corvellec, 2018). • Awards, prizes and certification promoting circularity (Cantú et al., 2021; Donner et al., 2021; Rizos et al., 2016).

3.2 Regulatory determinants

According to the reviewed literature, regulation can also have a substantial effect on the adoption of CBMs (Table 2). For instance, an important driver is the creation and establishment of laws and policies toward sustainability and CE (Cantú et al., 2021). However, the current lack of specific guidelines, supportive public procurement policies, and legal regulations addressing implementation of CE is limiting companies' adoption of CBMs (Cantú et al.,2021; Guldmann & Huulgaard, 2020; Han et al., 2020; Ingemarsdotter et al., 2020; Linder & Williander, 2017; Nascimento et al., 2019; Pedersen et al.,2019; Rizos et al., 2016; Salvador et al., 2020; Sarti et al., 2017). On the other hand, law enforcement has been identified in the literature as a driver of CBM adoption (Bianchini et al., 2019; Cantú et al., 2021; Han et al., 2020; Rizos et al., 2016); lobbying activities for the introduction of legislation and political incentives can also have a positive impact in the transition toward CBMs (Cantú et al., 2021; Lewandowski,2016).

Second, the lack of effective taxation policies and frequent changes in national tax policies can hinder companies' adoption of CBMs (Rizos et al., 2016; Shao et al.,2020). Indeed, if taxation on resources is low, companies may prefer to purchase cheaper raw mate-rials than using recycled raw materials (Rizos et al., 2016). Moreover, high taxation on labor may render labor-intensive reuse and recycling activities too expensive for companies (Guldmann & Huulgaard, 2020). On the other hand, tax benefits and tax breaks toward CE can allow the companies to adopt CBMs (Cantú et al., 2021).

Governments' expectations are also a factor that drives the transition to CBMs (Hankammer et al., 2019). However, the lack of defined targets and national goals can represent an important obstacle in the adoption process (Cantú et al., 2021; Levänen et al., 2018). Similarly, standards can also drive the transition. However, the imperfect manufacturing standards and company difficulties in meeting industry standards can hinder the adoption (Cantú et al., 2021;

Hopkinson et al., 2018; Huerta Morales, 2020; Shao et al., 2020). Finally, the lack of, or poor, frameworks and tools supporting business model innovation in the context of CE is mentioned in the literature as a key factor hindering the adoption of CBMs (Antikainen et al., 2016; Bianchini et al., 2019).

Table 2: Regulation determinants of CBM adoption

Determinant	Description	Examples and references
Government agenda	The list of subjects that the government are paying serious attention to at the given moment	• Government agenda and expectations (Hankammer et al., 2019). • Lack of defined national goals and targets in terms of sustainability and CE (Cantú et al., 2021; Levänen et al., 2018). • Lack of concrete, coherent and effective legislation (D'Amato et al., 2020; Donner et al., 2021; Guldmann and Huulgaard, 2020; Rizos et al., 2016).
Government regulation	Official rules that the government imposes on individuals and private companies, backed by penalties, in order to modify behaviour	• Creation and adoption of laws, policies and guidelines supporting sustainability and CE (Rizos et al., 2016; Linder and Williander, 2017; Sarti et al., 2017; Nascimento et al., 2019; Pedersen et al., 2019; Vermunt et al., 2019; Guldmann and Huulgaard, 2020; Han et al., 2020; Ingemarsdotter et al., 2020; Salvador et al., 2020; Cantú et al., 2021). • Continuity of policies (Bianchini et al., 2019; Uvarova et al., 2020). • Complexity and uncertainties of regulations (Olsson et al., 2018; Bianchini et al., 2019; Uvarova et al., 2020). • Lack of effective enforcement of environmental regulations and poor accountability of governments (Bianchini et al., 2019; Cantú et al., 2021; Han et al., 2020; Rizos et al., 2016).
Government taxation policies	The government's efforts to effectively manage the tax system by deciding which taxes to collect from whom and	• Taxation benefits aimed at supporting CE adoption and implementation (Cantú et al., 2021). • Lack of effectiveness and continuity in taxation policies supporting sustainability and CE (Rizos et al., 2016; Shao et al., 2020). • High taxation of labour-intensive reuse and recycling activities (Guldmann and Huulgaard, 2020).

	how much taxes should be paid	
Government funding and incentives	Financial assistance, grants or loans paid from the government	• Creation of government funding supporting CE initiatives (Cantú et al., 2021; Donner et al., 2021; Rizos et al., 2016). • Difficulty trying to secure funding (Guldmann and Huulgaard, 2020). • Government incentives (Bianchini et al., 2019; Cantú et al., 2021; Donner et al., 2021; Guldmann and Huulgaard, 2020; Han et al., 2020; Levänen et al., 2018; Marke et al., 2020; Schulte, 2013). • Support from policymakers in the form of training, funding and legislation (Guldmann and Huulgaard, 2020; Lewandowski, 2016; Rizos et al., 2016; Shao et al., 2020).
CE-oriented standards and frameworks	Standards represent the most adopted practices, and frameworks are employed to guide on the basic structure of something	• Lack of appropriate frameworks and tools supporting business model innovation for CE (Antikainen et al., 2016; Bianchini et al., 2019) – e.g., existing tools might not be replicable in different business environments (Antikainen et al., 2016; Cantú et al., 2021). • Lack of adoption of industry-wide standards that can drive the circular transition (Marke et al., 2020; Hopkinson et al., 2018; Huerta Morales, 2020; Shao et al., 2020; Cantú et al., 2021).
Lobbyism for CE and sustainability	The activity of undertaking activities aimed to influence legislation in relation to special interests	• Lobbying for the introduction of legislation, policy and incentives supporting sustainability and CE (Cantú et al., 2021; Lewandowski, 2016).

3.3 Market determinants

Another important category revealed by the literature review concerns market-related determinants of CBM adoption (Table3). An example is market demand, which can drive or hinder CBM transition (D'Amato et al., 2020; Rizos et al., 2016). Indeed, developing a consumer market and building loyalty in new consumer segments is crucial for companies that aim to advance the circularity agenda (Bocken et al., 2017). On the other hand, a lack of pressure from the demand side to develop or utilize a CBM may discourage companies from prioritizing CBM adoption (Cantú et al., 2021; Guldmann & Huulgaard, 2020; Rizos et al., 2016).

Interestingly, market competition has been mentioned in the literature solely as a barrier to CBM adoption (Donner et al., 2021; Rizos et al., 2016; Shao et al., 2020). Market dynamics, including the intensity of competition, along with cost pressure, can also negatively impact companies' adoption of CBMs (Hofmann & Jaeger-Erben, 2020). However, we argue that market competition can also be based on sustainability and circularity and thus represent a driving factor for the transition toward CBMs. Indeed, the possibility that working on circularity will enhance and improve brand image and reputation can be driving companies' CBM adoption (Bocken et al., 2017; Stål & Corvellec, 2018).

Various other market challenges are affecting companies in the adoption of CBMs. For instance, the availability of non-renewable resources in the market is a factor that influences both consumers' and governments' expectations, thus enabling the CBM transition (Hankammer et al., 2019). Additionally, ecological challenges such as biodiversity loss, climate change, and resource scarcity are driving the adoption of CBMs (Hofmann, 2019; Hofmann & Jaeger-Erben, 2020), which is often accelerated by the creation of new, innovative, and circularity-oriented ventures (Fraccascia et al., 2016).

However, there is still a lack of market benchmarks and "best practices" that companies can make use of, as well as a need for more case studies (Bocken et al., 2017; Hopkinson et al., 2018). Entering an existing market with a new circularity-oriented product is often described as being very challenging (Donner et al., 2021).

Table 3: Market determinants of CBM adoption

Determinant	Description	Examples and references
Market challenges	Obstacles that exist in a specific market	• Ecological challenges in the market, such as biodiversity loss, climate change and resource scarcity (Hankammer et al., 2019; Hofmann, 2019; Hofmann and Jaeger-Erben, 2020). • Lack of integration between the informal sector and waste management systems (Cantú et al., 2021; Levänen et al., 2018). • Challenges encountered by organizations when entering the market with a new, CE-oriented product (Donner et al., 2021) • Existence of exogenous factors such as the economic downturn, dampens interest in green business initiatives (Rizos et al., 2016)
Market uncertainties	Lack of knowledge or awareness about the market's future state	• Uncertainties related to the marketplace, along with the role and behaviour of its actors (Cantú et al., 2021; Heyes et al., 2018; Reim et al., 2019).
Market conditions and dynamics	The factors and forces that influence the consumers, suppliers and companies in a market	• Market conditions (Hopkinson et al., 2018; Uvarova et al., 2020). • Market dynamics, such as innovation dynamics and economic fragility (Hofmann and Jaeger-Erben, 2020).
Market guidelines and certifications	Rules and principles that apply to or affect the market, and the earning of official documents which attest certain characteristics of products or companies	• Lack of ad-hoc guidelines on how to implement CE in specific sectors (Nascimento et al., 2019). • Use of a transparency strategy, guarantees and certifications to tackle the users' scepticism and lack of trust (Cantú et al., 2021).
Market demand	The demand of goods and services from all possible customers	• Development of a CE-oriented, loyal consumer market (Bocken et al., 2017).

		• Lack of pressure from the demand side to develop or utilise a CBM (Cantú et al., 2021; Guldmann and Huulgaard, 2020; Rizos et al., 2016). • Clients' low willingness or ability to pay, which may be due to customers not valuing used products (Cantú et al., 2021; Vermunt et al., 2019). • Lack of support from the supply and demand network in the market (D'Amato et al., 2020; Rizos et al., 2016).
Market opportunities	Needs in the market that companies can utilise to grow	• Market opportunities in relation to the adoption of a CBM, especially in relation to the creation of new companies driving the transition to CE (Fraccascia et al., 2016).
Market competition	Rivalry between firms and organisations providing the products that serve the same needs for the same markets	• Competitive advantages of linear-based companies over circular ones in specific sectors (Cantú et al., 2021). • Fierce competition in the market and industries in relation to CBMs (Donner et al., 2021; Rizos et al., 2016; Shao et al., 2020).
Market benchmarks	The comparison between brands and products that operate in a market	• Lack of CBM 'best practices' and need for case studies (Bocken et al., 2017; Hopkinson et al., 2018). • Definition of CBM sector-specific patterns supporting the understanding of CBM viability and feasibility (Pieroni et al., 2021).
Market positioning	The exercise of branding and improving or strengthening the perception of the brand or product in the market	• Sales and marketing capabilities (Lehtimäki et al., 2020). • Support for sales promotion activities, marketing and branding (Uvarova et al., 2020). • Strategies aimed at enhancing and improving brand image (Bocken et al., 2017; Stål and Corvellec, 2018).
Market penetration	The successfulness of sales of a product or service in a specific market	• Lack of market access permission mechanisms (Shao et al., 2020).

3.4 Strategy determinants

An important group of determinants highlighted by many of the reviewed articles refers to the integration of CE, sustainability, and stakeholder value creation into business strategy (Table4).

Promoting the use of sustainable and circular strategies, integrating CE and corporate sustainability into a company's traditional business model, or creating a new circularity-oriented business model can act as a driving force for a company's CBM transition, while also inspiring other companies in the industry to do so (Cantú et al., 2021; Witjes & Lozano, 2016). Building resilience against various strategic challenges related to circularity and setting clear unambiguous targets for scaling up the CBM can also enable CBM adoption (Bocken et al., 2017; Hopkinson et al., 2018; Lewandowski, 2016). The literature review also showed that the transition becomes strenuous for companies that have not integrated CE as part of their strategy, mission, vision, or goals (Cantú et al., 2021). Many companies seem to be particularly challenged by prevailing linear business model structures and thinking and the narrow focus of their existing sustainability strategies (Guldmann & Huulgaard, 2020).

Clear metrics and decision tools can enable companies in the CBM transition by driving the implementation of stricter measures and the formulation of future actions (Hopkinson et al., 2018; Stål & Corvellec, 2018). However, the existing key performance indicators are mainly focused on linear economy and on products that eventually become waste (Vermunt et al., 2019). Adopting novel performance indicators that measure overall organizational success based on balanced ecological, social, and financial performance can ease the transition toward CBM (Hofmann, 2019).

The coexistence of traditional and CE-oriented business models can impact companies wanting to adopt CBMs, and companies might need to align investments with their previous business models (Olsson et al., 2018). Inclusive and added-value business models also offer a solution to tackling users' ability to pay (e.g., providing leasing or renting options to make products accessible) and addressing consumers' resistance to change (Cantú et al., 2021).

The potential for a company to position itself as a CE-oriented organization and thus increase its competitive advantage can be a driving factor for CBM adoption (Bocken et al., 2017; Hofmann & Jaeger-Erben, 2020; Lewandowski, 2016). However, the risk of cannibalization—for instance, cannibalization of a company's own market share or risk that new CBMs may lead to reduced profits if the new, longer-lasting products decrease sales of the established products—represents a serious obstacle for companies in the transition toward CBMs (Guldmann & Huulgaard, 2020; Linder & Williander, 2017; Salvador et al., 2020).

The supply chain can also affect the transition to CBMs, as vertical integration of the supply chain can enable strong IP and labelling strategy for companies, while benefiting from industrial symbiosis (Donner et al., 2021). The organizational type and structure of a company also influence its ability to adopt CBMs. For example, high organizational complexity can have a negative influence on adoption capabilities, whereas leaner organization types, such as academic spin-offs, typically defined also as science-based companies, can be more effective in driving the adoption of CBMs (Pedersen et al., 2019; Poponi et al., 2020). Finally, explicit implementation strategies and transition procedures focused on circularity represents strong enablers of CBM adoption (Lehtimäki et al., 2020; Lewandowski, 2016; Palmié et al., 2021).

Table 4: Strategy determinants of CBM adoption

Determinant	Description	Examples and references
Strategic focus on CE, sustainability and stakeholder value creation	When the organisation has a coherent and clear strategy for achieving its mission and vision in terms of CE, sustainability and stakeholder value creation	• Integration of CE and sustainability into the organization’s strategy, mission, vision, goals (Cantú et al., 2021). • Definition of clear targets associated to the scale up of CBMs (Bocken et al., 2017; Hopkinson et al., 2018; Lewandowski, 2016). • Adoption of clear sustainability-oriented metrics and decision tools (Hopkinson et al., 2018; Stål and Corvellec, 2018; Vermunt et al., 2019), measuring overall organizational success and business on

		balanced ecological, social, and financial performance (Hofmann, 2019). • Prevailing linear business model structures and thinking and narrow focus of existing sustainability strategies (Guldmann and Huulgaard, 2020). • Employing inclusive and added-value business models that can be used to tackling users' ability to pay (e.g. leasing or renting making products affordable and accessible) and handling consumers' reluctance to change (Cantú et al., 2021). • Creation of new business models, promoting the use of sustainable and circular strategies, and integration of CE and corporate sustainability (Cantú et al., 2021; Witjes and Lozano, 2016).
CE-oriented competitive advantage	Circumstances related to CE that puts an organisation in a favourable position	• Possibility that CBM adoption will increase competitive advantage (Bocken et al., 2017; Hofmann and Jaeger-Erben, 2020; Lewandowski, 2016).
CE-oriented supply chain strategy	The CE-oriented strategy regarding the planning, execution, monitoring and control of the supply chain	• Conflicts of interest between companies within the supply chain – e.g., high dependence of supplier, misaligned profit share along the supply chain (Bianchini et al., 2019; De Angelis, 2021; Lewandowski, 2016; Planing, 2015; Rizos et al., 2016; Vermunt et al., 2019). • Vertical integration within the supply chain (Donner et al., 2021).
Coexistence of traditional and CE-oriented business models	The existence of multiple business models at the same time	• The need to align investments with previous business models based on selling raw materials is an element that comes with co-existence of business models (Olsson et al., 2018). • Risk of cannibalization, for instance cannibalisation of own market share or risk that new CBMs may lead to decreased sales if the new, longer-lasting products reduce sales of the previous products (Guldmann and Huulgaard, 2020; Linder and Williander, 2017; Salvador et al., 2020).
CE implementation strategy	The methods employed to implement and maintain strategic plans in an	• Top-down strategy focused on increasing the efficiency of industrial symbioses (Donner et al., 2021). • Explicit implementation strategies for CBMs and effective circularity transition procedures

	organisation or company	(Lehtimäki et al., 2020; Lewandowski, 2016; Palmié et al., 2021).
Organizational type and structure	How the organization is structured and its activities are coordinated and delegated	• Organizational type and structure, and their influence on the organizational ability to adopt CBMs (Pedersen et al., 2019; Poponi et al., 2020).

3.5 Business case determinants

The literature also focuses on business case determinants of CBM adoption (Table 5). Particularly, access to capital and financial resources enabled by adopting a CBM (e.g., through crowdfunding, or external financing such as EU and government grants) can become a strong driver of CBM adoption (D'Amato et al., 2020; Guldmann & Huulgaard, 2020; Vermunt et al., 2019). The literature also focuses on cost reductions that can be achieved by employing a CBM, for example, through minimizing waste and maximizing resource efficiency (Marke et al., 2020; Olsson et al., 2018). However, CBMs may also require high upfront investment and costly management and operation, which can represent a great obstacle for some companies working on this transition (Bianchini et al., 2019; Heyes et al., 2018; Nascimento et al., 2019; Olsson et al., 2018; Pedersen et al., 2019; Reim et al., 2019; Vermunt et al., 2019). Moreover, the low prices of recycled materials can also hinder their collection and availability, with negative consequences for the implementation of circular supply chains (Cantú et al., 2021).

Other business case determinants of CBM adoption lie with the generation of new business and growth opportunities unleashed by the circularity transition, such as the opportunity to create additional revenue streams and profit increase by selling longer-lasting products targeting sustainability-oriented customers (Bocken et al.,2018; Cantú et al.,2021). The willingness and opportunity to attain profitability and economic benefit while promoting the local economy (e.g., through the creation of new products, jobs and industries; see Marke et al., 2020; Donner et al., 2021) and addressing sustainable development challenges (Cantú et al., 2021; Fraccascia et al., 2016; Han et al.,2020) are strong motivational factors for companies working on the transition toward CBMs.

Table 5: Business case determinants of CBM adoption

Determinant	Description	Examples and references
Access to resources	Possibility of access to money, materials, human capital, knowledge and other resources	• Access to capital and financial resources (D'Amato et al., 2020; Guldmann and Huulgaard, 2020; Vermunt et al., 2019). • Lack of supporting financing models (Rizos et al., 2016; Schulte, 2013).
Investment opportunities	Assets or items that have the opportunity to generate increase in value	• Dependency on large investments (Donner et al., 2021). • Risk of costly capital commitment (e.g. associated to employee motivation and expertise development) may hinder value creation in CBMs (Ünal et al., 2019). • High investment costs involved with CBMs and need of upfront investments, which may be associated with high uncertainty (Heyes et al., 2018; Pedersen et al., 2019; Reim et al., 2019; Vermunt et al., 2019). • Investors' reluctance in investing in CBMs (e.g., leasing) (Vermunt et al., 2019). • High investments required in knowledge and tools (Hopkinson et al., 2018).
Growth opportunities	The possibility of gaining value, size, resources or capital	• Job creation opportunities in relation to CBM adoption (Fraccascia et al., 2016). • New business opportunities and economic promotion of local areas, through the creation of new circularity-oriented industries, products and jobs (Donner et al., 2021; Marke et al., 2020)
Revenue opportunities	Items, products or tasks that if performed may generate new revenue	• New revenue opportunities related to the production of longer lasting products for circularity-oriented markets (Bocken et al., 2018; Cantú et al., 2021). • Increased sales of repaired, reconditioned and remanufactured products in the market (Guldmann and Huulgaard, 2020). • Economic benefits related to the adoption of circularity practices (Fraccascia et al., 2016; Han et al., 2020).

		• Unclear business case and lack of evidence of economic and financial benefits in relation to the adoption of CBMs (Guldmann and Huulgaard, 2020; Marke et al., 2020), which can lead to a lengthening time to market and resistance to adopt CBMs (Guldmann and Huulgaard, 2020).
Costs and cost reduction	Monetary expenditures and decrease in expenditures for producing, acquiring or maintaining business	• High upfront investment costs in relation to the adoption of CBMs (Vermunt et al., 2019). • High costs of CBMs linked to the recovery, transportation, and sorting of waste (Cantú et al., 2021), as well as to (re)manufacturing processes (Marke et al., 2020; Mboli et al., 2020). • Costly management, operations and planning processes related to CBM adoption due to more complex practices (Olsson et al., 2018; Bianchini et al., 2019; Nascimento et al., 2019). • Low price of virgin raw materials compared to recycled materials (Vermunt et al., 2019; Guldmann and Huulgaard, 2020), which can inhibit their collection and availability (Cantú., 2021). • Cost reductions may be achieved in CBMs through minimising waste and maximising resource efficiency (Marke et al., 2020; Olsson et al., 2018; Ranta et al., 2018).
Risks and risk reduction	Mitigating the likelihood and reducing the possible consequences of situations that may result in loss	• Investment, operational and implementation risks (Han et al., 2020; Linder and Williander, 2017) • Data security (e.g. reuse of technological devises) (Marke et al., 2020). • Uncertainties related to customer perception of second-hand products (Bocken et al., 2017) • Risks related to of radical innovation process needed to switch towards a CBM (Bocken et al., 2018; Heyes et al., 2018). • Effective risk management can act as an enabler for CBM adoption (Lehtimäki et al., 2020).

3.6 Collaboration determinants

In this systematic review, we found that many authors identify collab-oration as a vital determinant of CBM adoption (Table 6). Indeed, enhancing interactions and collaboration with customers (e.g., through product and service personalization and customization) can help drive a company's adoption of CBMs (Cantú et al., 2021; Han et al., 2020; Ünal et al., 2019). Collaboration with suppliers and partners can also impact the ability to switch to a CBM. Rizos et al. (2016) argue that the collaboration of all parties across the supply chain is needed for the circularity transition, and establishing collaboration and dialogue with key partners and actors within the value chain will drive the rate of CBM adoption (D'Amato et al., 2020; Rizos et al., 2016). In particular, initiatives such as the creation of reward programs and exclusive partnerships with suppliers can increase companies' interest in implementing CBMs (Cantú et al., 2021). Additionally, successful partnerships between the public and private sectors can help companies in undertaking this transition (Donner et al.,2021). However, the lack of compatibility with partners' business models may become a strong obstacle in this transition (Bianchini et al., 2019; Linder & Williander, 2017). So does the disconnection between local governments and companies, or the lack of support or interest from the sup-ply network and value chain to adopt CBMs (Bianchini et al., 2019; Guldmann & Huulgaard, 2020; Huerta Morales, 2020; Olsson et al., 2018; Shao et al., 2020). Weak innovation networks and partnerships are hindering factors too, and thus support for partnership platforms may be crucial (Uvarova et al., 2020). In practice, organizations will be confronted with organizing paradoxes—particularly competition versus collaboration—that require companies to integrate their resources and competences with their partners' resources and competences in the value chain and shift to higher degrees of cooperation to implement CE-oriented strategies (De Angelis, 2021).

The CBM transition can be driven by a company's ability to adapt to local settings (Ünal et al., 2019) and establish local collaborations, for instance by selecting and training local suppliers for recycling/reuse of products and materials (Mishra et al., 2021). In this context, information sharing and clarity of communication are both identified as key enablers of CBM adoption. Indeed, a lack of information, data, case studies, technical know-how, and expertise can hinder companies' ability to adopt CBMs (Pieroni et al., 2020; Rizos et al., 2016; Uvarova et al., 2020; Vermunt et al., 2019). Moreover, clear communication is needed to develop a consumer market based on creating awareness of the environmental and/or social values that an organization is aiming to create and carry out (Pedersen et al., 2019).

Internal collaboration is also identified as impacting the transition; conversely, intra-organizational separation can pose a risk for CBM adoption due to lack of agreement and shared direction and focus (Hofmann & Jaeger-Erben, 2020). Ultimately, support and commitment from the parent company and top management can also enable the transition to CBMs (Cantú et al., 2021; Guldmann & Huulgaard., 2020). The transformational and strategic leadership of key decision makers may represent a strong determinant of CBM adoption (Cantú et al., 2021; Zucchella & Previtali., 2019).

Table 6: Collaboration determinants of CBM adoption

Determinant	Description	Examples
Information sharing and clarity of communication	Exchange of knowledge and data, and the extent to which this exchange is effective	• Clear internal and external communication on CE (Cantú et al., 2021), promoting awareness of the environmental and/or social value that an organisation aims to create and deliver (Pedersen et al., 2019). • Transparency and traceability (Donner et al., 2021; Rizos et al., 2016; Salvador et al., 2020). • Lack of information (also due to asymmetric information and lack of information sharing), data, case studies, technical know-how, and expertise (Rizos et al., 2016; Vermunt et al., 2019; Pieroni et al., 2020; Uvarova et al., 2020; Ingemarsdotter et al., 2020; Cantú et al., 2021). • Lack of use of information management systems (Cantú et al., 2021; Vermunt et al., 2019).
Institutional support from leadership and parent companies	Support from the management, top leadership or	• Transformational and strategic leadership from key decision makers (Cantú et al., 2021; Zucchella and Previtali, 2019).

	organisation with controlling interest in the company	• Support and commitment from a company top management or from a parent companies (Cantú et al., 2021; Guldmann and Huulgaard, 2020). • Lack of reference point to which organizations, and particularly SMEs, can ask support when adopting CBMs (Rizos et al., 2016).
Internal collaboration	Individuals working in the same organisation collaborating on achieving shared goals or projects	• Small companies might benefit from undertaking multiple roles in the value chain (Ünal et al., 2019). • Intra-organizational separation can pose as a hindrance for the companies to be able to adopt CBMs (Hofmann and Jaeger-Erben, 2020). • There is also risk of the organising paradox: concentration versus decentralisation; separation versus integration (within organizational functions/departments) (De Angelis, 2021).
Collaboration with suppliers and partners	The act of working together with suppliers and partners to achieve shared goals or projects	• Lack of partners and lack of compatibility with partners' business models (Bianchini et al., 2019; Heyes et al., 2018; Linder and Williander, 2017; Vermunt et al., 2019). • Disconnection between local governments and companies, or lack of support or interest from supply network and value chain (Bianchini et al., 2019; Donner et al., 2021; Guldmann and Huulgaard, 2020; Huerta Morales, 2020; Olsson et al., 2018; Shao et al., 2020). • Lack of effective collaboration mechanism (Cantú et al., 2021). • Clustering and networking (Donner et al., 2021; Rizos et al., 2016; Uvarova et al., 2020). Reward programs and exclusive partnerships with suppliers (Cantú et al., 2021). • Collaboration between all parties across the value chain (Cantú et al., 2021; Lehtimäki et al., 2020), by establishing dialogue with key partners and operators (D'Amato et al., 2020; Rizos et al., 2016), and working on collaborative design for reuse and recycling (Mishra et al., 2021). • Unclear distribution of roles and responsibilities across the value chain (Ingemarsdotter et al., 2020). • Dependency on multiple (mainly external) stakeholders for the return of products/resources/materials increasing complexity of CBM design (Salvador et al., 2020; Vermunt et al., 2019).

Collaboration with customers	The act of working together with clients and customers	• Interactions and collaborations with customers (e.g. personalisation, customization) (Cantú et al., 2021; Han et al., 2020; Ünal et al., 2019). • Reliable customer relationships, which can increase the likelihood of customer acceptance of circularity-oriented value proposition (Carraresi and Bröring, 2021).
Collaboration with competitors	The act of working together with competing companies to achieve shared goals or projects	• Organising paradoxes – particularly competition versus collaboration – which require companies to integrate their resources and competences and shift to higher degrees of cooperation (De Angelis, 2021)
Collaboration with local community	The act of working together with members of the community in the area to achieve shared goals or projects	• Collaboration with local community, e.g., selection and training of local suppliers (Mishra et al., 2021). • Adaptation to local context and conditions (Ünal et al., 2019; Cantú et al., 2021).

3.7 Operations determinants

Operations-related factors may also have a strong impact on a company's ability to adopt a CBM (Table 7). Indeed, the potential for optimizing logistics costs can incentivize companies to switch to CBMs (Donner et al., 2021). However, when discussing the operations determinants of CBM adoption, many authors focus on the lack of adequate infrastructure supporting CE, which is crucial in order to employ CBMs effectively (Cantú et al., 2021; Geissdoerfer et al., 2018; Reim et al., 2019; Uvarova et al., 2020). In particular, some authors argue that adopting a CBM can be costly (e.g., in terms of distribution planning, production planning, and inventory management; see Rizos et al., 2016), and companies need to possess appropriate organizational resources (e.g., sufficient space and facilities, time, human resources, and employee knowledge) to do so (Cantú et al., 2021; Donner et al., 2021; Guldmann & Huulgaard., 2020; Lewandowski., 2016; Stål & Corvellec, 2018; Uvarova et al., 2020).

Fragmented, dispersed, or overly complex supply chain infrastructures are also mentioned in the literature as strong obstacles to the adoption and implementation of CBMs (Guldmann & Huulgaard, 2020; Salvador et al., 2020) especially because adopting a CBM is likely to further increase complexity throughout the whole supply chain (Rizos et al., 2016). Some studies argue that the risk of conflict of interest in companies and dissonant profit-sharing within the sup-ply chain can particularly threaten the CBM adoption rate (Bianchini et al., 2019; Lewandowski, 2016; Ranta et al., 2018). Some companies may experience difficulties implementing circular solutions because they are locked in at the bottom of the value chain (Rizos et al., 2016), while others may be challenged by the need to separately manage multiple positions in the value chain (Ranta et al., 2018). Moreover, powerful stakeholders across the value chain may resist change due to their status quo interests and the current uneven allocation of power (Rizos et al., 2016).

Challenges concerning the traceability, recovery, transportation, and sorting of waste may stop companies from transitioning toward CBMs (Cantú et al., 2021; Huerta Morales, 2020; Stål & Corvellec, 2018). Reverse logistics networks and return flows must be developed and managed by companies in order to facilitate waste traceability and recovery and thus support a smooth and successful circularity transition (Cantú et al., 2021; Linder & Williander, 2017; Nascimento et al., 2019; Rizos et al., 2016). Traceability can also attract sustainability-oriented customers, who value the possibility of tracking the sustainability impact of their purchases along their whole life cycle (Cantú et al., 2021; Donner et al., 2021). In this regard, the academic literature suggests that geographic dispersion and large distances between production location, sources of waste, customers, and other partners in the supply chain may pose challenges to waste traceability and recovery and can thus become barriers to CBM adoption (Bianchini et al., 2019; Cantú et al., 2021; Carraresi & Bröring., 2021; Donner et al., 2021; Guldmann & Huulgaard., 2020; Lewandowski, 2016; Ünal et al., 2019). Under such conditions, actors in the market may experience uncertainties about product returns in respect of quality, quantity, market value, and timing (Bocken et al., 2018; Cantú et al., 2021; Donner et al., 2021; Guldmann & Huulgaard, 2020; Ingemarsdotter et al., 2020; Lewandowski, 2016; Olsson et al., 2018; Sarti et al., 2017; Shao et al., 2020; Stål & Corvellec., 2018; Ünal et al., 2019; Vermunt et al., 2019). Voluntary relocation is cited in the literature as a possible solution to this issue, due to the fact that it can enable better communication and collaboration between companies in the supply chain (Marke et al., 2020).

Furthermore, product category characteristics and restrictions are often cited in the literature as factors preventing companies from adopting CBMs, whereas product design for CE is necessitated to enable the transition (Cantú et al., 2021; Guldmann & Huulgaard, 2020; Hofmann & Jaeger-Erben, 2020; Huerta Morales, 2020; Ingemarsdotter et al., 2020; Linder & Williander, 2017; Salvador et al., 2020; Sumter et al., 2018; Vermunt et al., 2019). There is a particular need for design to reuse, repair, remanufacture, and recycle, while allowing for product replicability, upgradability, and scalability (Bocken et al., 2017; Cantú et al., 2021; Donner et al., 2021; Guldmann & Huulgaard, 2020; Hopkinson et al., 2018; Lieder & Rashid, 2016; Stål & Corvellec, 2018; Zucchella & Previtali, 2019).

Finally, specific industries may experience huge challenges in the development and implementation of CBMs along the supply chain. For example, the vulnerability of the fashion industry along with its changing trends are often cited as barriers in the implementation of

CBMs (Guldmann & Huulgaard, 2020; Ingemarsdotter et al., 2020; Linder & Williander, 2017; Salvador et al., 2020).

Table 7: Operations determinants of CBM adoption

Determinant	Description	Examples
Organizational resources	The assets available to a company for the day to day functioning of the company	• Lack of capital and other organizational resources (sufficient space and facilities, time, human resources, employee knowledge) (Cantú et al., 2021; Donner et al., 2021; Guldmann and Huulgaard, 2020; Ingemarsdotter et al., 2020; Lewandowski, 2016; Linder and Williander, 2017; Stål and Corvellec, 2018; Uvarova et al., 2020; Zucchella and Previtali, 2019).
Operational efficiency and complexity	The company or organisation's ability to deliver goods or services with minimal degree of waste (production, time, material, finance, inventor, labour waste etc).	• Administrative bureaucracy and other administrative barriers (Cantú et al., 2021; Rizos et al., 2016; Uvarova et al., 2020; Vermunt et al., 2019). • Increased need for operational efficiency and greater complexity, which requires distribution planning, production planning and inventory management – which can be costly (Rizos et al., 2016). • Continuously having to develop new products suitable for standardization and customization (Huerta Morales, 2020).
Materials management systems	All the activities that are related to a company's materials and material flows	• Challenges concerning the traceability, recovery, transportation, and sorting of waste (Cantú et al., 2021; Huerta Morales, 2020; Stål and Corvellec, 2018). • Lack of societal awareness about waste separation and dispersion of post-consumer waste (Cantú et al., 2021; Vermunt et al., 2019). • Development of effective waste collection and storage systems (Salvador et al., 2021). • Uncertainties about product returns in terms of quality, quantity, market value and timing (Bocken et al., 2018; Cantú et al., 2021; Donner et al., 2021; Guldmann and Huulgaard, 2020; Ingemarsdotter et al., 2020; Lewandowski, 2016; Olsson et al., 2018; Sarti et al., 2017; Shao et al., 2020; Stål and Corvellec, 2018; Ünal et al., 2019; Vermunt et al., 2019).

		• Limited availability on quantity and quality of recycled material (Cantú et al., 2021). • Tools to facilitate traceability in the supply chains, which is very important for customers (Cantú et al., 2021; Donner et al., 2021).
Product characteristics	A product's attributes or features that satisfy needs and wants of the consumer	• Design to reuse, recycle, remanufacture, upgrade, dismantle, disassemble, repair, replicate, and scale (Bocken et al., 2017; Cantú et al., 2021; Donner et al., 2021; Guldmann and Huulgaard, 2020; Hopkinson et al., 2018; Lieder and Rashid, 2016; Stål and Corvellec, 2018; Zucchella and Previtali, 2019). • Fast-changing trends in specific industries – e.g., fashion industry (Guldmann and Huulgaard, 2020; Ingemarsdotter et al., 2020; Linder and Williander, 2017; Salvador et al., 2020). • Product category restrictions, which can disable the company from adopting CBMs (Cantú et al., 2021; Guldmann and Huulgaard, 2020; Hofmann and Jaeger-Erben, 2020; Huerta Morales, 2020; Ingemarsdotter et al., 2020; Linder and Williander, 2017; Salvador et al., 2020; Sumter et al., 2018; Vermunt et al., 2019).
Procurement	The activity of acquiring goods/services from external sources	• Long standing procurement habits (Ingemarsdotter et al., 2020).
Supply chain infrastructure	The assets and systems that are driving the network between a company and its suppliers	• Fragmented, dispersed or complex supply chain infrastructures, that are difficult to control (Guldmann and Huulgaard, 2020; Salvador et al., 2020), and might require that companies need to separately manage multiple positions in the supply chain (Ranta et al., 2018). • Optimization of logistics costs (Donner et al., 2021). • Conflict of interest within companies and misaligned profit-share along the supply chain (Bianchini et al., 2019; Lewandowski, 2016; Planing, 2015; Ranta et al., 2018). • Resistance to change from the powerful stakeholders across the value chains, due to their status quo interests (Rizos et al., 2016). • Effective management and development of reverse logistics networks and return flows (Cantú et al.,

		2021; Linder and Williander, 2017; Nascimento et al., 2019; Rizos et al., 2016). • Difficulties for some companies to implement a green solution because of being locked in at the bottom of the supply chain (Rizos et al., 2016). • Lack of adequate infrastructure that supports the functioning or implementation of CE (Geissdoerfer et al., 2018; Uvarova et al., 2020; Cantú et al., 2021).
Geographical proximity	The physical distance or placement of and between actors in market	• Geographic proximity to production location, customers, sources of waste, industry, R&D, and other strategic resources (Lewandowski, 2016; Bianchini et al., 2019; Ünal et al., 2019; Guldmann and Huulgaard, 2020; Cantú et al., 2021; Carraresi and Bröring, 2021). • Voluntary relocation (Marke et al., 2020).

3.8 Knowledge determinants

Intellectual property, along with technological and organizational knowledge and expertise, is considered by the reviewed literature as impacting factors of CBM adoption (Table 8). In particular, according to Bocken et al. (2017) and Lehtimäki et al. (2020), there is a need for com-prehensive knowledge on how to best create new business strategies and innovate business models in order to switch to circularity (Bocken et al., 2017; Lehtimäki et al., 2020). The reviewed literature also argues that business model innovation for circularity requires ad hoc support from top management—and this applies not only within large companies but also in SMEs (Pieroni et al., 2020; Uvarova et al., 2020). This support is particularly needed in the development of cross-functional competencies and dynamic capabilities within the organization, attributes that can foster the circularity transition (Bianchini et al., 2019; Cantú et al., 2021; Carraresi & Bröring, 2021; Lehtimäki et al., 2020; Lewandowski, 2016). Authors argue that currently, companies lack measures and procedures to support the development of innovation, as well as knowledge about innovation support opportunities (Uvarova et al., 2020). Moreover, Uvarova et al. (2020) observe that coordination and collaboration among the institutions providing support for development of CBMs are insufficient, making it more strenuous to adopt CBMs; they suggest that innovation platforms and training maybe helpful in this context. Finally, lack of CE-oriented organizational capabilities and in-house knowledge may hinder CBM adoption (Cantú et al., 2021; Guldmann & Huulgaard, 2020; Lewandowski, 2016).

Moreover, companies need up-to-date technological knowledge and expertise (Bianchini et al., 2019; Rizos et al., 2016; Uvarovaet al., 2020), for instance in relation to information and communication technologies that are necessary for product monitoring in multiple lifecycles (Lehtimäki et al., 2020). The fast rate of technological change can require frequent design changes which, if not mastered properly, may hinder product reuse and remanufacturing, thus hampering the CBM adoption rate (Guldmann & Huulgaard, 2020). Therefore, according to the reviewed literature, companies committed to the adoption of a CBM need to be well equipped in terms of technological development, upscaling, and testing (e.g., in relation to Industry 4.0 technologies) (Donner et al., 2021; Mboli et al., 2020; Nascimento et al.,2019). These companies can benefit significantly from CE-driven collaborations that generate opportunities for technology transfer and organizational learning (Mishra et al., 2021). In practice, authors identify a lack of technologies that facilitate companies in recycling and remanufacturing (Cantú et al., 2021; Guldmann & Huulgaard, 2020; Vermunt et al., 2019). Additionally, some companies lack expertise, knowledge, and in-house skill sets to repair and remanufacture, which may make their transition challenging (Bianchini et al., 2019; Cantú et al., 2021; Guldmann & Huulgaard, 2020; Pedersen et al., 2019; Pieroni et al., 2020; Rizos et al., 2016; Uvarova et al., 2020; Vermunt et al., 2019; Zucchella & Previtali, 2019). After-sale capabilities are also necessary in order to support service levels and life cycles and maximize retained value (Lehtimäki et al., 2020). In general, authors argue that there is a lack of, and need for, training on CE and CE-associated capabilities (Cantú et al., 2021; Guldmann & Huulgaard, 2020; Rizos et al., 2016; Uvarova et al., 2020). Particularly, experimentation capabilities and previous positive experiences with business model innovation can be strong assets for companies, as they can help to drive and enable the CBM adoption process considerably (Bocken et al., 2017, 2018; Fraccascia et al., 2016; Ünal et al., 2019).

Table 8: Knowledge determinants of CBM adoption

Determinant	Description	Examples
CE-oriented organizational capabilities	The existing skills, knowledge and expertise related to circular economy of the people in an organisation	• Lack of organizational capabilities and in-house knowledge about CE (Cantú et al., 2021; Guldmann and Huulgaard, 2020; Lewandowski, 2016). • After-sales capabilities, which are necessary to support after-sale services, extend product life-cycles and maximise retained value (Lehtimäki et al., 2020).
IP, know-how and expertise	Involves the copyrights, patents, trademarks, trade secrets, practical knowledge and skills that the company houses	• Lack of expertise, knowledge flow or in-house skill sets to repair and remanufacture (Bianchini et al., 2019; Cantú et al., 2021; Guldmann and Huulgaard, 2020; Pedersen et al., 2019; Pieroni et al., 2020; Rizos et al., 2016; Uvarova et al., 2020; Vermunt et al., 2019; Zucchella and Previtali, 2019). • IP and patents, which make a company's innovations more interesting for investors (Donner et al., 2021). • Need for comprehensive knowledge on creating new business strategies and circular business model innovation (Bocken et al., 2017; Lehtimäki et al., 2020).
Technology transfer and technological change	The act of conveying technology and the process for invention, innovation and diffusion of technology or processes	• Lack of appropriate technology and technologies that facilitate recycling, optimization, or remanufacturing (Cantú et al., 2021; Guldmann and Huulgaard, 2020; Vermunt et al., 2019). • Need for technological know-how and expertise (Bianchini et al., 2019; Mboli et al., 2020; Nascimento et al., 2019; Rizos et al., 2016; Uvarova et al., 2020), e.g., the need for information and communication technologies for product monitoring in multiple life cycles (Lehtimäki et al., 2020). • Need for technological testing and upscaling (Donner et al., 2021). • Rate of technological change, which may demand frequent design changes that hinders product reuse

		and remanufacturing (Guldmann and Huulgaard, 2020).
Innovation and support of innovation	The act of developing new products or processes and the assistance from other parties to do so	• Insufficient coordination and cooperation between institutions providing support for circular business model innovation (Uvarova et al., 2020). • Lack of knowledge on opportunities supporting circular business model innovation (Pieroni et al., 2020; Uvarova et al., 2020).
Experimentation and learning capabilities	Testing new methods or ideas, and the availability of practices and mechanisms that can promote learning in the company	• Lack of training on CE and CE-oriented capabilities (Cantú et al., 2021; Guldmann and Huulgaard, 2020; Rizos et al., 2016; Uvarova et al., 2020). • Development of cross-functional capabilities in addition to new organisational and dynamic competences (Bianchini et al., 2019; Cantú et al., 2021; Carraresi and Bröring, 2021; Lehtimäki et al., 2020; Lewandowski, 2016). • Business model innovation capabilities and experiences (Fraccascia et al., 2016). • CBM experimentation capabilities (Bocken et al., 2018, 2017; Ünal et al., 2019).

4. Discussion

This study presents a holistic overview of the current state of the art of determinants of CBM adoption, based on a systematic literature review of 67 journal articles. In total, the study identified 54 different categories of determinants, which were grouped into eight separate macro categories: culture, regulation, market, strategy, business case, collaboration, operations, and knowledge.

The first category, *Culture*, comprises the determinants that are related to the culture of an organization and its surrounding context, also including the attitudes and behaviors of employees, customers, managers, and other stakeholders. The societal culture, with its changing public opinion and pressure on matters concerning sustainability and circularity, can push companies toward circularity. The industrial culture can also affect an organization's willingness and capability of adopting CBMs, especially if the particular industry has a lack of

CE and sustainability awareness (Cantú et al., 2021; Carraresi & Bröring, 2021; Ingemarsdotter et al., 2020; Levänen et al., 2018; Pieroni et al., 2020; Stål & Corvellec, 2018; Vermunt et al., 2019). As reported by Circle Economy (2020), the transition toward circularity has stalled, and Lieder and Rashid (2016) argue that the implementation of circular economy is a demanding task due to the industries' and societies' current linear mindset and structures. Concurring with Lieder and Rashid's statement, our findings substantiate that societal and industrial culture can impact a company's adoption of CBMs. The reviewed literature shows that lack of trust and compatibility between partners in the supply chain can also hinder companies from switching to CBMs (Cantú et al., 2021; Guldmann & Huulgaard, 2020; Salvador et al., 2020; Zucchella & Previtali, 2019). Most of the literature in the Culture category considers change in attitudes and behavior, particularly of customers (Planing, 2015; Vermunt et al., 2019; Cantú et al., 2021; Hankammer et al., 2019), but also of employees and managers (Rizos et al., 2016), as a driving force for adoption of CBMs. This insinuates that education can play a key role in strengthening public awareness of the potential of circular solutions, which can in turn lead to an increase of CBM adoption.

In the *Regulation* category, the review showed that the adoption of CBMs in companies is dependent on the creation and establishment of laws and policies toward sustainability and CE (Cantú et al., 2021). Lobbying for CE drives the adoption rate in companies; however, the lack of defined targets and CE-oriented frameworks for supporting CBM innovation in companies can interfere with the adoption process (Cantú et al., 2021; Levänen et al., 2018). When looking at the literature from the Regulation category, government regulation was the most frequently mentioned determinant and was highlighted both as a driver (D'Amato et al., 2020; Hopkinson et al., 2018) and a barrier (Ingemarsdotter et al., 2020; Linder & Williander, 2017; Rizos et al., 2016). The literature considers a lack of supporting regulation (Ingemarsdotter et al., 2020; Linder & Williander, 2017; Rizos et al., 2016), ineffective policies (Vermunt et al., 2019), and the complexity of regulations (Bianchini et al., 2019) to particularly hinder CBM adoption. This suggests that there is an opportunity to increase the adoption of CBMs by initiating change at governmental and policy levels, which would support companies that seek to embrace CBMs across value chains.

The market has a strong impact on companies, and multiple determinants are found in the review related to the Market category. Companies are likely to be driven toward CBM adoption in order to keep up with market demand—for instance by trying to develop a consumer market and to build loyalty in new consumer segments (Bocken et al., 2017). The literature also refers to market competition as deter-mining the levels of adoption; however, only barriers were found in the literature, due to the fact that fierce competition in the market can hinder companies from adopting CBMs (Donner et al., 2021; Rizos et al., 2016; Shao et al., 2020). It is interesting that none of the reviewed articles list market competition as a driving force of CBM adoption, as one might think that some companies would be likely to feel pressured to adopt CBMs in order to remain a valid sustainability-oriented actor in the market. The most frequently mentioned determinant in the literature in the Market category was market demand. On one hand, some authors considered market demand to hinder CBM adoption due to its current ambiguity (Guldmann & Huulgaard, 2020). On the other hand, other authors argued that market demand can push companies to adopt CBMs, as new circularity-oriented solutions are demanded by clients and customers (D'Amato et al., 2020). This may lead to an upsurge in market competition and a decrease in market uncertainties (Heyes et al., 2018; Reim et al., 2019) for companies wanting to adopt a CBM.

The *Strategy* category also encompasses a multitude of determinants. An organization's strategy, and in particular its focus on CE, sustainability, and sustainable value creation, may determine whether the organization will be able to successfully utilize circularity in its business model or not. The company must take an active choice in implementing circular practices and acquiring the necessary resources. Even though CBM adoption offers the potential for the company to position itself as a leader within CE, the risk of cannibalization of its own market share and decreased sales of established products may stop companies from actively switching to a CBM (Bocken et al., 2018; Guldmann & Huulgaard, 2020; Hofmann & Jaeger-Erben, 2020; Linder & Williander, 2017; Salvador et al., 2020). The reviewed literature shows that adopting novel performance indicator sets that measure overall organizational success on balanced ecological, social, and financial performance can drive the adoption of CBMs (Hofmann, 2019). Interestingly, determinants falling within the Strategy category were the least covered across all the collected literature. Since CBM adoption is often considered a strategic management approach, this identifies a need for academia to further investigate how companies can develop implementation strategies and strengthen their strategic focus on CBMs.

As part of the *Business Case* category, access to financial resources is an often-mentioned determinant of CBM adoption. Particularly, multiple authors find that there is a lack of supporting financing models to promote innovative business models (Rizos et al., 2016; Schulte, 2013) and that the high up-front investments of CBM adoption and costly management and operation planning processes can stop companies from engaging in the transition toward CBMs (Bianchini et al., 2019; Nascimento et al., 2019; Olsson et al., 2018; Vermunt et al., 2019). However, the reviewed literature also highlights that companies still see CBM adoption as a generator of opportunities to attain profitability and economic benefit for the company and society as a whole (e.g., job creation and economic growth at the local level) (Cantú et al., 2021; Fraccascia et al., 2016; Han et al., 2020).When discussing the complexity of implementing circular economy, Lieder and Rashid (2016) argue that the economic benefits related to circular economy are hard to imagine. Our findings however show that companies appreciate the benefits that adoption of CBMs can offer but that it is rather the lack of access to financial resources and the high investment costs that hinder a large-scale implementation of CBMs in industry. In practice, access to financial resources can be improved through collaborative practices such as public–private partnerships, impact investing, and crowdfunding, while high investment costs can be reduced through the sharing of assets and resources within the value chain.

Therefore, *Collaboration* with clients, suppliers/partners, customers, local community, competitors, and internal stakeholders are all considered to be factors that could determine the companies' ability to succeed in adopting CBMs. Rizos et al. (2016) argue that the collaboration of all parties across the supply chain is essential, and establishing collaboration and dialogue with key partners and actors within the value chain can drive CBM adoption (D'Amato et al., 2020; Rizos et al., 2016). On this matter, CE-oriented strategic leadership and commitment are needed in order for a company to prioritize collaboration activities as part of its transitioning strategy (Cantú et al., 2021; Guldmann & Huulgaard, 2020). It is, however, likely that the companies choosing to utilize collaboration strategies will be confronted with organizing paradoxes—particularly competition versus collaboration—that require them to integrate their resources and competences with their partners' resources and competences in the value chain and shift to higher degrees of cooperation in order to collaboratively implement CE strategies (De Angelis,2021). To deal with the complexity of this organizing paradox, companies need to establish mutual trust and aligned incentives for all involved parties, in order to enable stakeholders to collaborate constructively and share knowledge, resources, and risks (Cantú et al., 2021; Guldmann & Huulgaard, 2020; Salvador et al., 2020; Zucchella & Previtali, 2019).

Operations in an organization can have a strong impact on its ability to employ green solutions, particularly if the supply chain infra-structure is fragmented, dispersed, or complex (Guldmann

& Huulgaard, 2020; Salvador et al., 2020). The introduction of a CBM is expected to add complexity throughout the supply chain, and companies may refuse to further complicate an already weak supply chain. However, we found in the review that companies also experience an optimization of logistics while adopting a CBM, which may represent a strong adoption incentive for organizations (Donner et al., 2021; Rizos et al., 2016). The review also shows that some companies experience a lack of organizational resources (e.g., human resources, knowledge, and facilities), which are needed to transfer from a linear to a CBM (Cantú et al., 2021; Donner et al., 2021; Guldmann & Huulgaard, 2020; Lewandowski,2016; Stål & Corvellec, 2018; Uvarova et al., 2020). The most frequent operational determinants of CBM adoption addressed by the literature are supply chain infrastructure (e.g., Cantú et al., 2021; Guldmann & Huulgaard, 2020) and materials management systems (e.g., Ingemarsdotter et al., 2020; Salvador et al., 2020). The literature indicates the need for organizational resources to enable CBM adoption, such as commitment of financial resources (Linder & Williander, 2017; Zucchella & Previtali, 2019), human resources (Lewandowski, 2016; Uvarova et al., 2020), and adequate facilities (Donner et al., 2021). However, this study did not identify a more comprehensive investigation on the tangible and intangible organizational resources needed to drive CBM adoption. The growing literature on dynamic capabilities could sup-port this debate (Bezerra et al., 2020; Chari et al., 2022; Khan et al., 2020; Santa-Maria et al., 2021; Strauss et al., 2017), explicitly linking strategic resources and capabilities to CBM success.

Finally, the category that we perceive as stemming from the most internal side of an organization is *Knowledge*. One frequent aspect debated by the literature related to this category regards the role of digital technologies (Bressanelli et al., 2018; Ranta et al., 2021), internet of things (Ingemarsdotter et al., 2020), and other Industry 4.0 technologies in general (Nascimento et al., 2019).Besides, the literature also focuses on the need for intellectual property, knowledge, and expertise in creating new business strategies and business model innovation in order for circularity to become strongly integrated into the organizational business model (Bocken et al., 2017; Lehtimäki et al., 2020). The literature argues a lack of, and need for, training in the capabilities associated with circular economy and CE (Cantú et al., 2021; Guldmann & Huulgaard, 2020; Rizos et al., 2016; Uvarova et al., 2020). There is also need for guidance and support programs for employees (Cantú et al., 2021; Uvarova et al., 2020). The literature is also concerned with technology and its related capabilities, and references report a lack of appropriate technologies that facilitate recycling, optimization, or remanufacturing (Cantú et al., 2021; Guldmann & Huulgaard, 2020; Vermunt et al., 2019). Knowledge about execution of circular activities and practices (e.g., after-sales capabilities and skills on how to repair and remanufacture) is particularly needed and becomes an investment issue for companies (Cantú et al., 2021; Guldmann & Huulgaard, 2020; Vermunt et al., 2019). Only a few studies in the reviewed literature mentioned internal knowledge determinants of CBM adoption, such as the lack of in-house knowledge on circular economy, the need for required expertise and knowledge about the products' potential to become circular (Guldmann & Huulgaard, 2020), and after-sales capabilities (e.g., to support service levels and life-cycles and maximize retained value; see Lehtimäki et al., 2020). The lack of knowledge on circular economy and its strategic and operational implications throughout organizations is still an issue to be addressed to accelerate the transition toward CBMs. Throughout the review process, it became evident that many of the studies cited determinants that related to multiple categories among the eight identified here. In general, it can be argued that it is likely that a company will simultaneously experience both drivers and barriers from various categories while transitioning toward a CBM—with its business model being impacted by external factors stemming from the environment in which the company operates and the internal factors that arise within the organization.

4.1 Key takeaways for practice

The findings of this paper can assist practitioners across industries to identify potential determinants that are likely to impact their companies' CBM adoption processes. Moreover, the findings can be used to aid decision makers in organizations to develop strategies and tactics and execute activities that can support the reduction of external and internal barriers and leverage drivers while adopting a CBM. By identifying and categorizing these determinants explicitly, this study provides insights that practitioners can use to critically analyze the factors affecting their current business models and the role they can play in the transition toward circularity. These insights can serve to inspire strategic action and act as guidelines for the execution of CBM adoption.

This research indicates that all types of organizations, independent of their size, resources, or starting point, can experience a plethora of hindrances and drivers to CBM adoption. Among the drivers, partnerships and collaborations are highlighted in the literature as strong enablers of CBM adoption and can therefore be strongly recommended for practitioners in order for their organizations to overcome the barriers together.

4.2 Key takeaways for academia

This paper contributed to academia by providing a holistic overview of the current state of the art on the topic of determinants of CBM adoption. We also presented a categorization map that uses a structured approach to classifying the determinants. The study may con-tribute to a better academic understanding of why resistance (e.g., Cantú et al., 2021; Ingemarsdotter et al., 2020) or hesitation toward CBM adoption is still prevalent in the industry and how to address and decrease these obstructions.

The paper also highlights a need for knowledge, innovation, and technology on the topics of CBM adoption and circularity practices (e.g., Bocken et al., 2017; Lehtimäki et al., 2020) in order for the companies to adequately engage in this transition, thus illuminating opportunities for research on these topics. Research may thus actually serve as an enabler of CBM adoption in companies, as many companies are struggling with the lack of resources about the topic. More-over, collaboration with academic institutions could be used as an opportunity for assisting companies with the transition, while gathering data for academic purposes on the issues faced by organizations in the process of adopting CBM practices.

4.3 Key takeaways for policy

The insights provided in this study are relevant for policy-makers at both a national and international level in their role to devise circular economy policy frameworks and initiatives. Many of the determinants that were discovered in this study were focused on the need for regulation, policies, and legislation in the various sectors and industries. The vast quantity of literature that highlighted this issue suggests that there is a compelling need for new and updated policies and laws (Cantú et al., 2021; Guldmann & Huulgaard, 2020; Han et al., 2020; Hopkinson et al., 2018; Ingemarsdotter et al., 2020; Levänen et al., 2018; Lewandowski, 2016; Linder & Williander, 2017; Nascimento et al., 2019; Pedersen et al., 2019; Rizos et al., 2016; Salvador et al., 2020; Uvarova et al., 2020; Vermunt et al., 2019). The study can be used by policy-makers to highlight areas where policies are especially needed and where the organizations that are seeking to adopt CBMs are experiencing challenges related to outdated, obstructive policy. This aspect is particularly relevant, as policy-making can have a direct impact on the other determinants of CBM adoption.

The acquired list of determinants also showed that companies are experiencing a multitude of barriers when adopting CBMs. The number of barriers outweighed the number of drivers found in the study, which may point to a lack of incentives for companies to adopt CBMs. There is thus reason to argue that governments should invest more in incentivizing the companies to adopt circular practices. This could be done through financial support, regulation and policy establishment, tax benefits, knowledge support, or partnership establishment (Cantú et al., 2021; Donner et al., 2021; Rizos et al., 2016; Uvarova et al., 2020; Vermunt et al., 2019).

5. Conclusion

This paper provides a review of the academic literature on drivers and barriers related to the adoption of CBMs and contributes to the academic debate by providing a categorization of internal and external determinants based on eight different groups and several subgroups. The categories presented in the paper are also likely to be of interest to companies adopting CBMs, as they may assist them in discovering the determinants that they may experience, or be of use to them when developing strategies to deal with these determinants. The study also highlights a need for policy-making on a national and inter-national level, and it can be used by policy-makers to highlight struggles that organizations tend to experience. Finally, the paper adds to the academic literature on CBMs, by providing a better academic understanding of the determinants that affect organizations transitioning to CBMs. Indeed, the existing literature on the topic has mostly focused on barriers to CBM adoption on a case-study level, or on specific industries or company types: Few authors have focused on developing a general overview of CBM determinants. As this study is focused on all types of organizations and industries, it is applicable to any company that has either already implemented circularity or is considering making the shift.

5.1 Limitations of the study

The most relevant limitations of this work arise in the selection of key-words used in the search string. The search string was set to only allow articles that used the wording “business model” in the title. This means that articles that could still be applicable and focused on business model literature but have chosen to not use “business model” in the title, would be overlooked. There is therefore the possibility that relevant articles were excluded from the review. Relevant literature may also have been excluded in the process of defining inclusion/exclusion criteria.

Some articles may not have included the defined criteria in the abstract, but still might have offered interesting insights on the topic, or determinants to CBMs. To prevent this from occurring to the greatest extent possible, there were always two researchers responsible for assessing the abstracts of the articles, and both researchers had to agree on the suitability or the reason for exclusion of each article. Grey literature was also excluded from the literature search, which could be a limiting factor of the review, as grey literature might provide data not used in academic literature, which could reduce publication bias (Paez,2017). Only peer-reviewed literature found in scientific databases was employed in this study. Finally, the analysis could also benefit from categorizing the various organizational types, geographies, and preliminary challenges in order to acquire a deeper understanding of the different determinants that are likely to affect companies in various situations. However, the limitations of this paper can be overcome by future studies, in which various methodological methods are employed to test the validity of the findings in this study and investigate the contexts where the findings might not be accurate or applicable.

5.2 Further research

The topic of CBMs is still in its early stages, but it is rapidly advancing and requires appropriate approaches and tools that organizations can employ to assist them in the transition. There are many opportunities for future research, both to fill theoretical and practical gaps in the study of CBM adoption. Future studies may investigate the determinants of CBM adoption on specific industries or examine the strategies and practices that are successful in confronting the extensive range of barriers that organizations meet and help companies to utilize the existing drivers. As governments and local authorities increase their focus on sustainable development and circular economy, it is expected that regulatory and policy-making initiatives will also increase—leading to the necessity to study the effects of such policies on the adoption of CBMs.

Moreover, not many companies have made the transition from a fully linear to a fully CBM. There is thus an opportunity to investigate the experiences and learnings of the companies that have fully or partly transitioned and examine the determinants they experienced and which strategies or solutions they employed to solve the issues that emerged. Interesting insights can also emerge, when comparing these determinants and their interrelations in developed and developing countries. Future studies can explore how these drivers and barriers affect companies differently depending on the characteristics of their socio-cultural context.

Future studies are invited to employ the list of determinants uncovered in this study and to test the determinants with both academics and practitioners to verify their applicability and identify possible missing determinants. In this sense, further studies can investigate the most critical determinants and how they interact with each other. Unveiling such cause-and-effect relationships can provide a more in-depth understanding of the drivers and barriers for CBM adoption in practice.

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Appendix

Appendix 1. Supporting information on the study sample and inclusion and exclusion criteria for each reviewed article.

Title	Authors	Journal	Year	Inclusion in, or exclusion from, the final sample	Notes	Exemplary quote
A choice behavior experiment with circular business models using machine learning and simulation modeling	Lieder, M; Asif, FMA; Rashid, A	Journal of Cleaner Production	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
A circular business model mapping tool for creating value from prolonged product lifetime and closed material loops	Nussholz, JLK	Journal of Cleaner Production	2018	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
A decoupling perspective on circular business model implementation: Illustrations from Swedish apparel	Stal, HI; Corvellec, H	Journal of Cleaner Production	2018	Included	The coders found in the article relevant information on determinants of circular business model adoption	"This paper advances an alternative explanation for implementation patterns observed in relation to CBMs by arguing that the drivers and barriers of CBM adoption are not primarily functional but rather institutional (e.g., DiMaggio and Powell, 1983)." (p. 630)
A Definition and Theoretical Review of the Circular Economy, Value Creation, and Sustainable Business Models: Where Are We Now and Where Should Research Move in the Future?	Lahti, T; Wincent, J; Parida, V	Sustainability	2018	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
A Design Thinking Framework for Circular Business Model Innovation	Guldmann, E;	Journal of Business Models	2019	Excluded	The coders did not find in the article any relevant information	Not available

	Bocken, NMP; Brezet, H				on determinants of circular business model adoption	
A Framework for Sustainable Circular Business Model Innovation	Antikainen, M; Valkokari, K	Technology Innovation Management Review	2016	Included	The coders found in the article relevant information on determinants of circular business model adoption	"Currently, a majority of the business modelling tools and methods lack at least some of the identified and needed elements for innovating business models in a circular economy." (p. 1)
A framework for the adoption of green business models in the Ghanaian construction industry	Lamptey, T; Owusu-Manu, DG; Acheampon g, A; Adesi, M; Ghansah, FA	Smart and Sustainable Built Environment	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
A new business model for baby prams based on leasing and product remanufacturing	Mont, O; Dalhammar, C; Jacobsson, N	Journal of Cleaner Production	2006	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
A new circular business model typology for creating value from agro-waste	Donner, M; Gohier, R; de Vries, H	Science of the Total Environment	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
A Review and Evaluation of Circular Business Model Innovation Tools	Bocken, N; Strupeit, L; Whalen, K; Nussholz, J	Sustainability	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
A systemic logic for circular business models	Fehrer, JA; Wieland, H	Journal of Business Research	2020	Included	The coders found in the article relevant information on determinants of circular business model adoption	"As outlined by Laukkanen and Patala (2014), and Greenwood et al. (2011), paying more explicit attention to enrolling allies and understanding their collective actions in CBMs might help to overcome critical barriers that hinder sustainable and social innovation, such as lack of customer acceptance, short time horizons, and the lack of awareness and

						understanding among market and social actors." (p. 8)
A typology of circular start-ups: Analysis of 128 circular business models	Henry, M; Bauwens, T; Hekkert, M; Kirchherr, J	Journal of Cleaner Production	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
An Internet of Things-enabled decision support system for circular economy business model	Mboli, JS; Thakker, D; Mishra, JL	Software - Practice & Experience	2020	Included	The coders found in the article relevant information on determinants of circular business model adoption	"One of the criticisms of circular economy is lack of scaling up, however; technology could be an enabler for scaling circular business model" (p. 2)
Barrier analysis for product service system using interpretive structural model	Kuo, TC; Ma, HY; Huang, SH; Hu, AH; Huang, CS	International Journal of Advanced Manufacturing Technology	2010	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Barriers to circular business model innovation: A multiple-case study	Guldmann, E; Huulgaard, RD	Journal of Cleaner Production	2020	Included	The coders found in the article relevant information on determinants of circular business model adoption	"The article presents a multiple-case study of the circular business model innovation process in 12 Danish companies that includes a cross-case analysis across start-ups and incumbents and across different company sizes, industries and customer segments. The article furthermore compares the barriers derived from this empirical work to barriers found in the sustainable innovation literature" (p. 1)
Barriers to the circular economy: evidence from the European Union (EU)	Kirchherr, J; Piscicelli, RB; Kostense-Smit, E; Muller, J; Huibrechtse-Truijens, A; Hekkert, M	Ecological Economics	2018	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Building a circular plastics economy with informal waste pickers: Recyclate	Gall, M; Wiener, M;	Resources Conservation and Recycling	2020	Excluded	The coders did not find in the article any relevant information	Not available

quality, business model, and societal impacts	de Oliveira, CC; Lang, RW; Hansen, EG				on determinants of circular business model adoption	
Business model development for sustainable apparel consumption The case of Houdini Sportswear	Holtstrom, J; Bjellerup, C; Eriksson, J	Journal of Strategy and Management	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Business model experimentation for circularity: Driving sustainability in a large international clothing retailer	Bocken, NMP; Miller, K; Weissbrod, I; Holgado, M; Evans, S	Economics and Policy of Energy and the Environment	2017	Included	The coders found in the article relevant information on determinants of circular business model adoption	"This study provides insights into how to conduct lean startup type business model experimentation for circularity in a large organisation. For practitioners, the benefits of academic-industry collaboration, and the oscillating dynamics of business model experimentation are illuminated." (p. 1)
Business Model in Circular Economy	Ionescu, CA; Coman, MD; Lixandru, M; Groza, D	Valahian Journal of Economic Studies	2017	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Business model innovation for circular economy and sustainability: A review of approaches	Pieroni, MPP; McAloone, TC; Pigosso, DCA	Journal of Cleaner Production	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Business Model Innovation for Resource-efficiency, Circularity and Cleaner Production: What 143 Cases Tell Us	Lopez, FJD; Bastein, T; Tukker, A	Ecological Economics	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Business model innovation for sustainability: An investigation of consumers' willingness to adopt product-service systems	Sattari, S; Wessman, A; Borders, L	Journal of Global Scholars of Marketing Science	2020	Included	The coders found in the article relevant information on determinants of circular business model adoption	"Previous literature argues that there is an insufficientamount of information regardingthe consumer's (demand side) role in successful implementation of a Circular BusinessModel (CBM) as a tool for increasing sustainable consumption. Therefore, this

						studycontributes tofilling this gap and adds to the understanding of CBM from consumers'perspective. Furthermore, the purpose here was to gather more insight about the possibledeterminants of consumers'willingness to adopt PSS as an approach to implementinga CBM towards achieving sustainable development goals" (p. 286)
Business Model Innovation in a Circular Economy Reasons for Non-Acceptance of Circular Business Models	Planing, P	Open Journal of Business Model Innovation	2015	Included	The coders found in the article relevant information on determinants of circular business model adoption	"Table 4 shows the summary of reasons for non-acceptance of circular economy business models." (p. 7)
Business model innovation through second hand retailing	Hvass, KK	The Journal of Corporate Citizenship	2015	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Business Model Innovation to Create and Capture Resource Value in Future Circular Material Chains	Roos, G	Resources	2014	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Business models and supply chains for the circular economy	Geissdoerfer, M; Morioka, SN; De Carvalho, MM; Evans, S	Journal of Cleaner Production	2018	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Business models and supply chains for the circular economy	Geissdoerfer, M; Morioka, SN; De Carvalho, MM; Evans, S	Journal of Cleaner Production	2018	Included	The coders found in the article relevant information on determinants of circular business model adoption	"Empirical evidence from performance case studies reinforces the crucial role of network infrastructure and capabilities to enable CBM operations" (p. 17)

Business models and sustainable plastic management: A systematic review of the literature	Dijkstra, H; van Beukering, P; Brouwer, R	Journal of Cleaner Production	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Business Models for Circular Economy and Sustainable Development: The Case of Lease Transactions	Ionascu, I; Ionascu, M	Amfiteatru Economic	2018	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Business models for industrial symbiosis: A guide for firms	Fraccascia, L; Magno, M; Albino, V	Procedia Environmental Science, Engineering and Management	2016	Included	The coders found in the article relevant information on determinants of circular business model adoption	"Firms without any prior experience of IS exchanges suffer from lack of awareness about how to integrate the IS practice into their current business models and how to gain economic benefits from IS. Since the willingness to obtain economic benefits is the main driver pushing firms to implement the IS practice, this issue constitutes an important barrier to the development of new IS relationships" (p. 83)
Business models for industrial symbiosis: A taxonomy focused on the form of governance	Fraccascia, L; Giannoccaro, I; Albino, V	Resources Conservation and Recycling	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Business models for sustainable consumption in the circular economy: An expert study	Tunn, VSC; Bocken, NMP; van den Hende, EA; Schoormans, JPL	Journal of Cleaner Production	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Business models for the circular economy: Opportunities and challenges	Fraccascia, L; Giannoccaro, I; Agarwal, A; Hansen, EG	Business Strategy and the Environment	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available

Business Models in Circular Economy Concept	Rudnicka, A	Research Papers of the Wroclaw University of Economics	2018	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Challenges in supply chain redesign for the Circular Economy: A literature review and a multiple case study	Bressanelli, G; Perona, M; Saccani, N	International Journal of Production Research	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Challenges of the Introduction of Circular Business Models within Rural SMEs of EU	Uvarova, I; Atstaja, D; Korpa, V	International Journal of Economic Sciences	2020	Included	The coders found in the article relevant information on determinants of circular business model adoption	"This study has a policy implication as we suggest that the government should play an important role in promotion of circular business models in rural SMEs." (p. 128)
Changing the economic paradigm: Towards a sustainable business model	Guinot, J	International Journal of Sustainable Development and Planning	2020	Included	The coders found in the article relevant information on determinants of circular business model adoption	"In this work, first I present a description about the environmental challenges we are facing and the relationship with the current economic model; second, the need for a transition to a sustainable economic model based on common welfare; third, the change towards a sustainable organizational paradigm; and finally, a case of sustainable business such is Patagonia Inc" (p. 603)
Circular building materials: Carbon saving potential and the role of business model innovation and public policy	Nussholz, JLK; Rasmussen, FN; Milios, L	Resources Conservation and Recycling	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Circular Business Model Challenges and Lessons Learned- An Industrial Perspective	Oghazi, P; Mostaghel, R	Sustainability	2018	Included	The coders found in the article relevant information on determinants of circular business model adoption	"In order to identify the challenges of CBM transition, two major steps were taken. First, an extensive literature review was done to identify the barriers to CBM transition." (p. 6)
Circular business model implementation: Design choices, orchestration strategies, and transition	Palmié, M; Boehm, J; Lekkas, CK; Parida, V;	Journal of Cleaner Production	2021	Included	The coders found in the article relevant information on determinants of circular business model adoption	"The article also identifies transition pathways that enable firms to move between different implementation strategies in order to increase economic and environmental

pathways for resource-sharing solutions	Wincent, J; Gassmann, O					gains. The present article can serve as a stimulus for further detailed analyses of other CBMs that are important to a CE in the future" (p. 2)
Circular Business Model Innovation: Inherent Uncertainties	Linder, M; Williander, M	Business Strategy and the Environment	2017	Included	The coders found in the article relevant information on determinants of circular business model adoption	"Further, these barriers have never been analysed in the context of system-atic customer development for CBM (as described in the previous section). We address this through a case study in the next section." (p. 186)
Circular Business Model Transformation: A Roadmap for Incumbent Firms	Frishammar, J; Parida, V	California Management Review	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Circular Business Models for Extended EV Battery Life	Olsson, L; Fallahi, S; Schnurr, M; Diener, D; van Loon, P	Batteries	2018	Included	The coders found in the article relevant information on determinants of circular business model adoption	"In a workshop discussion with representatives from OEMs, recycling industry and the research community, legislation and responsibility were discussed as main issues to be clarified to stimulate more circular business models" (p. 8)
Circular business models for sustainable development: A waste is food restorative ecosystem	Zucchella, A; Previtali, P	Business Strategy and the Environment	2019	Included	The coders found in the article relevant information on determinants of circular business model adoption	"The abductive approach used led to the formulation of some research propositions and to the identification of some adoption factors and barriers to growth in circular business models." (p. 274)
Circular Business Models for the Bio-Economy: A Review and New Directions for Future Research	Reim, W; Parida, V; Sjodin, DR	Sustainability	2019	Included	The coders found in the article relevant information on determinants of circular business model adoption	"In addition, we develop a framework that describes the barriers to bio-economy-based circular business models..." (p. 1)
Circular business models generation for automobile remanufacturing industry in China Barriers and opportunities	Shao, J; Huang, S; Lemus-Aguilar, I; Unal, E	Journal of Manufacturing Technology Management	2020	Included	The coders found in the article relevant information on determinants of circular business model adoption	"This study contributes to the CBM literature by mapping the barriers and opportunities in remanufacturing. The results have shed some light into the field of sustainability in manufacturing firms by empirically testing the theoretical model. The results will help

						managers to design viable CBMs in different contexts." (p. 542)
Circular business models in biological cycles: The case of an Italian spin-off	De Angelis, R; Feola, R	Journal of Cleaner Production	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Circular Business Models in Textiles and Apparel Sector in Slovakia	Dano, F; Drabik, P; Hanulakova, E	Central European Business Review	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Circular business models in the European manufacturing industry: A multiple case study analysis	Urbinati, A; Rosa, P; Sassanelli, C; Chiaroni, D; Terzi, S	Journal of Cleaner Production	2020	Included	The coders found in the article relevant information on determinants of circular business model adoption	"In addition, the paper argues about the role of a peculiar external environmental condition, that of environmental regulation, in influencing how companies implement the managerial practices for a circular business model" (p. 2)
Circular business models in the medical device industry: paths towards sustainable healthcare	Guzzo, D; Carvalho, MM; Balkenende, R; Mascarenhas, J	Resources Conservation and Recycling	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Circular business models: Business approach as driver or obstructer of sustainability transitions?	Hofmann, F	Journal of Cleaner Production	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Circular business models: Current aspects that influence implementation and unaddressed subjects	Salvador, R; Barros, MV; da Luz, LM; Piekarski, CM; de Francisco, AC	Journal of Cleaner Production	2020	Included	The coders found in the article relevant information on determinants of circular business model adoption	"Therefore, this paper's aim is threefold: (i) identify researchers, topics of highlight and journals housing research on Circular Business Models worldwide, (ii) identify the main aspects that influence Circular Business Model implementation, and (iii) point the unaddressed subjects in the existing literature on Circular Business Models" (p. 1)

Circular Business Models: Defining a Concept and Framing an Emerging Research Field	Nussholz, JLK	Sustainability	2017	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Circular business models: level of maturity	Sehnem, S; Campos, LMS; Julkovski, DJ; Cazella, CF	Management Decision	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Circular business models: towards creation and capture of lasting value? Lessons from automotive recycling and reuse	Beulque, R; Aggeri, F; Abraham, F; Morel, S	Finance Contrôle Stratégie	2018	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Circular economy and paradox theory: A business model perspective	De Angelis, R	Journal of Cleaner Production	2021	Included	The coders found in the article relevant information on determinants of circular business model adoption	"Yet, the uptake of circular principles within the business community is rather slow (Babbit et al., 2018; Fehrer and Wieland, 2020; Parida et al., 2019). A reasonable conjecture about the reasons why this is the case is that such a transition is confronted with many practical challenges (e.g., regulatory, technological, cultural, market and organisational) (Kirchherr et al., 2018; Tura et al., 2019). These are described as 'soft' and 'hard' barriers (de Jesus and Mendonça, 2018)." (p. 1)
Circular economy business model design	Nasution, AH; Aula, M; Ardiantono, DS	International Journal of Integrated Supply Management	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Circular economy business model innovation: Sectorial patterns within manufacturing companies	Pieroni, MPP; McAloone, TC; Pigosso, DCA	Journal of Cleaner Production	2021	Included	The coders found in the article relevant information on determinants of circular business model adoption	"For example, only one out 182 patterns reported in Remane et al. (2017) is directly related to resource effectiveness or efficiency practices that could contribute to CEBM innovation. Specific patterns developed for

						sustainability-related issues have recently emerged." (p. 4)
Circular economy business models in developing economies: Lessons from India on reduce, recycle, and reuse paradigms	Goyal, S; Esposito, M; Kapoor, A	Thunderbird International Business Review	2018	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Circular Economy Business Models with a Focus on Servitization	Han, J; Heshmati, A; Rashidghalam, M	Sustainability	2020	Included	The coders found in the article relevant information on determinants of circular business model adoption	"One of the critical barriers to a transition to BMCEs is related to final consumers" (p. 9) (BMCEs = Business Models for Circular Economy)
Circular Economy Business Models: A Critical Examination	Whalen, CJ; Whalen, KA	Journal of Economic Issues	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Circular economy business models: The state of research and avenues ahead	Ferasso, M; Beliaeva, T; Kraus, S; Clauss, T; Ribeiro-Soriano, D	Business Strategy and the Environment	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Circular economy indicators for organizations considering sustainability and business models: Plastic, textile and electro-electronic cases	Rossi, E; Bertassini, AC; Ferreira, CD; do Amaral, WAN; Ometto, AR	Journal of Cleaner Production	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Circular entrepreneurship: A business model perspective	Cullen, UA; De Angelis, R	Resources, Conservation and Recycling	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Circular products and business models and environmental impact reductions: Current	van Loon, P; Diener, D; Harris, S	Journal of Cleaner Production	2021	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available

knowledge and knowledge gaps						
Collaboration as an enabler for circular economy: A case study of a developing country	Mishra, JL; Chiwenga, KD; Ali, K	Management Decision	2019	Included	The coders found in the article relevant information on determinants of circular business model adoption	"For developing countries where people are working with limited resources, co-development and investment in technology could enhance capability of companies towards CEBM transition" (p. 17)
Combined analyses of costs, market value and eco-costs in circular business models: eco-efficient value creation in remanufacturing	Vogtlander, JG; Scheepens, AE; Bocken, NMP; Peck, D	Journal of Remanufacturing	2017	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Configuring New Business Models for Circular Economy through Product-Service Systems	Pieroni, MPP; McAloone, TC; Pigosso, DCA	Sustainability	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Consumer acceptance of circular business models	Elzinga, R; Reike, D; Negro, SO; Boon, WPC	Journal of Cleaner Production	2020	Included	The coders found in the article relevant information on determinants of circular business model adoption	"The present study aimed to enrich the existing research on CBM consumer acceptance which lacks generalisable quantitative insights on preferential CBM design. Based on the current quantitative research design, generalised patterns can be detected which are valid across CBMs in the electronic sector and help to analyse diffusion and adoption of CBMs in various industries. Finally, this study made the first attempt to map the consumers perspective towards Circular Business Models and identify the consumers beliefs associated with the practicalities accompanying a Circular Economy." (p. 10)

Consumers are willing to participate in circular business models: A practice theory perspective to food provisioning	Borrello, M; Pascucci, S; Caracciolo, F; Lombardi, A; Cembalo, L	Journal of Cleaner Production	2020	Included	The coders found in the article relevant information on determinants of circular business model adoption	"Current analysis tackles two main research questions: (a) would consumers be willing to participate in a CBM based on novel food provisioning practices? and (b) what would be the drivers shaping their participation?" (p. 2)
Creating value in the circular economy: A structured multiple-case analysis of business models	Ranta, V; Aarikka-Stenroos, L; Makinen, SJ	Journal of Cleaner Production	2018	Included	The coders found in the article relevant information on determinants of circular business model adoption	"Through linking case analysis to previous literature, we developed five propositions for conducting circular business: 1) the cost efficiency of circular operations is the key proponent to successful CE business, 2) take-back services enable the acquisition of particular wastes as resources, but they need to be incentivized through re-ductions in customers' total waste management costs, 3) circular business models require the focal firm to separately manage multiple positions in the value chain" (p. 998)
Critical success and risk factors for circular business models valorising agricultural waste and by-products	Donner, M; Verniquet, A; Broeze, J; Kayser, K; De Vries, H	Resources Conservation and Recycling	2021	Included	The coders found in the article relevant information on determinants of circular business model adoption	"The aim of this article is to understand critical success and risk factors of eco-innovative business models that contribute to a circular economy via agricultural unavoidable waste or by-products valorisation." (p. 1)
Designing the business models for circular economy: Towards the conceptual framework	Lewandowski, M	Sustainability	2016	Included	The coders found in the article relevant information on determinants of circular business model adoption	"Additionally, the triple fit challenge has been recognized as an enabler of the transition towards a circular business model" Page 1
Developing and implementing circular economy business models in service-oriented technology companies	Heyes, G; Sharmina, M; Mendoza, JMF; Gallego-Schmid, A; Azapagic, A	Journal of Cleaner Production	2018	Included	The coders found in the article relevant information on determinants of circular business model adoption	"Table 1: Barriers and drivers to circular economy implementation identified by the participants (BECE step 2)" (p. 626)

Digital technologies catalyzing business model innovation for circular economy - Multiple case study	Ranta, V; Aarikka-Stenroos, L; Vaisanen, JM	Resources Conservation and Recycling	2021	Included	The coders found in the article relevant information on determinants of circular business model adoption	" ...3) what opportunities and barriers emerged when digital solutions were implemented for CE in the company's business process, on both a company- and larger-system level" (p. 6)
Do circular economy business models capture intended environmental value propositions?	Manninen, K; Koskela, S; Antikainen, R; Bocken, N; Dahlbo, H; Aminoff, A	Journal of Cleaner Production	2018	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Eco-Holonic 4.0 Circular Business Model to Conceptualize Sustainable Value Chain towards Digital Transition	Avila-Gutierrez, MJ; Martin-Gomez, A; Aguayo-Gonzalez, F; Lama-Ruiz, JR	Sustainability	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Eco-innovation and Circular Business Models as drivers for a circular economy	Vence, X; Pereira, Á	Contaduria y Administracion	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Embracing the variety of sustainable business models: A prolific field of research and a future research agenda	Dentchev, N; Rauter, R; Johannsdottir, L; Snihur, Y; Rosano, M; Baumgartner, R; Nyberg, T; Tang, XF; van Hoof, B;	Journal of Cleaner Production	2018	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available

	Jonker, J					
Emerging drivers and business models for equipment reuse and remanufacturing in the US: lessons from the biotech industry	Veleva, V; Bodkin, G	Journal of Environmental Planning and Management	2018	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Entrepreneurial Drivers for the Development of the Circular Business Model: The Role of Academic Spin-Off	Poponi, S; Arcese, G; Mosconi, EM; di Trifiletti, MA	Sustainability	2020	Included	The coders found in the article relevant information on determinants of circular business model adoption	"The aim of the paper is to investigate how spin off enterprises can be a driver for the development of a Circular Business Model..." (p. 1)
Evaluating the Environmental Performance of a Product/Service-System Business Model for Merino Wool Next-to-Skin Garments: The Case of Armadillo Merinox (R)	Bech, NM; Birkved, M; Charnley, F; Kjaer, LL; Pigosso, DCA; Hauschild, MZ; McAloone, TC; Moreno, M	Sustainability	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Experimenting with a circular business model: Lessons from eight cases	Bocken, NMP; Schuit, CSC; Kraaijenhagen, C	Environmental Innovation and Societal Transitions	2018	Included	The coders found in the article relevant information on determinants of circular business model adoption	"A circular business experimentation framework was developed and applied." (p. 79)
Exploring barriers to implementing different circular business models	Vermunt, DA; Negro, SO; Verweij, PA; Kuppens, DV; Hekkert, MP	Journal of Cleaner Production	2019	Included	The coders found in the article relevant information on determinants of circular business model adoption	"In this study, barriers in various CBMs were explored, to understand whether they differ for different CBMs and, if so, how. Our findings illustrate that barriers do indeed differ for the four CBMs studied." (p. 899)

Exploring garment rental as a sustainable business model in the fashion industry: Does contamination impact the consumption experience?	Clube, RKM; Tennant, M	Journal of Consumer Behaviour	2020	Included	The coders found in the article relevant information on determinants of circular business model adoption	"These psychological biases are riddled withcontradiction (Rozin & Fallon, 1987) yet result in avoidance behav-iours, presenting a barrier to circular business models." (p. 362)
Exploring How Usage-Focused Business Models Enable Circular Economy through Digital Technologies	Bressanelli, G; Adrodegari, F; Perona, M; Saccani, N	Sustainability	2018	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Exploring Industry 4.0 technologies to enable circular economy practices in a manufacturing context A business model proposal	Nascimento, DLM; Alencastro, V; Quelhas, OLG; Caiado, RGG; Garza-Reyes, JA; Lona, LR; Tortorella, G	Journal of Manufacturing Technology Management	2019	Included	The coders found in the article relevant information on determinants of circular business model adoption	"Some of the findings from the FGIs revealed that the challenges to implementing circular business models are that circularly manufactured products are expensive to build due to the high intensity of work" (p. 622)
Exploring Local Business Model Development for Regional Circular Textile Transition in France	Real, M; Lizarralde, I; Tyl, B	Fashion Practice - The Journal of Design Creative Process & the Fashion Industry	2020	Included	The coders found in the article relevant information on determinants of circular business model adoption	"The study defends the active role of social entrepreneurs in supporting circular transitions into regions and highlights the strong diversity of challenges they faced during the design of local business models, both at a technological, social and policy level." (p. 6)
Exploring Paradoxical Tensions in Circular Business Models-Cases from North Europe	Morales, AH	Sustainability	2020	Included	The coders found in the article relevant information on determinants of circular business model adoption	"The interview transcripts contained a detailed account of the CBMs, including main activities, interactions with consumers and suppliers and in particular, benefits and

						barriers related to the specific circular aspects of their business model."(p. 9)
Fintech and SMEs sustainable business models: Reflections and considerations for a circular economy	Pizzi, S; Corbo, L; Caputo, A	Journal of Cleaner Production	2021	Included	The coders found in the article relevant information on determinants of circular business model adoption	"The findings of the qualitative analysis suggest that Fintech, an example of sectors developed under the influence of Industry 4.0, can play a relevant role in the transition of SMEs toward a more sustainable business model leading to better integration of circular economy practices." (p. 1)
FlexZhouse: New business model for affordable housing in Malaysia	Bin Mohd Noor, MZ	A+BE Architecture and the Built Environment	2017	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Food sharing: Making sense between new business models and responsible social initiatives for food waste prevention	Sarti, S; Corsini, F; Gusmerotti, NM; Frey, M	Economics and Policy of Energy and the Environment	2017	Included	The coders found in the article relevant information on determinants of circular business model adoption	"Despite the positive social and environmental impact, these initiatives have to face some criticisms due to the lack of a dominant player and the high fragmentation of users among the existing platforms." (p. 1)
From flow to stock - New circular business models for integrated systems: A case study on reusable plastic cups	Cottafava, D; Riccardo, LE; D'Affuso, C	Procedia Environmental Science, Engineering and Management	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
From singular to plural: exploring organisational complexities and circular business model design	Pedersen, ERG; Earley, R; Andersen, KR	Journal of Fashion Marketing and Management	2019	Included	The coders found in the article relevant information on determinants of circular business model adoption	"Findings: The analysis highlights multiple challenges emerging when a fashion product with a significantly extended lifecycle passes through different users, organisations, and business models. It is concluded that it is difficult to talk about a circular business model (singular) as circular economy solutions depend on the contributions of multiple stakeholders with business models." (P. 1)

From theory to practice: systematising and testing business model archetypes for circular economy	Pieroni, MPP; McAloone, TC; Pigosso, DCA	Resources Conservation and Recycling	2020	Included	The coders found in the article relevant information on determinants of circular business model adoption	"In particular, a hesitant organisational culture and limited awareness, information, and in-house competencies are considered core barriers for the implementation of CEBMs by companies " (p. 2)
Going in circles: new business models for efficiency and value	Lopes de Sousa Jabbour, AB	Journal of Business Strategy	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Homo Sustentabilis: circular economy and new business models in fashion industry	Marques, AD; Marques, A; Ferreira, F	SN Applied Sciences	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
How does business model redesign foster resilience in emerging circular value chains?	Carraresi, L; Bröring, S	Journal of Cleaner Production	2021	Included	The coders found in the article relevant information on determinants of circular business model adoption	"Furthermore, to overcome the uncertainty revealed by our interviewees to adopt the new technology of phosphorus recovery, BMI could even be implemented step-wise (Laudien and Daxbock, 2016; Tunn et al., 2019). Indeed, incumbent companies could run parallel the circular business models together with the current linear one - developing ambidexterity capacity on the business model level (O'Reilly and Tushman 2013)." (p. 11)
Implementation of a circular economy-based business model for landfill management companies	Cudecka-Purina, N; Atstaja, D	Journal of Business Management	2018	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Implementation of Circular Economy Business Models by Small and Medium-Sized Enterprises (SMEs): Barriers and Enablers	Rizos, V; Behrens, A; van der Gaast, W; Hofman, E; Ioannou, A; Kafyeke, T; Flamos, A;	Sustainability	2016	Included	The coders found in the article relevant information on determinants of circular business model adoption	"The aim of this paper is to increase knowledge and understanding about the barriers and enablers experienced by SMEs when implementing circular economy business models" (p. 1)

	Rinaldi, R; Papadelis, S; Hirschnitz-Garbers, M; Topi, C					
Improving Circular Economy Business Models: Opportunities for Business and Innovation A new framework for businesses to create a truly circular economy	Chen, CW	Johnson Matthey Technology Review	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Innovative and sustainable business models in the fashion industry: Entrepreneurial drivers, opportunities, and challenges	Todeschini, BV; Cortimiglia, MN; Callegaro-de-Menezes, D; Ghezzi, A	Business Horizons	2017	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Insect Farming for Feed and Food Production from a Circular Business Model Perspective	Madau, FA; Arru, B; Furesi, R; Pulina, P	Sustainability	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Insects for sustainable animal feed: inclusive business models involving smallholder farmers	Chia, SY; Tanga, CM; van Loon, JJA; Dicke, M	Current Opinon in Environmental Sustainability	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Integrated thinking and reporting towards sustainable business models: a concise bibliometric analysis	Di Vaio, A; Syriopoulos, T; Alvino, F; Palladino, R	Meditari Accountancy Research	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Integrating a business model perspective into	Sarasini, S; Linder, M	Environmental Innovation	2018	Excluded	The coders did not find in the article any relevant information	Not available

transition theory: The example of new mobility services		and Societal Transisions			on determinants of circular business model adoption	
Integrating circular business models and development tools in the circular economy transition process: A firm-level framework	Chen, LH; Hung, PY; Ma, HW	Business Strategy and the Environment	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Investigating circular business models in the manufacturing and service sectors	Upadhyay, A; Akter, S; Adams, L; Kumar, V; Varma, N	Journal of Manufacturing Technology Management	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Investigating the Current Business Model Innovation Trends in the Biotechnology Industry	Horvath, B; Khazami, N; Ymeri, P; Fogarassy, C	Journal of Business Economics and Management	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Key aspects for designing business models for a circular bioeconomy	Salvador, R; Puglieri, FN; Halog, A; de Andrade, FG; Piekarski, CM; De Francisco, AC	Journal of Cleaner Production	2021	Included	The coders found in the article relevant information on determinants of circular business model adoption	"While analyzing and synthesizing the existing literature, a few takeaway lessons could be derived from this review, comprising issues that could potentially act as either key drivers or hampering factors for a CBE." (p. 10) (CBE = Circular Bioeconomy)
Learning from Failure and Success: The Challenges for Circular Economy Implementation in SMEs in an Emerging Economy	Cantu, A; Aguinaga, E; Scheel, C	Sustainability	2021	Included	The coders found in the article relevant information on determinants of circular business model adoption	"The study found that CE implementing barriers can be further exacerbated by the business model's lack of fit with its operational context." (p. 28)

Life cycle assessment of innovative circular business models for modern cloth diapers	Hoffmann, BS; Morais, JD; Teodoro, PF	Journal of Cleaner Production	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Management control in circular economy. Exploring and theorizing the adaptation of management control to circular business models	Svensson, N; Funck, EK	Journal of Cleaner Production	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Managerial practices for designing circular economy business models The case of an Italian SME in the office supply industry	Unal, E; Urbinati, A; Chiaroni, D	Journal of Manufacturing Technology Management	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Managing a Complex Global Circular Economy Business Model: Opportunities and Challenges	Hopkinson, P; Zils, M; Hawkins, P; Roper, S	California Management Review	2018	Included	The coders found in the article relevant information on determinants of circular business model adoption	"This article presents an in-depth case study detailing the history, experiences, and wider practitioner and policy lessons from a circular economy business model over a 30-year period, highlighting the successes, difficulties, and conflicts of adopting a circular economy model." (p. 71)
Managing business model innovation for relocalization in the process and manufacturing industry.	Geissdoerfer, M; Weerdmeester, R	Journal of Business Chemistry	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Material reuse in buildings: Implications of a circular business model for sustainable value creation	Nussholz, JLK; Rasmussen, FN; Whalen, K; Plepys, A	Journal of Cleaner Production	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Modelling environmental value: an examination of sustainable business	Pal, R; Gander, J	Journal of Cleaner Production	2018	Excluded	The coders did not find in the article any relevant information	Not available

models within the fashion industry					on determinants of circular business model adoption	
Modelling the Interplay Between Institutions and Circular Economy Business Models: A Case Study of Battery Recycling in Finland and Chile	Levanen, J; Lyytinen, T; Gatica, S	Ecological Economics	2018	Included	The coders found in the article relevant information on determinants of circular business model adoption	"Developed framework combines business model conceptualization with institutional theorization to understand how institutions in- fluence on business conduct. Business model concept is used to describe organizational activities and managerial cognition in a structured manner and institutional theory is used to identify features that may facilitate or hamper particular activities in a particular operational environment. Countries' institutional environments related to the advancement of circular economy differ from each other and therefore comparison between the situations provides an interesting context to study the dynamics between companies' business models and the institutional features." (p. 373)
New business models for a radical change in resource efficiency	Schulte, UG	Environmental Innovation and Societal Transitions	2013	Included	The coders found in the article relevant information on determinants of circular business model adoption	"Beginning with an analysis of the business constraints imposed by increasingly scarce resources, in this paper I make the case for a ‘circular economy’. The principles of this approach are outlined, as is the need for new business models. I also discuss incentives to stimulate enterprises to enter the circular economy." (p. 43)
Open principles in new business models for information systems	Müller, M; Vorraber, W; Slany, W	Journal of Open Innovation: Technology, Market, and Complexity	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available

Opportunities and challenges in IoT-enabled circular business model implementation - A case study	Ingemarsdotter, E; Jamsin, E; Balkenende, R	Resources Conservation and Recycling	2020	Included	The coders found in the article relevant information on determinants of circular business model adoption	"By elucidating these challenges, this paper contributes with IoT-specific insights to the available literature about challenges in circular business model implementation." (p. 1)
Organizational transition management of circular business model innovations	Hofmann, F; Jaeger-Erben, M	Business Strategy and the Environment	2020	Included	The coders found in the article relevant information on determinants of circular business model adoption	"Building on this, the article provides a set of propositions on how an organizational transitionmanagement may be configured and what incumbents require to successfully navi-gate circular business model innovation" (p. 2770)
Over the hill? Exploring the other side of the Rogers' innovation diffusion model from a consumer and business model perspective	Wells, P; Nieuwenhuis, P	Journal of Cleaner Production	2018	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Overcoming the Main Barriers of Circular Economy Implementation through a New Visualization Tool for Circular Business Models	Bianchini, A; Rossi, J; Pellegrini, M	Sustainability	2019	Included	The coders found in the article relevant information on determinants of circular business model adoption	"The main existing barriers to CE model adoption can be divided in different categories, as shown in Table 1 [23–26]." (p. 2)
Pay-per-use business models as a driver for sustainable consumption: Evidence from the case of HOMIE	Bocken, NMP; Mugge, R; Bom, CA; Lemstra, HJ	Journal of Cleaner Production	2018	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Product design and business model strategies for a circular economy	Bocken, NMP; de Pauw, I; Bakker, C; van der Grinten, B	Journal of Industrial and Production Engineering	2016	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Product-service systems business models for circular supply chains	Yang, M; Smart, P; Kumar, M;	Production Planning and Control	2018	Excluded	The coders did not find in the article any relevant information	Not available

	Jolly, M; Evans, S				on determinants of circular business model adoption	
Product–service systems for office furniture: barriers and opportunities on the European market	Besch, K	Journal of Cleaner Production	2005	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
PSS Strategic Alignment: Linking Service Transition Strategy with PSS Business Model	Sholihah, M; Maezono, T; Mitake, Y; Shimomura, Y	Sustainability	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Reducing e-waste in China's mobile electronics industry: the application of the innovative circular business models	Marke, A; Chan, C; Taskin, G; Hacking, T	Asian Education and Development Studies	2020	Included	The coders found in the article relevant information on determinants of circular business model adoption	"The objectives of this research are to (1) fill the evidence gap of circular business activities and (2) enrich the knowledge base about the drivers of and barriers to circular economy business model (CEBM) that supports e-waste reduction in China's mobile electronics industry." (p. 591)
Remanufacturing with upgrade PSS for new sustainable business models	Copani, G; Behnam, S	Journal of Manufacturing Science and Technology	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Rethinking the fashion collection as a design strategic tool in a circular economy	Ræbild, U; Bang, AL	The Design Journal: An International Journal for All Aspects of Design	2017	Included	The coders found in the article relevant information on determinants of circular business model adoption	"This study investigates how the collection, as a particular design framework, might be reconfigured as a strategic driver for garment longevity furthering sustainable fashion design. The paper is based on a case study of Vigga, a Danish company that has adopted a circular business model, offering a subscription service for eco-certified baby clothing. Due to the limited data (single case) and the highly segmented field (children's garments) we propose to view the outcome of this investigation as indicative – pointing to potentials" (p. 5590)

Sharing for a circular economy? an analysis of digital sharing platforms' principles and business models	Schwanholz, J; Leipold, S	Journal of Cleaner Production	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Spreading Sustainability Innovation through the Co-Evolution of Sustainable Business Models and Partnerships	Cantele, S; Moggi, S; Campedelli, B	Sustainability	2020	Included	The coders found in the article relevant information on determinants of circular business model adoption	"The first section provides the theoretical backgrounds of the three core concepts, presented in two subsections on issues regarding sustainable and innovative BMs, and collaborations and partnerships and their main features and drivers." (p. 1)
Stakeholders, innovative business models for the circular economy and sustainable performance of firms in an emerging economy facing institutional voids	Jabbour, CJC; Seuring, S; Jabbour, ABLD; Jugend, D; Fiorini, PD; Latan, H; Izeppi, WC	Journal of Environmental Management	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Strategic Decisions Related to Circular Business Model in a Forerunner Company: Challenges Due to Path Dependency and Lock-In	Lehtimäki, H; Piispanen, VV; Henttonen, K	South Asian Journal of Business and Management Cases	2020	Included	The coders found in the article relevant information on determinants of circular business model adoption	"This study sheds light on the ways by which path dependency and lock-in contribute to CBM innovation and can explain a CE strategy failure." (p. 402)
Supply chains in circular business models: processes and performance objectives	Vegter, D; van Hillegersberg, J; Olthaar, M	Resources Conservation and Recycling	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Sustainable business model innovation: A review	Geissdoerfer, M; Vladimirova, D; Evans, S	Journal of Cleaner Production	2018	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available

Sustainable business model: A review and framework development	Goni, FA; Chofreh, AG; Orakani, ZE; Klemes, JJ; Davoudi, M; Mardani, A	Clean Technologies and Environmental Policy	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Sustainable business modeling of circular agriculture production: Case study of circular bioeconomy	Ryabchenko, O; Golub, G; Turčeková, N; Adamičková, I; Zapototskyi, S	Journal of Security and Sustainability Issues	2017	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Sustainable Business Models: A Review	Nosratabadi, S; Mosavi, A; Shamshirband, S; Zavadskas, EK; Rakotonirainy, A; Chau, KW	Sustainability	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Sustainable Production in a Circular Economy: A Business Model for Re-Distributed Manufacturing	Turner, C; Moreno, M; Mondini, L; Salonitis, K; Charnley, F; Tiwari, A; Hutabarat, W	Sustainability	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Systemic circular business model application at the company, supply chain and society levels-A view into	Rovanto, IK; Bask, A	Business Strategy and the Environment	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available

circular economy native and adopter companies						
The application of chemical leasing business models in Mexico	Schwager, P; Moser, F	Environmental Science and Pollution Research	2006	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
The circular economy business model: Examining consumers' acceptance of recycled goods	Calvo-Porral, C; Levy-Mangin, JP	Administrative Sciences	2020	Included	The coders found in the article relevant information on determinants of circular business model adoption	"The lack of consumer interest and awareness is one of the major barriers in the transition from linear business models to circular business strategies (Kirchherr et al. 2018)." (p. 4)
The competitiveness of firms through the sustainable business model: A decade of research	Di Tullio, P; Valentinetti, D; Rea, MA	Industria	2018	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
The Ecocanvas as a business model canvas for a circular economy	Daou, A; Mallat, C; Chammas, G; Cerantola, N; Kayed, S; Saliba, NA	Journal of Cleaner Production	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
The industrial symbiosis approach: A classification of business models	Albino, V; Fraccascia, L	Procedia Environmental Science, Engineering and Management	2015	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
The Role of Product Design in Creating Circular Business Models: A Case Study on the Lease and Refurbishment of Baby Strollers	Sumter, D; Bakker, C; Balkenende, R	Sustainability	2018	Included	The coders found in the article relevant information on determinants of circular business model adoption	"In the transition to a circular economy companies are exploring new business models, implying a shift from selling products to offering products in circular business models, such as leasing. Product design is

						thought to play a crucial role in enabling this." (p. 1)
The use of decision support tools to accelerate the development of circular economic business models for hard disk drives and rare-earth magnets	Frost, K; Jin, HY; Olson, W; Schaffer, M; Spencer, G; Handwerker, C	Materials Research Society - Energy & Sustainability	2020	Included	The coders found in the article relevant information on determinants of circular business model adoption	"A case study of hard disk drives (HDDs) and rare-earth magnets is presented to show the use of decision support tools to identify and assess the barriers and opportunities for circular business models. " (p. 1)
Three circular business models that extend product value and their contribution to resource efficiency	Whalen, KA	Journal of Cleaner Production	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Toward circular economy implementation: a comprehensive review in the context of manufacturing industry	Lieder, M; Rashid, A	Journal of Cleaner Production	2016	Included	The coders found in the article relevant information on determinants of circular business model adoption	"Secondly, closed-loop supply chains must adequately reflect CE business operations. This includes operations such as assembly, forward transport, and customer use phase as well as reverse transport in order to account for quality, quantity, and timing of product returns which are considered as one of the critical barriers of CE implementation [29]." (p. 1958)
Towards a circular economy – How business model innovation will help to make the shift	Planing, P	International Journal of Business and Globalisation	2018	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Towards a more Circular Economy: Proposing a framework linking sustainable public procurement and sustainable business models	Witjes, S; Lozano, R	Resources Conservation and Recycling	2016	Included	The coders found in the article relevant information on determinants of circular business model adoption	"The integration of CS into a company's traditional business models (Baumgartner, 2009; Lozano, 2012; Murray et al., 2015) has driven companies to rethink and redesign their business models to better engage with stakeholders, while creating competitive advantages for customers, the company, and society (Lüdeke-Freund, 2010; Porter and Kramer, 2011; Stubbs and Cocklin, 2008).

						Recently, a number of authors have discussed the redesign of business models in order to move to more sustainable business models" (p. 40)
Towards a new taxonomy of circular economy business models	Urbinati, A; Chiaroni, D; Chiesa, V	Journal of Cleaner Production	2017	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Towards a value stream perspective of circular business models	Galvao, GDA; Homrich, AS; Geissdoerfer, M; Evans, S; Ferrer, PSS; Carvalho, MM	Resources Conservation and Recycling	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Towards Circular Business Models: A systematic literature review on classification frameworks and archetypes	Rosa, P; Sassanelli, C; Terzi, S	Journal of Cleaner Production	2019	Included	The coders found in the article relevant information on determinants of circular business model adoption	"From an industrial perspective, this categorization could represent a starting point to better understand which is the preferable CBM to be adopted e depending on internal strategies to be pursued e by uncovering challenges and opportunities." (p. 14)
Towards circular business models: Identifying consumer needs based on the jobs-to-be-done theory	Hankammer, S; Brenk, S; Fabry, H; Nordemann, A; Piller, FT	Journal of Cleaner Production	2019	Included	The coders found in the article relevant information on determinants of circular business model adoption	"Our analysis revealed that 11 of the 30 needs are currently not well satisfied. These needs are linked as innovation opportunities to potential PSSs, providing a foundation for customer-centric value propositions design to foster the implementation of the CE" (p. 341)
Towards Circular Economy implementation: an agent-based simulation approach for business model changes	Lieder, M; Asif, FMA; Rashid, A	Autonomous Agents and Multi-Agent Systems	2017	Included	The coders found in the article relevant information on determinants of circular business model adoption	"In a CE customers are perceived as integral part of the business and therefore customer acceptance of new business models becomes crucial as it determines the successful implementation of CE." (p. 1377)

Towards sustainability? Forest-based circular bioeconomy business models in Finnish SMEs	D'Amato, D; Veijonaho, S; Toppinen, A	Forest Policy and Economics	2020	Included	The coders found in the article relevant information on determinants of circular business model adoption	"Based on the analysis of interview data gathered from SME managers, this study expands and refines the conceptualization of sustainable circular bioeconomy and related business models. The results, coupled with recent literature (cf. Section 5), can provide some insights into the challenges and opportunities posed by a transition towards a circular bioeconomy, particularly in the context of the Finnish forest- based industry (Table 3)" (p. 9)
Transition thinking and business model innovation-towards a transformative business model and new role for the reuse centers of Limburg, Belgium	Gorissen, L; Vrancken, K; Manshoven, S	Sustainability (Switzerland)	2016	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Transition towards Sustainable Solutions: Product, Service, Technology, and Business Model	Nasiri, M; Rantala, T; Saunila, M; Ukko, J; Rantanen, H	Sustainability	2018	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Unlocking the circular economy through new business models based on large-scale data: An integrative framework and research agenda	Jabbour, CJC; Jabbour, ABLD; Sarkis, J; Godinho, M	Technological Forecasting and Social Change	2019	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available
Value Creation in Circular Business Models: The case of a US small medium enterprise in the building sector	Unal, E; Urbinati, A; Chiaroni, D; Manzini, R	Resources Conservation and Recycling	2019	Included	The coders found in the article relevant information on determinants of circular business model adoption	"Drivers of this dimension are surely the price, intended as the different modes of offering value to the customer, and promotion, which means the extent to which a company makes its compliance with circular economy visible to the stakeholders (Heerde et al., 2013)." (p. 294)

Циркулярная Экономика: Основные Бизнес-Модели И Экономические Возможности	Валько, ДВ	Russian Journal of Economic Theory	2020	Excluded	The coders did not find in the article any relevant information on determinants of circular business model adoption	Not available

5. ARTICLE B

Title: Circular Business Model Innovation in The Built Environment: A Delphi Study

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Abstract

The built environment is responsible for a third of global greenhouse gas emissions; by 2050, roughly two-thirds of the global population will live in cities. There is an urgent need for companies to decouple economic growth from resource consumption, and business model innovation can play a key role in advancing the adoption of circular economy and material reuse practices. This paper employs a three-round Delphi study with 25 international experts, to examine the hindering and enabling factors as well as the most promising strategies for circular business model innovation (CBMI) in the built environment. Building on the experts' recommendations, this study suggests 34 strategies that can be employed by actors in the built environment to capitalize on the drivers of CBMI and overcome the barriers to its implementation. These strategies are classified into four categories: "Understanding the loop," "Facilitating the loop," "Promoting the loop," and "Regulating the loop."

Keywords: Circular business model, business model innovation, strategy, built environment, construction industry, Delphi method.

1. Introduction

By 2030, three billion people will need new housing, and by 2050, around two-thirds of the world's population will be living in cities (United Nations, 2018). This will lead to a rapid increase in building and infrastructure projects. However, the construction industry already has a major negative impact on the climate and is responsible for 39% of the global energy-related carbon emissions (World Green Building Council, 2019). With the increasing need for housing, the built environment must meet the needs of the population while also drastically decreasing its footprint.

The circular economy is emerging as a viable approach to reaching sustainable development by fundamentally transforming the way companies create, capture, and deliver value (Leone et al., 2023). The circular economy is defined as "restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles" (Ellen Macarthur Foundation, 2015, p. 2). The circular economy is credited with promoting economic growth through the creation of new businesses and jobs, decreasing price volatility, minimizing costs of materials, and strengthening the security of supply, while also reducing environmental pressures and impacts (Patwa et al., 2021; EMF, 2016).

The need for change combined with the promising properties of the circular economy have catapulted the circular economy and circular business models (CBMs) to the top of corporate boards' strategic agendas and the center of government funded initiatives (Bocken et al., 2014; Fehrer & Wieland, 2021). However, although CBMs are considered critical devices to improve the state of the globe and humanity's well-being, their adoption rates remain limited in practice (Fehrer & Wieland, 2021).

Circular business model innovation (CBMI) is considered a useful approach to advancing the adoption of CBMs in practice (Bigliardi & Filipelli, 2021; Chirumalla et al., 2022). Research is therefore needed to understand the perspectives and actions of managers in order to support firms in the CBMI process (Geissdoerfer et al., 2022). To date, many studies on circular economy and CBMs have focused on specific industries—predominantly in relation to consumer goods (Adams et al., 2017; Eberhardt et al., 2019). However, research on CBMI in the built environment context, and particularly examining strategic recommendations that practitioners can employ in their own business models and organizations (Adams et al., 2017), is limited. Filling this research gap is urgently needed, to generate up-to-date knowledge and provide practitioners with applicable strategies for advancing companies' transition toward CBMI. This paper aims to ameliorate this research gap by addressing the following research questions:

> **RQ1.** What are the existing drivers of, and barriers to, circular business model innovation in the built environment?

> **RQ2.** What strategies can be employed to capitalize on the drivers of, and overcome the barriers to, circular business model innovation in the built environment?

To answer these research questions, we employed a Delphi method, interviewing experts to examine the drivers of and barriers to CBMI in the built environment, and identifed the strategies that are best suited to capitalize on the drivers and overcome the barriers (Dalkey & Helmer, 1963). We conducted the Delphi study with 25 international experts on circular economy, CBMs, and the built environment. The data gathered enabled the authors to identify the barriers and drivers that the experts considered imminent in the industry, along with 34 strategies that can be used to tackle drivers and barriers and thus stimulate CBMI in the built environment. We propose a classification of the 34 strategies into four main categories related to their contribution to closing the resource loops: “Understanding the loop,” “Facilitating the loop,” “Promoting the loop,” and “Regulating the loop.”

This study contributes to the academic discussion on CBMs and CBMI, while exploring the challenging context of circularity-oriented innovation in the built environment. It also adds to the practical debate by exploring why CBMI is moving languidly in practice, and suggesting actions that can accelerate the transition toward circularity in the built environment.

This article is structured as follows. Section 2 describes the relevant literature, followed by the research design and methods in Section 3. Section 4 exhibits the findings from the expert interviews, Section 5 presents the study discussion, and Section 6 concludes the study by presenting the key takeaways for academia, practice, and policy along with the study’s limitations and suggestions for future research.

2. Literature review

The two core areas of the circular business model innovation literature that have guided this study are reviewed below.

2.1 Circular business model innovation

A business model is a conceptual tool that provides insight into how a company conducts business to create and capture economic value (Schaltegger et al., 2012). Achieving the shift toward circular business models requires business model innovation (Ruiter et al., 2022), a holistic approach assisting companies to achieve change (Osterwalder et al., 2005; Boons & Lüdeke-Freund, 2013). To achieve business model innovation, companies can either reconfigure the main elements of the company’s existing business model, or design entirely new business models (Zott & Amit, 2010; Massa & Tucci, 2013; Nußholz et al., 2020).

CBMI is a specific type of business model innovation that supports the circular economy paradigm. Indeed, business model innovation can play a key role in increasing the adoption of circular economy and material reuse practices in industry (Guldmann & Huulgaard, 2019: Ness & Xing, 2017; Nußholz & Milios, 2017; Hopkinson et al., 2018; Nußholz et al., 2019; Nußholz et al., 2020). The transition toward CBMs aims to "create, deliver and capture value while implementing circular strategies that can prolong the useful life of products and parts (e.g., repair and remanufacturing) and close material loops (e.g., recycling)" (Nußholz, 2018, p. 187). Despite the vibrant scholarly debate on CBMs, academic literature still lack studies investigating what drives and hinders CBMI and what is required to support the innovation process toward CBMI (Linder & Williander, 2017; Urbinati et al., 2017; Bocken et al., 2018; Guldmann & Huulgaard, 2019, 2020). In this study, we aim to fill this gap by focusing on drivers, barriers, and strategies connected to CBMI in the built environment.

2.2 Circular business model innovation in the built environment

The construction industry is responsible for using 50% of all materials consumed in Europe and is one of the largest industries globally, with nearly $10 trillion spent on construction materials and goods annually (McKinsey & Company, 2020; Global Alliance for Buildings and Construction, 2016; Eurostat, 2020). However, notwithstanding its immense size and impact on the environment, the construction industry is one of the least willing to innovate (Ghaffar et al., 2022). It has been characterized as slow to change (Gambatese & Hallowell, 2011), and lacking innovativeness (Laborde & Sanvido, 1994; Koskela & Vrijhoef, 2001a; Brockmann et al., 2016). Scholars have also found that compared to other industries, the built environment industry's performance in terms of productivity, quality, and product functionality has been poor due to a low rate of innovation (Winch, 1998; Gann, 2000; Koskela & Vrijhoef, 2001b).

The term “built environment” encompasses both the construction industry itself and the man-made building and infrastructure stocks which comprise the physical, natural, economic, social, and cultural capital of the built environment (Hassler & Kohler, 2014). The built environment offers a fitting context for exploring CBMI, since the industry must change its high material consumption, and the circular economy has potential to assist this change through four core circular economy principles (Nußholz, 2018; Çetin et al., 2021). The first principle is “Narrowing resource loops,” which relates to decreasing the use of resources via efficiencies throughout the production and design process (Çetin et al., 2021). The second principle is “Slowing resource loops” and concerns prolonging the useful life of goods, increasing their utilization, and avoiding unnecessary consumption (Nußholz, 2018; Tunn et al., 2019; Çetin et al., 2021). The third principle is “Closing resource loops” and refers to material recovery once the end-of-life of a material is irreversibly reached, for instance through post-consumer recycling or reuse of materials (Stahel, 1994; Bocken et al., 2016; Nußholz, 2018; Çetin et al., 2021). Finally, the fourth principle is “Regenerating resource loops” and entails leaving the environment and society in an improved state, for instance by recovering biodiversity (Çetin et al., 2021). Narrowing, slowing, closing, or regenerating resource loops requires radical and holistic alterations to a company’s offers and value chain (Wells & Seitz, 2005; Bocken et al., 2016; Nußholz, 2018). In this study, we therefore build on the existing literature on CBMI and the built environment, and aim to provide strategies that can be employed by companies operating in the built environment.

3. Research Methods

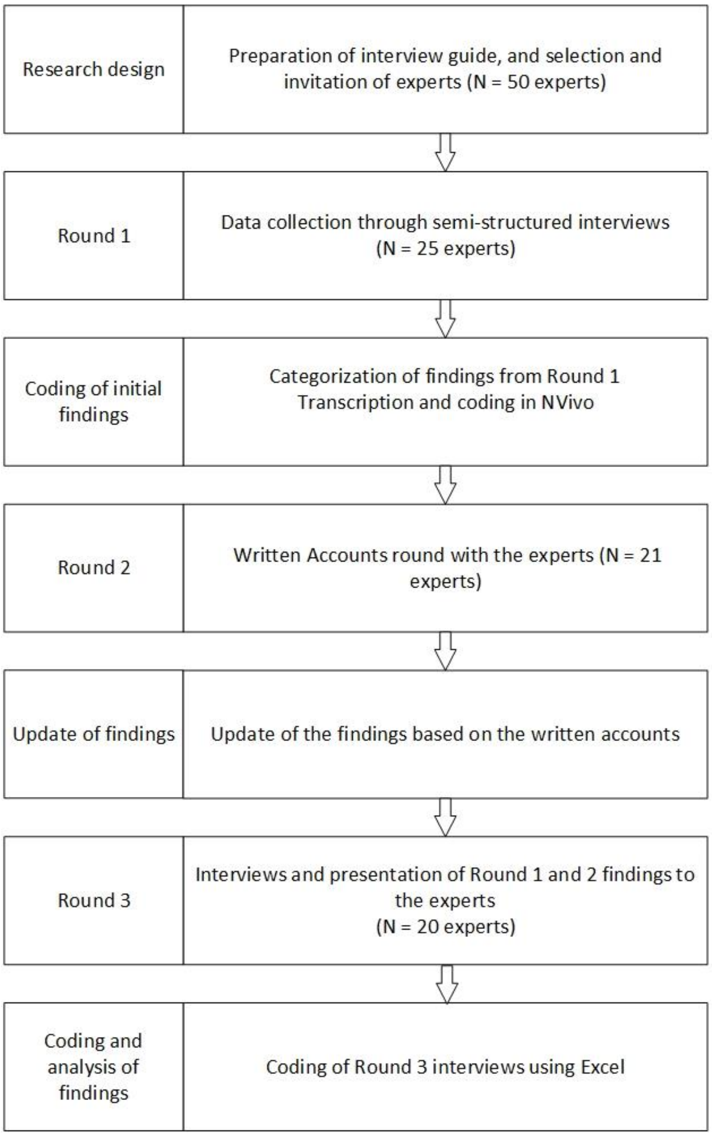
The following section describes in detail the iterative, three-round Delphi study employed in this research.

3.1 The Delphi Method

The Delphi method is a consensus-building research method in which participant responses are refined over multiple rounds (Keeney et al., 2011). Dalkey and Helmer (1963) describe the Delphi method as “a method used to obtain the most reliable consensus of opinion of a group of experts by a series of intensive questionnaires interspersed with controlled feedback” (p. 458). The Delphi method does, however, have its limitations. It can be considered time consuming due to its multiple rounds, it may raise concerns regarding the definition of “experts,” and it collects subjective inputs from the experts (Keeney et al., 2011). To reduce these risks, this study has been designed with careful consideration when selecting experts and developing the interview guide (see Sections 3.2 and 3.3).

Delphi studies are usually designed in two or three stages (Okoli & Pawlowski, 2004; Seuring & Müller, 2008; Mahanty et al., 2021). This research has been designed in three stages: one preliminary interview round in which 25 experts agreed to participate, one written account round where 21 of the experts contributed, and one second interview round in which 20 of the experts assisted in the study. The expert selection process is described in Section 3.2, while the three interview rounds are explained in further detail in Sections 3.3, 3.4, and 3.5. Figure 1 illustrates the process followed in this study.

Figure 1. Data collection process map



3.2 Expert selection

The representation of experts in a Delphi study is recommended to be as heterogeneous as possible (Cuhls et al., 2002). In this study, we have therefore considered the following aspects when selecting the interviewee sample:

1. Area of expertise (i.e., built environment, CBMs, circular economy)
2. Value chain spread (e.g., contracting, architecture, consulting, social housing)
3. Employment (with a requirement of having at least five years of experience in the field)

4. Geographic background (to include views from both developed and developing countries)

5. Company size (ranging from small to large companies)

6. Gender (to ensure female representation in a male-dominated industry)

7. Age (to include multiple perspectives on the topic coming from people with different experience and levels of seniority).

Purposive sampling was thus employed for this study to derive the viewpoints of experts with a wide range of perspectives and varied backgrounds. Experts were selected considering their experience working with circular economy, CBMs, and the built environment. Danaeifard et al. (2019) argue that in a guided study, wherein the sample size is evolutionary and followed-up, the saturation point can be reached with approximately 12 participants (Danaeifard et al., 2019; Farahani & Teymournejad, 2021). However, for this study it was considered important to have a larger sample size to secure the views of academics, practitioners, and civil servants alike, and to include perspectives from various geographies and areas of expertise. To include a diverse set of viewpoints, factors such as age and gender were also significant when experts were invited to participate in the study. Of 50 contacted experts, 25 agreed to participate. The interviewee sample comprises 15 practitioners, 8 academics, and 2 civil servants (see Table 1). After conducting 25 first-round interviews with the selected experts, the authors recognized that the data collection had reached a theoretical saturation point once the experts’ responses became largely repetitive; additional interviews were therefore not required. To identify the experts, we searched through relevant academic publications, topical conferences, and networks, as well as white papers and governmental reports. Moreover, during the first interview round, we asked experts to refer us to other experts, following the snowball sampling technique (Wohlin, 2014).

Table 1. Expert overview

#	Interviewee code	Country	Expertise	Sector	Round 1	Round 2	Round 3
1	Academic 1	Sweden	CBMs, BE	Engineering research	x	x	x
2	Academic 2	Denmark	CBMS, BE	Social science research	x	x	x
3	Academic 3	United Kingdom	CE, BE	Architecture research	x	x	x
4	Academic 4	Germany	CBMS, BE	Management research	x	x	x
5	Academic 5	Columbia	CE, BE	Sustainability research	x	x	
6	Academic 6	United Kingdom	CBMS, BE	Engineering research	x		
7	Academic 7	France	CE, BE	Engineering research	x	x	x
8	Academic 8	Brazil	CE, CBMS	Sustainability research	x	x	x
9	Practitioner 1	Netherlands	CBMS, BE	Real estate firm	x	x	x
10	Practitioner 2	Denmark	CBMS, BE	Circular venture	x	x	x
11	Practitioner 3	Sweden	CBMS, BE	Circular venture	x	x	x
12	Practitioner 4	Denmark	CBMS, BE	Circular venture	x	x	x
13	Practitioner 5	Denmark	CE, BE	Social housing firm	x	x	x
14	Practitioner 6	Denmark	CBMS, BE	Circular venture	x	x	x
15	Practitioner 7	Denmark	CBMS, BE	Architecture firm	x	x	x
16	Practitioner 8	Netherlands	CBMS, BE	Circular venture	x	x	
17	Practitioner 9	Denmark	CBMS, BE	Circular venture	x		
18	Practitioner 10	Norway	CBMs, BE	Consulting firm	x	x	x
19	Practitioner 11	Denmark	CE, BE	Material supplying firm	x		
20	Practitioner 12	Denmark	CE, BE	Material supplying firm	x	x	x
21	Practitioner 13	Denmark	CE, BE	Contracting firm	x	x	x
22	Practitioner 14	Sri Lanka	CE, CBMs, BE	Consulting firm	x	x	x
23	Practitioner 15	United States	CE, CBMs	Consulting firm	x	x	x
24	Civil servant 1	Denmark	CE, CBMs	Innovation sector	x	x	x
25	Civil servant 2	Denmark	CE, CBMs	Waste treatment sector	x	x	x

3.3 Round 1: First interview

The first interview round was structured as a semi-structured interview. During the interview, experts were asked for their opinions on what drivers and barriers exist for CBMI in the built environment, and what strategies they consider useful to capitalize on the drivers and overcome the barriers. We employed semi-structured interviews, as they allowed us to ask every interviewee the same set of questions while also gathering in-depth insights and permitting follow-up questions and clarifications when necessary (Bryman, & Bell, 2015). While conducting the interviews, we followed the seven practical steps of interviewing proposed by Kvale (1996): (1) thematizing the interview project, (2) designing the interview guide, (3) interviewing, (4) transcribing, (5) analyzing, (6) verifying, and (7) reporting. The Round 1 interviews were conducted with 25 experts individually in the period between September and October 2022, and lasted for approximately an hour, either in person or online using Microsoft Teams teleconferencing software. Subsequently, the interviews were transcribed verbatim and coded in NVivo to enable discovery of recurring themes.

This paper employs the Gioia methodology, developed by Gioia et al. (2013) on the basis of interpretative logic of grounded theory. Following these principles, the data were interpreted through the coding steps of first-order concepts, second-order themes, and aggregate dimensions. These steps were undertaken and applied as follows:

1. First-order concepts. This step involves breaking up the textual data into discrete parts and developing codes to label each part. In this study, this step was finalized when the coding structure could be considered stable, resulting in 74 first-order concepts.

2. Second-order themes. In the second step, we sought similarities among the first-order concepts and clustered the codes into categories, until we reached theoretical saturation through the concept and theme development process (Glaser & Strauss, 1967; Gioia et al. (2013). We eventually ended up with 20 second-order themes.

3. Aggregate dimensions. As soon as a workable collection of concepts and themes was finalized, the second-order themes could be boiled down into second-order aggregate dimensions (Gioia et al., 2013). Our analysis pointed to three overarching conceptual dimensions. In Figures 2 and 3, we present the data structure, which is an artifact of the inductive coding developed in this step (Shankar et al., 2022).

3.4 Round 2: Written accounts

To ensure completeness of the findings before conducting the follow-up interviews (see Section 3.5), we sent each of the experts a copy of the findings from the first interview round and requested that they assess whether the list of drivers and barriers were conclusive. This round was employed to give the experts time to read the gathered data in full, reflect on it, and provide their opinion on the completeness of the data collection from the first interview round. The written accounts method was selected as it is a time-efficient method of gathering high quality, descriptively rich data (Handy & Ross, 2005). The experts were encouraged to identify drivers, barriers, or strategies that did not emerge during the first interview round, replying as briefly or fully as they wished. The experts did not add any new barriers or drivers in this written accounts round. However, they did register five additional strategies that they believed should be represented in the list of strategies to either overcome barriers or capitalize on drivers of CBMI.

3.5 Round 3: Follow-up interview

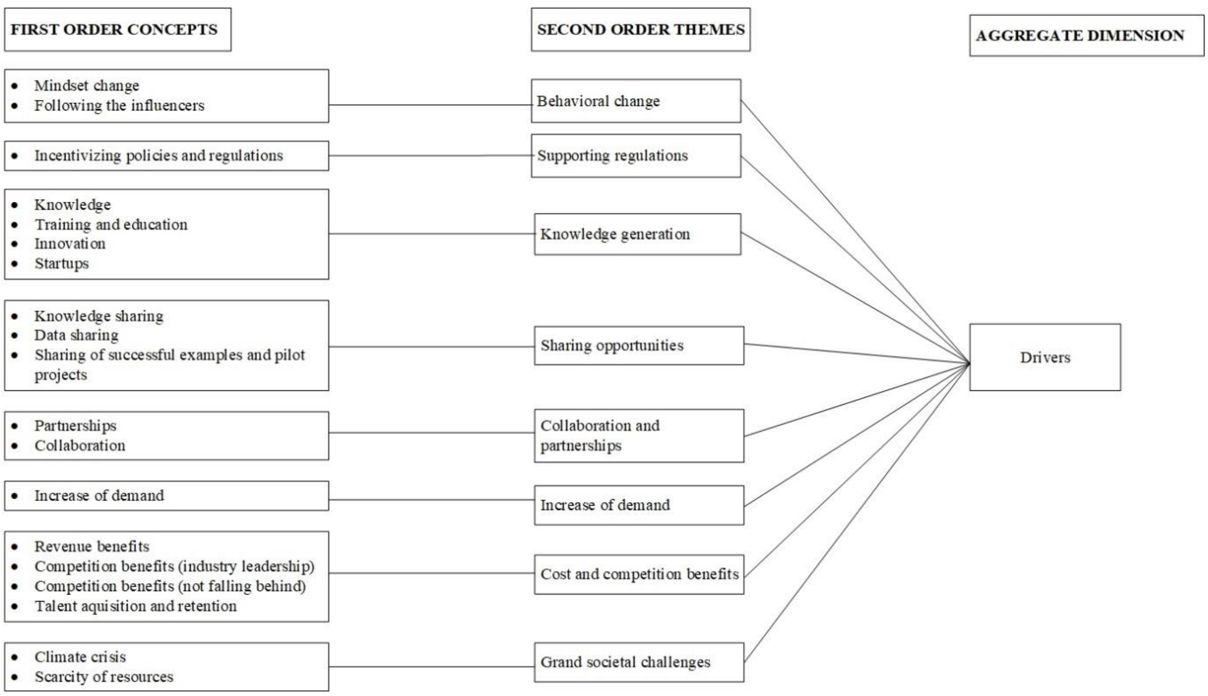
Round 3 focused on follow-up interviews with the experts, and was designed based on the results from Round 1 and Round 2. The aim of this interview round was to rank drivers and barriers according to their impact on CBMI in the built environment, and determine which strategies are best suited to capitalizing on drivers and overcome barriers. Of the 25 experts, 20 (80%) agreed to participate in the Round 3 interviews (Table 1). These interviews were transcribed verbatim and coded using Excel, with each of the experts' responses coded into a separate spreadsheet.

4. Results

4.1 Drivers

The majority of the experts listed three or more drivers of CBMI in the built environment (first-order codes). These drivers were grouped by the researchers into eight categories using the Gioia Methodology (Gioia et al., 2013): “Behavioral change,” “Supporting regulation,” “Knowledge generation,” “Sharing opportunities,” “Collaboration and partnerships,” “Increase of demand,” “Cost and competition benefits,” and “Grand societal challenges” (see Figure 2).

Figure 2. Overview of drivers derived from first-round interviews with the experts using the Gioia methodology (Gioia et al., 2013)



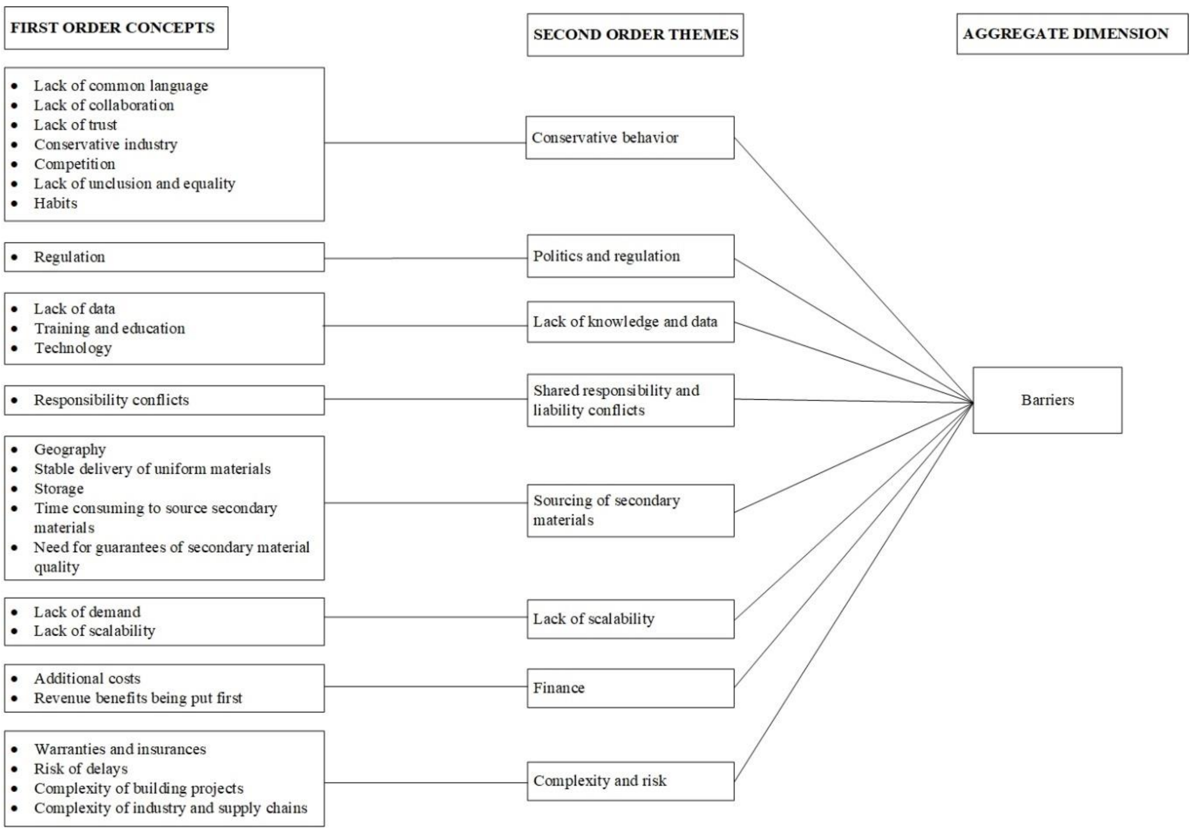
In particular, most of the experts emphasized “Cost and competition benefits” as a a highly effective driver for CBMI in the built environment. Academic 4 explained, “Cash is king and financial incentive is the main incentive.” However, not all companies acting on CBMI are driven by monetary advantage. Indeed, some of them innovate their business model to tackle grand societal challenges, as expressed by Practitioner 12: “There’s an increasing number of actors who have a genuine concern about climate change.” Multiple experts also noted that becoming sustainability front-runners motivated companies to increase CBMI. Academic 5 explained, “It is more about the actual willingness of the companies to become leaders and front-runners for the sustainability agenda in our industry.” However, the experts noted that increasing CBMI is not only motivating for companies wanting to become front-runners but also for the ones that do not want to fall behind. Practitioner 7 explained, “Not building sustainably is also a huge risk, because you might not be allowed to do the building project, or someone might not be willing to live there or to buy the building.” This finding, proposing that multiple companies wish to lead the industry’s CBMI transition even though the uptake of CBMs is limited to date, may suggest that readiness for CBMI in the built environment is growing, but that the companies in the industry are not yet equipped with CBMI capabilities to take on the front-runner responsibilities.

Even though regulation was one of the most frequently suggested barrier to CBMI, the experts also highlighted “Supporting regulation” as a major driving factor. Practitioner 13 stated, “The demands from the government are pretty much the primary driver right now.” The EU taxonomy was highlighted as currently forcing a change in the industry, for instance by Practitioner 6, who emphasized, “But other firms are driven heavily by the EU taxonomy. So, this is where there will be a shift in the coming years.” This study’s findings thus suggest a need for greater levels of involvement from policy-makers to drive the CBMI agenda. It is interesting, however, that only the experts from countries within the European Union (EU) and European Economic Area (EEA) highlighted regulation as a main driving factor. This may suggest that the EU taxonomy has altered the attitude toward regulatory aid to advance the circular transition.

4.2 Barriers

Following the same procedure as for the drivers, we asked the experts to identify barriers to CBMI in the built environment and then developed second-order codes based on the Gioia Methodology (Gioia et al., 2013), ultimately generating eight main barrier categories: "Conservative behavior," "Politics and regulation," "Lack of knowledge and data," "Shared responsibility and liability conflicts," "Sourcing of secondary materials," "Lack of scalability," "Finance," and "Complexity and risk," as shown in Figure 3.

Figure 3. Overview of barriers derived from first-round interviews with the experts using the Gioia methodology (Gioia et al., 2013)



Some of these barrier categories were more frequently highlighted by the experts, for instance the "Finance" category, which was considered by multiple experts to be a crucial hindrance to CBMI in the built environment. Practitioner 7 explained,

> “I think the biggest barrier is that the built environment is essentially a service to the financial industry. It has become an asset class, to the degree where the ultimate valuation of a building’s success is the financial outcome, not the actual building (…) And that means that the built environment is not necessarily the most innovative, but the innovation that has happened has been on reducing price and time.”

The finding that many of the experts said that demonstrating the financial benefit of CBMI is needed to incentivize companies and decisionmakers might have been anticipated, given existing scholarly findings on barriers to CBMI (Geissdoerfer et al., 2022). However, it is interesting to note that the experts in this study highlighted how the industry, which is recognized to be slow to change, has innovated to decrease costs. This finding is particularly notable considering that CBMs have been proven to offer cost savings through minimizing waste and maximizing resource efficiency (Assmann et al., 2023). This presents an opportunity for incentivizing the industry’s CBMI efforts by proving potential financial gains.

“Politics and regulation” was also highlighted by the experts as a barrier category with a substantial impact on CBMI in the built environment. Academic 5 suggested, “Regulation is currently not lowering the barrier of entry but is actually ensuring that companies are better off just keeping it business as usual.” Some experts also suggested that the regulations must be reconstructed to allow companies to employ secondary materials. As noted above, regulation was mentioned both as a main driver to CBMI, but also as a main barrier. In particular, the experts with architecture backgrounds identified regulation as a hindering factor, and argued that this was due to regulations’ obstructive impact on freedom to design, which they considered crucial for the purpose of developing circular design practices.

“Lack of knowledge and data” was emphasized by the experts as impeding the CBMI to companies operating in the built environment. Practitioner 11 suggested that there is also a lack of knowledge regarding how to use the data "Many employees have no knowledge of the existence of documentation. They have no knowledge on how to use the data and how that data can put their products in the market compared to competitors." This finding suggests not only that companies should openly share data, but they may also benefit from teaching their own employees how to make better use of openly existing data to increase CBMI.

4.3 Ranking of the top drivers and barriers

To better understand the experts' views, we also asked participants to select the three barrier and driver categories with the greatest impact on CBMI in the built environment industry. As shown in Figure 4, 75% of the experts felt that one of the greatest drivers of CBMI is "Supporting regulation." Figure 5 shows that 70% of the experts agreed on "Complexity and risk" as one the greatest barriers to CBMI in the built environment industry.

Figure 4. Bar charts depicting the most impactful CBMI drivers in the built environment, according to the interviewed experts

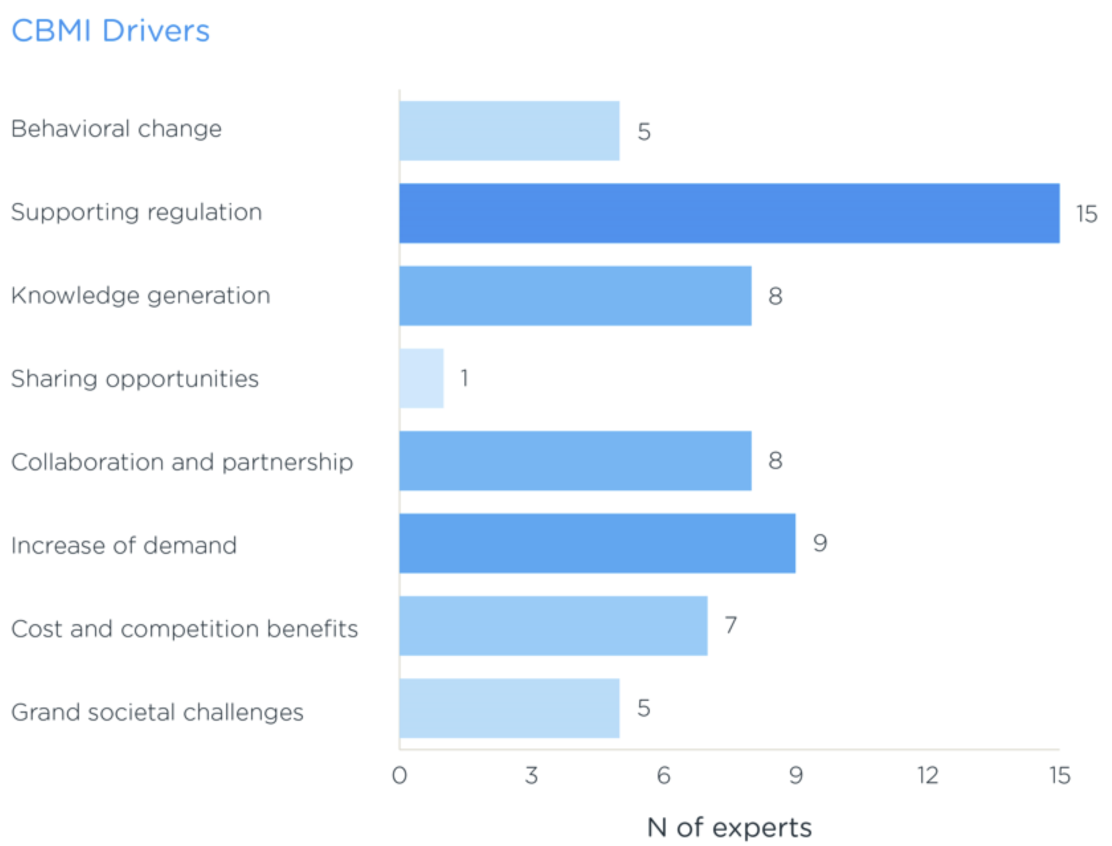
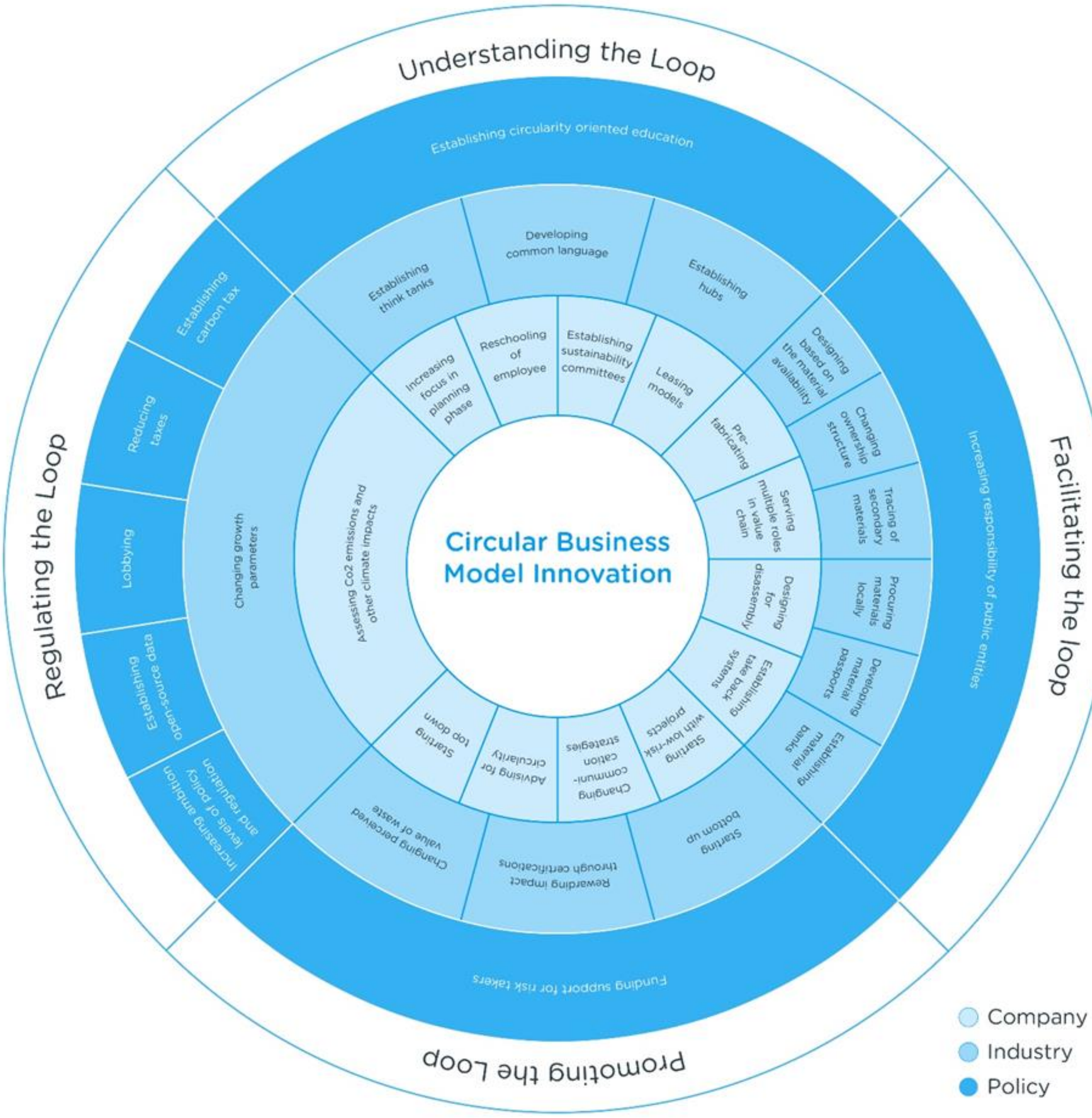


Figure 5. Bar charts depicting the most impactful CBMI barriers in the built environment, according to the interviewed experts

4.4 Strategies to capitalize on drivers and overcome barriers

Subsequently, the experts were asked to recommend strategies that they believed can assist in increasing CBMI in the built environment. The suggested strategies were grouped by the authors into four categories: “Understanding the loop,” “Facilitating the loop,” “Promoting the loop,” and “Regulating the loop” contingent on their inherent strategies’ contribution to closing resource loops. The experts highlighted that these can have an impact at a company, industry, and policy level. Therefore, before the written accounts round, the researchers categorized each of the strategies into company, industry, and policy levels and included these levels to the proposed classification shown in Figure 6.

Figure 6. Circular business model innovation strategies



When constructing the “Understanding the loop” category, we assembled the strategies that focus on increasing comprehension and knowledge of circularity and can be used to increase CBMI through educating the industry. For instance, hubs were highlighted as an approach for companies to share knowledge, along with risks and sustainability impacts. However, not all the experts agreed to the potential of hubs: Academic 4 argued that this would require certain arrangements, stating, “If a hub was created, you would need to make sure that all the companies that were in that hub, were actually equally passionate about making it work without trying to win on their own.” Establishing leasing models is another strategy that can contribute to better understanding the loop: leasing models, for example, can enable material producers to gather great amounts of data from a recurring user base. Despite the potential of leasing models, not all experts agreed: Academic 7 explained, “I think the difficulty will be the valuation of the elements in between each lease. How do you assess the quality of your material after a 20-year period, for instance?”

Multiple strategies were classified into the “Facilitating the loop” category due to their role in facilitating the actual undertaking of CBMI in the built environment. One of the strategies in this category concerns changing ownership structures. Practitioner 1 attested that, “Due to a change in the ownership model, we will have a long-term perspective, and are also more naturally inclined to think much more circular and in repetition, because (…) we must maintain it.” Practitioner 7 saw its potential to ensure increased quality in the building projects, explaining, “We need to incentivize quality. So, if we keep ownership throughout the building’s lifecycle, that’s definitely an obvious way to do that.” Another strategy that can play a role in facilitating the loop is to serve multiple roles in the value chain, and Academic 3 suggested a way to do so by “Owning more of the value chain, for instance having design and manufacturing within the same firm.”

The "Promoting the loop" category comprises strategies that can promote and endorse CBMI across the industry. One of these strategies is to start with low-risk projects. Practitioner 11 described the reason why starting with low-risk projects can be useful: "It is not going to save the world (…) It is such limited volumes, but it is something that we'll be able to show you." Another strategy that was emphasized to promote the loop was to change communication strategies, and Practitioner 11 argued, "The customers need to see circularity as better business. (…) we need to guide our sales staff and communicate differently to the customers."

The strategies belonging to the "Regulating the loop" category aim to propose or adapt circularity-oriented regulations that can increase the adoption of CBMI in the built environment. One of the strategies recommended by the experts was reducing taxes on secondary materials. Practitioner 10 commented, "It could be necessary to remove tax on reused or recycled products and materials." The experts also argued that changing growth parameters could be a useful method to increase CBMI. By changing the concept of growth, which is currently mostly measured through financial progress, the industry could move toward a more circularity-focused trade, which will lead to a perceptible upsurge in CBMI. Practitioner 6 contended,

> "Up until now, for many decades, the only real growth parameter we have been able to focus on is the gross national product of the country. And we have still not, as far as I see, figured out how to make a society system and economic system that figures out how do we make an incentive for you and I to buy fewer clothes, to use less energy, to take care of our materials?"

4.5 Linking strategies to the drivers and barriers

An essential part of this study concerns identifying the connections between all the recommended strategies and each driver and barrier category. Doing so provides a better understanding of the dependence of the experts' recommendations on tackling specific drivers or barriers. This will help companies get a clearer picture of what strategies to employ, given their particular circumstances. Tables 2 and 3 depict the top three strategies selected by the experts for each driver and barrier category. The suggested strategies are grouped into three levels, based on their impact at a policy, industry, and company level. Sections 4.4.1, 4.4.2, and 4.4.3 discuss the strategies recommended by the experts at each of these levels.

Table 2. Strategies recommended by the experts for each driver category

Driver Category	**Top recommended strategies**	**Level**	**Percentage of experts recommending the strategy**
Behavioral change	Establishing circularity oriented education	Policy	70%
	Developing common language	Industry	55%
	Increasing ambition levels of policy and regulation	Policy	45%
	Changing communication strategies	Company	45%
Supporting regulations	Increasing ambition levels of policy and regulation	Policy	65%
	Establishing open source data	Policy	40%
	Establishing carbon tax	Policy	35%
	Developing common language	Industry	35%
Knowledge generation	Establishing circularity oriented education	Policy	65%
	Establishing hubs	Industry	50%
	Reschooling of employees	Company	45%
Sharing opportunities	Establishing Open source data	Policy	65%
	Establishing hubs	Industry	45%
	Advising for circularity	Company	35%
Collaboration and partnerships	Establishing hubs	Industry	70%
	Changing ownership structures	Industry	40%
	Increasing responsibility of public entities	Policy	35%
Increase of demand	Funding support for risk takers	Policy	55%
	Increasing ambition levels of policy and regulation	Policy	50%
	Establishing material banks	Industry	45%

Cost and competition benefits	Changing communication strategies	Company	55%
	Changing growth parameters	Industry	40%
	Funding support for risk takers	Policy	35%
	Establishing circularity oriented education	Policy	35%
	Reschooling of employees	Company	35%
Grand societal challenges	Changing growth parameters	Industry	50%
	Designing based on material availability	Company	45%
	Changing perceived value of waste	Industry	45%

Table 3. Strategies recommended by the experts for each barrier category

Barrier category	**Top recommended strategies**	**Level**	**Percentage of experts recommending the strategy**
Conservative behavior	Establishing circularity oriented education	Policy	70%
	Reschooling of employees	Company	65%
	Funding support for risk takers	Policy	50%
Politics and regulation	Increasing ambition levels of policy and regulation	Policy	75%
	Lobbying	Policy	45%
	Establishing carbon tax	Policy	35%
Lack of knowledge and data	Establishing open source data	Policy	75%
	Establishing circularity oriented education	Policy	65%
	Reschooling of employees	Company	60%
Shared responsibility and liability conflicts	Funding support for risk takers	Policy	60%
	Increasing focus in planning phase	Company	40%
	Serving multiple roles in value chain	Company	35%
	Increasing ambition levels of policy and regulation	Policy	35%
	Changing ownership structures	Industry	35%
Sourcing of secondary materials	Designing based on material availability	Company	75%
	Establishing material banks	Industry	75%
	Procuring materials locally	Company	55%
Lack of scalability	Increasing ambition levels of policy and regulation	Policy	50%
	Funding support for risk takers	Policy	40%

	Changing perceived value of waste	Industry	40%
	Establishing material banks	Industry	40%
Finance	Reducing taxes	Policy	65%
	Funding support for risk takers	Policy	55%
	Changing perceived value of waste	Industry	50%
Complexity and risk	Increasing focus in planning phase	Company	60%
	Funding support for risk takers	Policy	55%
	Increasing ambition levels of policy and regulation	Policy	50%
	Changing ownership structures	Industry	50%

4.5.1 Strategies recommended at the company level

One of the most commonly recommended strategies at the company level was "Reschooling of employees," which involves providing employees the knowledge base required to work with circular solutions and practices. This strategy was highlighted by 45% of the experts as particularly useful in capitalizing on the "Knowledge generation" driver, whereas 65% of the experts considered reschooling of employees useful to tackling the "Conservative behavior" barrier. This finding, suggesting reschooling of employees, will require extensive investment from companies; it is thus likely that further research is needed to prove the return on investment.

Multiple experts also recommended "Increasing focus in planning phase," which concerns allocating time in the earliest stage of the project to make circularity-oriented decisions. This strategy was recommended by 60% of the experts to address the "Complexity and risk" barrier. Thus, this study's findings suggest that including CBMI strategies into a project requires an even stronger focus on circular economy, requiring companies and project owners to adjust funding to accommodate a prolonged circularity-oriented planning phase.

"Changing communication strategies," for instance, was recommended by 55% of the experts to capitalize on the "Cost and competition benefits" driver by attracting new and more ambitious clients. Changing communication strategies to reach CBMI may also involve shifting from "hope making" marketing and communication to an increasingly realistic approach, albeit without fearmongering.

4.5.2 Strategies recommended at the industry level

According to the experts, one of the most promising strategies at the industry level was "Establishing hubs." According to 70% of the experts, creating hubs in which members collaborate on projects and share knowledge and even project risks could improve "Collaboration and partnerships," as actors in the industry tend to work together already. Although the experts see potential in establishing hubs, greater levels of involvement from policymakers and the establishment of government-led funding may be necessary to facilitate and incentivize industry-wide commitment.

Another strategy that experts cited was "Developing common language" by establishing a consistent use of terms used when communicating about circularity across the built environment. Indeed, 55% of the experts felt that establishing a common language could take advantage of the growing "Behavioral change" driver. The high percentage of experts suggesting this need is encouraging, considering that the development of a common language is likely to require participation across the practice, policy, and academia domains.

Seventy-five percent of the experts also believed that the strategy "Establishing material banks" is crucial to overcoming the CBMI barrier "Sourcing of secondary materials" by ensuring that the industry has a marketplace to both source, repurpose and dispose of secondary materials. This finding is worth noting as there are multiple startups (e.g., Rehub and Circle Bank) that have developed material banks that cater to the needs of the industry. However, since the majority of the experts interviewed cited a need for material banks, it can be argued that the established material banks are not satisfying the industry's needs, and that there may still be market opportunity for other companies wishing to fill this gap.

4.5.3 Strategies recommended at the policy level

When asked which strategies could be used to capitalize on CBMI drivers and overcome CBMI barriers, the experts highlighted numerous strategies at the policy level, as shown in Tables 2 and 3.

Particularly, "Increasing ambition levels of policy and regulation" was highlighted as a policy-level strategy that could both alleviate barriers and utilize drivers. Indeed, 65% of the experts believed that introducing more ambitious policies and regulations could capitalize on the "Supporting regulation" driver, whereas 75% of the experts considered it useful to overcoming barriers related to "Politics and regulation." Considering that the majority of the experts contributing to this study were practitioners—only two were civil servants—this finding indicates that the industry's faith in regulations' potential to boost CBMI is high. Seeing that interest for regulation is high in the industry also indicates a willingness from industry to participate in policymaking efforts.

One of the most frequently recommended strategies at the policy level, to both capitalize on drivers and decrease barriers, was "Establishing circularity oriented education." Seventy percent of the experts believed that introducing circularity-oriented knowledge to the current and future workforce could capitalize on the "Behavioral change" driver. Further, 70% of the experts opined that introducing education on circularity could reduce the barrier of "Conservative behavior" that is prevalent in the construction industry. This finding suggests that knowledge is considered key to decreasing conservative behavior in the industry. However, education at the university level is not sufficient to change the industry's mindset and awareness of CBMI: there is need for awareness across various age groups, backgrounds, and educational levels.

Another policy-level strategy that the experts felt held potential for both decreasing barriers and capitalizing on drivers was “Funding support for risk takers”: 55% of the experts contended that by incentivizing companies in the built environment to take more risks, the industry can better capitalize on the “Increase of demand” driver. Assisting risk-embracing actors with funding was also recommended by 60% of the experts as a strategy to overcome “Responsibility conflicts” barriers. Considering this finding, one question that arises is: who would fund the risk takers? Since scholarly studies have proposed that the circular economy holds great potential to advance social ecological system resilience (Geissdoerfer et al., 2017; Ishii & van Houten, 2020), it can be argued that governmental and public bodies can benefit from providing financial support to entities that are willing to engage in the risk of CBMI, as the benefits of CBMI can be substantial.

5. Discussion

This study has examined the drivers and barriers related to CBMI in the built environment, and has identified strategies that practitioners can employ to either overcome the barriers or capitalize on the drivers. Through a three-round Delphi study with 25 experts, we derived eight driver categories and eight barrier categories that experts believed influenced CBMI in the built environment. The driver categories are “Behavioral change,” “Supporting regulation,” “Knowledge generation,” “Sharing opportunities,” “Collaboration and partnerships,” “Increase of demand,” “Cost and competition benefits,” and “Grand societal challenges.” The barrier categories are “Conservative behavior,” “Politics and regulation,” “Lack of knowledge and data,” “Shared responsibility and liability conflicts,” “Sourcing of secondary materials,” “Lack of scalability,” “Finance,” and “Complexity and risk.”

Based on the drivers and barriers proposed by the interviewed experts, the results of this Delphi study suggest 34 strategies actors in the built environment can employ to capitalize on the drivers of CBMI and overcome its barriers. Based on the Gioia methodology (Gioia et al., 2013), this study uses the strategies recommended by the experts to develop a conceptual framework that includes four categories of CBMI strategies:

1. **Understanding the loop:** strategies that increase the knowledge that is required to implement CBMI;
2. **Facilitating the loop**: strategies that assist in the actual undertaking of CBMI;
3. **Promoting the loop**: strategies that assist in endorsing an uptake of CBMI;
4. **Regulating the loop**: strategies that propose or adapt CBMI-oriented regulations.

These four categories were developed to classify the strategies based on their approach to changing resource loops in the built environment. However, these categories may also be widely applicable across industries, as the strategies are especially relevant for other resource-intensive industries, such as the fashion industry. These four CBMI strategy categories are prompted by the need for systemic innovation approaches and are different from the circular economy principles widely accepted in the CBM literature (Nußholz, 2018; Çetin et al., 2021). Indeed, these categories address the urgent need for solution-oriented guidelines that are actionable in practice (Konietzko et al., 2020), proposing strategies to reduce the speed of resource flows through the economic system.

Our first recommendation is the use of the "Understanding the loop" category as the starting point for boosting CBMI, as it includes strategies that increase the knowledge required to implement CBMI. Scholars have argued that there is a current lack of knowledge, not only on the theoretical basis of CBMI for decision makers, but also about the implications and needs of CBMI across organizational levels and types (Coscieme et al., 2021).

Second, we propose the “Facilitating the loop” category, comprising strategies that assist in the actual undertaking of CBMI. To date, scholars argue that a main barrier to reaching widespread adoption of CBMs and CBMI is the lack of guidance and strategies for companies on implementing CBMs and circular solutions in practice (Galvão et al., 2022). This study finds that strategies aiming to facilitate CBMI are sorely needed on each level of the strategic pyramid: the corporate level (e.g., serving multiple roles in the value chain), business level (e.g., reschooling employees), and functional level (e.g., designing for disassembly) (Kozyk & Zalutska, 2017).

Third, we propose the “Promoting the loop” category, which embraces strategies needed to increase adoption of CBMI. This is critical, as changing resource loops successfully requires cross-company and cross-industry collaborations. Considering that the uptake of CBMs remains limited, the need for effective strategies that can facilitate this gap are sorely needed (Stål & Corvellec, 2018; De Angelis, 2021).

Fourth, we propose the “Regulating the loop” category, which encompasses strategies that propose or adapt circularity-oriented regulations to increase CBMI. Strategies that boost the regulatory progress are needed, as CBMI often requires the commitment of policy organizations, for instance through incentive regulations and financing mechanisms. We anticipate developing strategies within the “Regulating the loop” category to become increasingly important in light of recent regulatory developments. For instance, the EU Taxonomy will have an impact on companies and industries across EU borders, given the global nature of trade flows and financial markets. Thus, strategies ensuring that companies and markets within and outside of the EU work together are needed, particularly as the circular economy requires global-scale transformations and fundamental alterations in broad economic structures (Lieder & Rashid, 2016; Konietzko et al., 2020). Combined, these four categories complement the circular economy principles, providing actionable strategies that practitioners can employ to strengthen their CBMI. We have listed these categories in the order that we argue will serve these companies. We do not, however, consider this a linear process, but rather an iterative process in a "loop" that requires continuous attention and progression.

6. Conclusion

This study presents a three-round Delphi study addressing the circular economy and the built environment that aims to answer the two research questions posed in the introduction.

To answer these questions, this study applied a three-round Delphi approach using interviews and written feedback. To respond to the first research question, in Round 1, the 25 experts gave insight into what drivers and barriers they believe had the most impact on CBMI in the built environment. Guided by the Gioia methodology (Gioia et al., 2013), the researchers developed eight driver and eight barrier categories. The accumulated driver and barrier categories were fed back to the experts in Round 2 as a written accounts exercise. The third round of data collection involved a follow-up interview, where participants were asked to select the three driver and barrier categories they considered to have the greatest impact on CBMI in the built environment. The highest ranked driver category, "Supporting regulation," was chosen by 75% of the experts, and the highest ranked barrier category, "Complexity and risk," was chosen by 70% of the experts.

To address the second research question, the first round of interviews gathered the experts' recommended strategies for capitalizing on the drivers and tackling the barriers. Following Round 1, these strategies were sorted into four proposed categories: "Understanding the loop," "Facilitating the loop," "Promoting the loop," and "Regulating the loop." In the third round of data collection (i.e., follow-up interviews), the experts were requested to identify, for each CBMI driver and barrier, the strategies they believed could foster the transition toward CBMs.

This study therefore resulted in an extensive overview of the strategies that the experts recommend that practitioners employ when tackling a particular barrier or driver to CBMI.

6.1 Key takeaways for academia

This study contributes to the research field on CBMI, which has remained under-studied in academic research, particularly regarding the process of innovating business models toward circularity (Guldmann & Huulgaard, 2018; Guldmann & Huulgaard, 2020; Linder & Willander, 2017; Urbinati et al., 2017; Bocken et al., 2018). The findings of this study add to the academic debate on what drives and hinders CBMI, and the strategies that can support the innovation process toward CBMI. Moreover, the findings of this study stress the need for the generation and dissemination of knowledge about CBMI, suggesting that research and public disclosure of academic results could prove to be highly effective drivers of CBMI, as well as knowledge sharing among academia, policy, and practice.

There has been limited research bringing light to the application of CBMI in the built environment, in particular an absence of studies providing strategic recommendations that practitioners can apply to their own business models and organizations (Adams et al., 2017). This study contributes to an improved and updated academic understanding of why CBMI in the built environment is still transitioning slowly, and what actions are needed to progressively foster CBMI in the built environment. The findings of this study also emphasize the need to inaugurate relevant higher education that increases the understanding and knowledge required to perform CBMI. Moreover, the findings support the significance of academia’s role in driving mindset change within industries and companies, and exhibits the importance and potential of academic advancements in the field of CBMI.

6.2 Key takeaways for practice

The findings presented in this study are relevant for practitioners, particularly managers and decision-makers in companies operating in the built environment who aim to foster CBMI within their businesses. This study can assist these practitioners first by providing an extensive overview of the barriers and drivers to CBMI in the built environment. At a practical level, the study presents 34 strategies that companies operating in the built environment can employ to capitalize on the drivers and overcome the barriers. By using this study to assess which of the barriers and/or drivers their company is experiencing, the practitioner can select the appropriate recommended strategies to overcome that particular barrier or capitalize on a specific driver. The study's findings are not restricted to a specific geographical context and can assist practitioners across the globe to identify drivers, barriers, and strategies.

Furthermore, the strategies presented in this study, particularly at the company level, indicate that experts are requesting action from decision-makers empowered to support CBMI efforts. This study suggests that these experts have faith in the strategies that can be performed by practitioners to increase CBMI. Therefore, the findings of this study can guide decision-makers in the analysis of what is hindering and driving their companies' adoption of CBMI, and what strategic actions are relevant on their path to reaching CBMI.

6.3 Key takeaways for policy

The insights presented in this study are relevant for policymakers at regional, national, and international levels who are concerned with circular economy initiatives and policies. When developing rules and regulations for circular economy, policymakers may benefit from considering the drivers, barriers, and strategies highlighted by the experts interviewed in this study. These experts also emphasized that the 34 proposed strategies have impact on all three levels (i.e., policy, industry, and company), but placed a particular emphasis on the policy level strategies, suggesting a pressing need for circularity-related policymaking. This result is consistent with the experts' recommendation to escalate circular economy policy frameworks and initiatives. Further corroborating this view, 75% of the experts ranked "Supporting regulations" as the greatest driver to CBMI in the built environment. Thus, the findings of this study clearly indicate that policymakers' attention is needed to assist companies in overcoming prevalent CBMI barriers and capitalizing on current CBMI drivers.

6.4 Limitations of the study

The limitations of this study relate to methodological aspects and the focus on one specific industry. The fundamental methodological limitations related to the selection of experts. Being a Delphi study, this research bases its findings on subjective opinions of experts who work with circular economy in the built environment. The subjective nature of the data and the geographically-limited sample may limit the findings' generalizability. Furthermore, the focus on one industry may limit the study's applicability across industries. However, the high-level discoveries, for instance the proposed categorization of CBMI strategies, can likely be generalized across industries and national borders. Moreover, the driver and barrier categories, as well as the recommended strategies, are provided by experts from the built environment, so these findings are not likely to be relevant in their entirety across every industry. However, they may be extensively applicable to other resource-intensive industries, regardless of geographical location.

6.5 Future research

On the basis of this study and its limitations, we propose a number of directions for future research. First, as this study considered CBMI particularly in the context of the built environment, future studies can explicate further by examining what company types may benefit from the respective strategies proposed, and assessing the applicability of each of the strategies in practice. Additionally, future studies can expand on this study by developing tools that enable companies across industries to identify the most impactful CBMI barriers and drivers in their specific contexts. Finally, the experts identified the impact of the impending material crisis on the industry, and the potential consequent critical juncture for the adoption of circularity in the built environment. Future studies could therefore investigate the impact of increasing raw material prices on resource-intensive industries, particularly the effect on CBMI implementation by this new financial, social, and geopolitical context.

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Appendix

Appendix 1. Table of drivers derived from interview round 1

Driver theme	Subtheme	Power quote	Supporting quote
Cost and competition benefits	Revenue benefits	"Cash is king and financial incentive is the main incentive" (Academic 4)	"I see that some of the companies that are acting on circularity now are doing it because they see it as an alternative to get more for the money" (Practitioner 11) "A lot of clients are willing to pay for sustainability now" (Academic 2)
	Competition benefits (Industry leadership)	"It is more about the actual willingness of the companies to become a leader and frontrunners for the sustainability agenda in our industry" (Academic 5)	"I think the question is, who will be the first to really on a large scale implement this into an actual building" (Practitioner 2) "The leading actors want to show that they are innovative and are leading the change towards building sustainably. So, for us, being a startup, we can piggyback on them because, they have big names and if they want to be the first ones building circularly, it is easier to convince others to build like that too." (Practitioner 3)
	Competition benefits (not falling behind)	"Not building sustainably is also a huge risk because you might not be allowed to do the building project, or someone might not be willing to live there or to buy the building." (Practitioner 7)	"The demand will come. So, companies they need to do it, because otherwise they will lose in the long run" (Academic 2)

		"An unacceptable risk is definitively that your company dies because you are not willing to adopt the circular agenda." (Civil servant 1)	
	Talent acquisition and retention	"In hiring situations companies are asked by new, high potential employees. What are your green ambitions? They don't want to work for the evil guy. So, for some companies, this change starts with the talent." (Practitioner 2)	
Sharing opportunities	Knowledge sharing	"Even though it is your competitor. If we have very interesting examples of companies that are doing really nice work within circular business model innovation, we need to share it. Companies are like humans; we like to compare and reach after each other" (Academic 8)	"There is a need for knowledge to be brought back from the market to the producers." (Practitioner 12)
	Data sharing	"Promoting transparency in the whole built environment, about objects, materials, products, etc. I think that would be the biggest asset that we can get to stimulate this whole circular movement." (Practitioner 8)	
	Sharing of successful examples and pilot projects	"It is really important to see, and experience what other companies are doing, I think that's really important. Even though it is your competitor. If we have very interesting examples of companies that are doing really nice work within circular business model innovation, across the supply chain." (Academic 8)	"The first question is, do you have any references similar to this building? Where we can see that it is actually working?" (Practitioner 14)
Collaboration and partnerships	Partnerships	"Partnerships are essential in order to create this across the industry, because all parts need to collaborate in order to create this." (Practitioner 10)	"We need to maybe stop thinking only I can do this. We need to try ways to partner up and make those partnerships accountable and take care of them and

			maintain them and be clear who does what and what is in it for me and so on." (Academic 5)
	Collaboration	"I don't think that it is something that cannot be done, but it will demand more of the stakeholders in the industry, it will demand more collaboration. That is driving us" (Academic 1) "You cannot build sustainably alone" (Civil servant 1)	"So, when you look at the whole value chain, if you create collaboration, I think you can create positive environmental, economic and social value across the value chain" (Practitioner 10)
Knowledge generation	Knowledge	"Now with the certifications, for example, they are also likely to have a division with people within their company only working with sustainability. I mean, if you're a small company, or small construction firm doesn't have a sustainability manager. Yeah, all the large construction firms have several of them. So, they have the knowledge." (Practitioner 3)	
	Training and education	"There's a lot of things going on also in the education area. There's a lot of knowledge institutions and science institutions that do research on it" (Practitioner 13)	"When the companies are educating employees with certifications, or knowledge sharing meetings, that is both increasing the awareness and connecting people that can collaborate" (Academic 1)
	Innovation	"I think you can see more and more innovation. And I think because there is a very big potential in the built industry as well. Like there are a lot of fields where you can innovate and explore potential new business models and values. So, I think it is easy to innovate and work with that. But I think the difficulty is to make it a new normal and to actually adopt it." (Practitioner 10)	

	Startups	"There are small startups that are trying to grow and serve that market. Sometimes, part of their business model is also really to create awareness. And they not only develop designs and products, but have also started a whole movement, that is a driving" (Academic 4)	
Increase of demand	Demand	"There is more demand now. I think mostly realizing that we cannot meet climate targets, if we're not looking at the embodied emissions and the materials and the way we manage materials throughout the lifecycle, I think that put circularity on the agenda and companies to experiment with circular building solutions." (Academic 4)	"It is just the backbone of capitalism, supply and demand, and that will regulate the market. So, I think that is probably the main drivers" (Academic 2)
Behavioral change	Mindset change	"I think there's more and more people who are just realizing or adopting the mindset that this is really, really serious." (Practitioner 2) "There's a traction towards new materials where you can see what it is made from instead of all these white, shiny surfaces, and you don't even know what the materials are made of. That's behind us." (Practitioner 9)	
	Following the influencers	"I actually see that a lot of ideas come from somebody with a burning passion. And then somebody else take over and make a business out of it." (Civil servant 2)	"Now, a lot of I see a lot of new type of talent entering the built environment, but for a long time, they weren't there." (Practitioner 7)
Supporting regulation	Policies	"But what will be the real game changer I think, is our policies, so where circularity is mandated, and companies need to be compliant with it." (Academic 4)	"I think the demands from the government is pretty much the primary driver right now." (Practitioner 13) "But other firms are driven heavily by the EU taxonomy. So this is where there will be a shift in the coming years." (Practitioner 6)

Grand societal challenges	Climate crisis	"I think there's an increasing amount of actors who have a genuine concern about climate change" (Practitioner 12)	"I meet companies where sustainability is a part of their soul, it is a part of the mission, it could be very well described on the homepage. But often it is not because they don't spend that much time on it, because they just do it." (Practitioner 6)
	Scarcity of resources	"Finally, they come to us now, because they're actually getting more and more into the situation where they can't find the products they used to do" (Practitioner 6)	"Another business driver is material scarcity which the construction sector companies are experiencing now. Secondary material supplies is just a new potential source." (Academic 4)

Appendix 2. Table of barriers derived from interview round 1

Barrier theme	Subtheme	Power quote	Supporting quote (s)
Conservative behavior	Lack of common language	"The way that I work with circularity in the Netherlands is based on something that is set up currently by the Dutch government. If I take this, and I walk past the border and go to Belgium, there is nobody who has a clue what this means." (Practitioner 8)	"But if I take a look at what we are doing, and what we are seeing in this whole circular environment, every country is doing it differently." (Practitioner 8)
	Lack of collaboration	"And for circularity, we know that it needs collaboration and that everyone in the chain is contributing to making something circular, but they are just a lot of individual parties, or individual actors with their own interests. And circularity is not a common interest by default." (Academic 4)	"I think it is difficult to innovate when you have to you kind of start over every time that you, you have a new building team and a new kind of project." (Academic 1)
	Lack of trust	"It is not possible to innovate if there is lack of trust in the value chain because we are all dependent on each other" (Civil servant 1)	
	Conservative industry	"I know our industry, I think we can be proactive, but we're still constrained by some boundaries, but we can be proactive." (Academic 5)	"It is an industry that is very hard to move. It is demanding." (Practitioner 5)

			“I think everything in the built environment moves a little slowly, right?” (Practitioner 2) “That's interesting, because I don't perceive it as slow” (Academic 8)
	Competition	“It wasn't working as a business model to have an architectural firm and upcycling firm in the same business. because there's all kinds of issues about open bidding for contractors and they're effectively specifying their own products on their own projects, which kind of goes against some EU competition rules” (Academic 3)	“It is hard trying to be a small company or a startup trying to provide circularity in a traditional industry” (Practitioner 4)
	Lack of inclusion and equality	“And the biggest problem for transitioning, if I look into diversity in the construction industry is not the amount of women in the business because there's a lot of women in the business. But to be honest, they're sitting in the wrong position, human resources, administration, health and safety, and corporate sustainability. And when the shit really hits the fan, and the project is out of control economically, then “the boss”, that is often a he, then he will dominate the sustainability and health and safety or human resource person,	

		because now we're in to save our business.” (Practitioner 6)	
	Habits	“I think we are so used to the way that things have been that we are unable to really fathom how things might be different because we are scared.” (Practitioner 2)	“And it is also the fact that there's so many unknowns when doing something differently.” (Academic 3)
Politics and regulation	Regulation	“The biggest barrier is that the regulations we have today are only for new materials (…) You can't have the same standards for new materials and for secondary materials. You need to relax the requirements” (Practitioner 13) “Why do animals have rights, but materials do not?” (Civil servant 1)	“Due to political considerations, a lot of things has to be quite efficient on the building side.” (Academic 1) “Regulation is currently not lowering the barrier of entry, but are actually ensuring that companies are better off just keeping it business as usual” (Academic 5)
Lack of knowledge and data	Lack of data	“I think digitizing information within individual companies is something that they need to fix. And if you don't fix it now, you will be so far behind all your other competitors, that you would really have a business problem” (Practitioner 8)	“There's a data gap. So it is difficult to measure if we look at the climate footprint what happens if we use some reused bricks instead of a new slate facade, because we don’t have the data” (Practitioner 1)

	Training and education	"I would be reluctant, and I will be slightly slower to adopt a new technology or, you know, offense in innovation in the industry, because I might have to train all the workforce again, and might have to re-engage my suppliers, I might have to re-specify my requirements."	"Many employees have no knowledge of the existence of documentation. They have no knowledge on how to use the data and how that data can put their products in the market compared to competitors. So, this awareness is not in place" (Practitioner 11) "So, I would say, a huge barrier at present is really education. It is like, like, what, how do we know what the barriers are? If we don't even really know what a circular economy business model is, in means, right? And what that looks like?"
	Technology	"People that are green within the area need to use technology, Google, and find research papers, whitepapers and knowledge centers and they reach out to people to gain knowledge" (Practitioner 6)	
Shared responsibility and liability conflicts	Responsibility conflicts	"And we need to deliver most importantly, documentation and responsibility issues, which is the biggest issue when working with reuse materials." (Practitioner 6)	"It is really hard to place responsibility, because I think that people tend to point at each other, right? Like the contractor partner points at the client, the client points at the regulation, regulation points at the private industry, all pointing in this circle" (Academic 2)

			"I think it is a big like showstopper that no one is willing to take the responsibility." (Academic 1)
Sourcing of secondary materials	Geography	"Maybe there are some banks already in Copenhagen, but it is a bit far away for us when we are in in the middle of the country. So, we have to transport the secondary materials and you can't inspect it by yourself." (Practitioner 5)	"Where do the materials come from, where can I pick them up and how long must I transport them, that is a concern" (Academic 6)
	Stable delivery of uniform materials	"How do we know how much there is? Are we going to be able to get hold of it all the time? And by the time we need it?" (Academic 6) "We need scale and uniformity of secondary materials." (Civil servant 1)	"We really see companies saying they need a guarantee that they could have the same material every month, and that all the materials are the same each time" (Practitioner 2)
	Storage	"It is hard to reuse or save materials because it is easier to get rid of it due to lack of space" (Academic 1)	
	Time consuming to source materials	"It is just extremely hard to source what we need in time" (Practitioner 1)	"It is hard to, to know where to find the materials. I think that is very much what is stopping us" (Practitioner 5)

	Guarantees of quality of secondary materials	"If there were some guarantees the industry could use it (secondary materials), but we must know what we are buying" (Practitioner 5)	"It is also that materials can be old, can behave in different ways, and they have different exposures. So, you cannot just generalize or make one system that fits all materials in one category, because materials can be exposed to very different environments throughout their lifetime, right. So, if you take a beam out in one building, it will not behave the same way as a beam in another. So, it is really hard to guarantee the quality" (Academic 2)
Lack of scalability	Lack of demand	"The market demand will only increase very slowly in volume, as such there's not going to be that boss interested in investing into to circular construction materials basically." (Practitioner 12)	"It is a question about the hen and the egg what comes first, we need people to make big orders in orders for companies like us and others to invest and to take the chance to go full on because we need to produce in big volumes in order to reach affordable prices. But the problem is that very few are willing and interested in placing big orders in very small companies where they don't have things on stock." (Practitioner 6)
	Lack of scalability	"But we still need to see much better results in terms of actually delivering co2 reductions from circularity. And I think one of the reasons like we haven't seen enough of that. One, because we haven't scaled enough yet." (Practitioner 7)	"If we could build a whole building made of a reused material, and the price would also be on a fair level where our business case would work, then we would definitely explore that road. But right now, it is really difficult to do that due to the limited scalability" (Practitioner 1)

Finance	Additional costs	"So, there's this pressure on prices on buildings not rising, so the engineers can't spend time on doing circularity and the architects are maybe copying a solution that they already had used on another project." (Practitioner 9)	"If you want to push the circular way of thinking forward, you also need to think about all that it is not just the material costs. We may build cheaper, but you also have the wages of the people who has to transport it, and remodel it or rebuild it again. That's often more expensive." (Practitioner 13)
	Revenue benefits being put first	"I think the biggest barrier is that the built environment is essentially a service to the financial industry. It has become an asset class, to the degree where the ultimate valuation of a building's success is the financial outcome, not the actual building (…) And that means that the built environment is not necessarily the most innovative, but the innovation that has happened has been on reducing price and time" (Practitioner 7)	"So I think that what hinders the development is that there is so much focus on the economic value now, instead of looking a bit more long term and looking at the economic value that may come 10-20-30 years in the future, and also even after five years or three years." (Practitioner 10) "I think the biggest problem is the need for finance" (Academic 1) "Not seeing the financial benefit yet has been the biggest barrier, I guess" (Practitioner 8) "If you're just building a building and then selling it, then you wouldn't be interested in investing in expensive and long-lasting products." (Practitioner 9)
Complexity and risk	Warranties and insurances	"It is a problem that there is no insurance covering secondary materials, insurance hasn't matured for that. So, we have had to go meet with the top CEO in a big insurance company. And he had to give	

	an exception so we could get the project approved. So, the companies are fighting to do this." (Civil servant 2)	
Risk of delay	"When the system is set up to reward efficiency, what is an acceptable risk?" (Civil servant 1)	"I think circularity would often create extra work, because it is not as tested, not as established. And there are so many reasons why something could fall under the table or scratched off the list of ideas." (Academic 4) "Nobody can be delayed by anyone else or there's going to be massive penalties. And so delivery on time is essential, then nobody's going to want to use a supplier that doesn't have a track record and doing that." (Academic 6)
Complexity of building projects	"Buildings are very specific types of products. So maybe it is particularly difficult. Maybe also, all the standards and performance requirements that buildings, with very good reason need to fulfill, make it more difficult" (Academic 4)	"There's a sort of slowness and reluctance across the industry, I think. And I think it is partly just down to the fact that doing a building is an expensive and risky thing. Like there's so much to go wrong when you're building a building, that most of the time, people just want to do the stuff that they've done before" (Academic 6)
Complexity of industry and supply chain	"The main reason why the construction industry is in many ways difficult, is that the value chain is so long, and the amount	"I would point to the value chain as a main area of obstacles, because the construction sector is so interwoven, and the building chain is so fragmented, because you need so many

		of interest stakeholders is so diverse." (Practitioner 6)	different capabilities and each capability for each company." (Academic 4). "I think one hypothesis is that the construction industry typically has a very, very long and complex supply chain. So, I'd say that the sector might be slower to adopt innovation because you have to convince and bring together many different stakeholders." (Academic 8).
	Unwillingness to take risk	"So, there's a big risk in terms of who will take the risk" (Academic 1)	"They will go in the direction where they risk the least. That's how simple it is, and everyone sticks to the well-known products that is well documented and that's it." (Practitioner 12)

Appendix 3. Table of strategies from interview Round 1

Strategy	Power quote	Supporting quote
Changing communication strategies	"So, we used to be very happy go lucky (…) But now we are trying to change into a more serious approach stating that we don't have enough materials. The prices of materials are increasing like crazy. So, we have a viable alternative" (Practitioner 2)	"The customers needs to see circularity as better business. We need to play them good, so therefore we need to guide our sales staff and communicate differently to the customers" (Practitioner 11)
Establishing hubs	"We recommend that companies could partner up with different companies from the different parts of the value chain. Because we are not all experts in everything, so we need to take the experts from the specific area." (Practitioner 13)	"I think one thing that would be extremely beneficial, was if there was an opportunity to create more sort of safe spaces in the industry in general, but also within the project to share knowledge, but also share risk and sustainability impact" (Practitioner 7) "If a hub was created, you would need to make sure that all the companies that were in that hub, were actually equally passionate about making it work without trying to win on their own" (Academic 4) "So, we're actually no longer seeing that sort of increase in wellbeing with the increase in our economic wellbeing. So maybe there was an opportunity there also, to combine the two and look towards creating new types of business models for buildings that has also that social element and that cocreator opportunity" (practitioner 7)
Changing perceived value of waste	"But just coming into our showrooms, even on a startup budget should try to make it look exclusive, so that you want to touch it and use it. Even though, most of those things we've literally been into containers to pick up." (Practitioner 2)	

Changing ownership structures	"We need to incentivize quality. So, if we keep ownership throughout the building's lifecycle, that's definitely an obvious way to do that" (Practitioner 7)	"So due to a change in ownership model, we will have a long-term perspective, and are also more naturally inclined to think much more circular and in repetition, because when we construct the building, we know that a lot of the things during the years will be changed again and again and we must maintain it (Practitioner 1)
Changing growth parameters	"The definition, we have been setting up for growth for decades, we need to figure out how can we still define growth, because we need growth in order to have an income to pay for the healthcare system, and to pay for the schools and everything. We actually need growth in some way, in a society. And up until now for many decades, the only real growth parameter we have been able to focus on is the gross national product of the country. And we have still not as for I see, figured out how to make a society system and economical system that figures out how do we make an incentive for you and I to buy less clothes, to use less energy to take care of our materials? Because that means that we are actually using less? And who can make a business on consumers using less? So it is just a very difficult topic, and how do we create businesses that make money based on the fact that we are not going to use more, that is a huge problem" (Practitioner 6)	"I think we should revalue the whole economic system, you know, maybe not focus on GDP anymore." (Practitioner 10)
Leasing models	"I'm a big fan of leasing and think of Phillips, they had this service of leasing their products to huge office buildings. And it makes sense to have their own products going back to their own product line in terms of the small parts. Then they always have data on it, but also have their own people with the knowledge to service their own parts (Practitioner 14)	"And there also more sophisticated business models that are not only circularizing the offering itself, the product itself, which is the apartment but also the adjacent stream of services that you have. So instead of saying - I have my own washing machine, I have my own lawn mower, and so on so forth, the circle is the streams of services that are connected to your house as well" (Academic 8) "I think the difficulty will be the valuation of the elements in between each lease. How do you assess the quality of your material after a 20 year period, for instance? And then you would need

		techniques to say if a material is the same as it was 20 years ago, or if it has this degraded" (Academic 7)
Increasing responsibility of public entities	"I think it is easier for them (public entities) to be involved in the long term. So I think, talking about maybe reusing elements or a fully circular model, if I had to start somewhere, I think I would start with public entities and try to incite them to go in that direction, because they will be able to take the risks." (Academic 7)	"So I think the power of public authorities, it is something not negligible." (Academic 7)
Co2 and climate calculations	"If I could recommend companies to start with something it would be to start by looking at their own company, and do thorough climate mapping and climate calculations" (Practitioner 13)	
Take-back systems	"They (Takeback systems) can be used men companies do not want to be dependent on external material suppliers in the future." (Practitioner 8)	"When you're asked if we can see push from clients it is usually the material prices that makes them become more interested. They're asking about the possibility to reuse and design for disassembly, or take back systems." (Practitioner 10)
Reducing taxes	"It could be necessary to remove tax on reused or recycled products and materials. I think would push it (CBMI), and to increase adoption of secondary materials I think we must remove tax on reused and recycled raw material" (Practitioner 10)	

Developing material passports	"Material passports are a great strategy but we need to ensure that all the pieces around it really works. So that material passports actually have a function. I'm really curious about how we as an industry are going to make that happen?" (Academic 5) "I think material passports can reduce risks." (Civil servant 1)	
Starting bottom up	"I recommend grassroot movements because people are driving change. They want to feel better with themselves and the environment, being more circular and sustainable. And the increase in conscious awareness can become a very strong driver" (Academic 8)	
Starting top down	"So I really think that policies and regulations and laws and things like that are very strong, top down drivers for circular business model innovation." (Academic 8)	
Establishing circularity oriented education	"I really think one way of doing it, is because the biggest and most impactful way of creating a change is to create a new education." (Civil servant 1)	
Starting with low-risk projects	"It is not going to save the world. No way whatsoever. It is such limited volumes, but it is something that we'll be able to show you, and point the direction the customers wants. It is also a tool to change the attitude from the construction staff on the building sites on how they look on the circularity of manufacturing and waste handling and things like that." (Practitioner 11)	"I recommend that you start in the low-risk areas, like in sheds in the yard or maybe only doing parts of a building with some new material or building method, and then you can scale it up." (Practitioner 9) "Direct reuse is really hard, so that is why companies are trying to make sheds, etc. which has lower risk." (Civil servant 1)

Prefabricating	"I really believe in industrial production of houses and prefabricating as much as you can, because then you can have modules and parts that can be easily moved around or changed or demounted." (Practitioner 3)	
Advising for circularity	"Whether it is public or private building owners, developers, and entrepreneurs. They need help, especially on the building site, how can they be more circular? How can they be more sustainable? How can they contribute in a positive way? How can they structure the documentation demands to achieve certifications on sustainability? Or follow the EU Taxonomy" (Practitioner 13)	
Establishing material banks	"I think right now we need some supply from those who are going to have these banks of materials. That is what's missing, because right now I wouldn't know where to go or where to call or where to get this circular material or how many of each material there are. Or if you can choose the dimension or if you are you going to design the building after what is it possible to get? So I think it is a bit hard. I think it is a bit difficult right now. (Practitioner 5) "We need two types of material banks. The banks that offer data, and the bank that offers materials." (Civil servant 1)	"So that is a very big issue that all of our customer, they think they can get every secondary material everywhere but it is not possible now. They need that" (Practitioner 11)
Procuring materials locally	"I guess with circularity, we're looking for greater resilience in some way. And my view is that there should be of emphasis on more local material procurement, and processing and production" (Academic 3)	
Sustainability committees	"Having green committees that are taking care of, or getting in more circular projects or ideas to the company" (Practitioner 5)	

Increasing ambition levels of policy and regulation	"I think regulation should really sit down and see the touch points where regulation would just lower that barrier of entry and make that happen." (Academic 5)	
Serving multiple roles in the value chain	"I think actually playing multiple roles in the value chain is going to be key for circularity." (Academic 4)	"There's no one who's integrated throughout the value chain and who can just crunch the whole thing and make the value chain work in a different way. It is always reliant on lots of people working together to do something different, which naturally is harder to move." (Academic 6) "Owning more of the value chain, for instance having design and manufacturing within the same firm. And being able to develop complex, ambitious projects, having extensive data, for instance about much waste you have, and what you might be able to do with that" (Academic 3)
Increasing focus in the planning phase	"We must allocate more time early on in a project." (Civil servant 1)	
Open-source data	"The state should ensure open-source data and documents about various materials and components." (Civil servant 1)	
Funding support for risk takers	"There should be funds that support companies who are willing to take on risks in projects." (Civil servant 1)	
Designing based on material availability	"In architecture, a focus has been "Form follows function" indicating that the shape of the building should relate to its intended function or purpose. But going forward, I think we should use	

	"Function follows form", and design buildings dependent on what materials we have and what is available to us." (Practitioner 14)
Developing common language	"We need a common language, and I agree with that, we must develop a common language or certainly a shared understanding of what we mean." (Civil servant 1)
Lobbying	"And then I think there is an old-fashioned strategy that we shouldn't neglect, and that is lobbyism." (Civil servant 1)

Appendix 4. Interview guide – First-round interviews

Themes	Main Questions	Sub Questions
Introduction	What is your current role?	• What is your educational background? • How do you work with circularity in your position? • What is your understanding of CBMI?
Drivers and barriers	What are the most imminent hindrances when adopting circular business model practices? What are the greatest drivers of circular business model innovation?	• Do you see resistance from your supply chain regarding adopting circular business model practices? • Do you perceive that any of the barriers / drivers are due to your geographical location? • What would you recommend policymakers to do in order to increase circularity in the built environment?
Strategies, tactics and data	What kind of strategies or actions do you believe can be used to foster circular business model innovation in the industry?	• If you could give any recommendations to companies in the built environment wanting to adopt circular business models, what would it be?
	How do you think CBMs are applicable to companies operating the built environment?	• Would you say CBMs are more difficult or easy to employ in the construction industry than other industries?
Industry	What could you recommend to the industry to speed up the transition?	• Do you believe the construction industry is moving slowly or fast when it comes to the circular transition? And why?
	Do you see a push for CBMI in the supply chain and the industry?	

Wrap-up	What do you believe I should ask the other experts about? Is there anything you would like to add or talk about?

Appendix 5. Input from experts through the written accounts round

Strategy
Think tanks
Rewarding impact through certifications
Carbon tax
Tracing of secondary materials
Reschooling of employees

Appendix 6. Strategies proposed by the experts grouped into Policy, Company and Industry level

	Policy level	**Industry level**	**Company level**
Understanding the loop	Establishing circularity oriented education	Establishing hubs	Leasing models
		Establishing think tanks	Sustainability committees
		Developing common language	Reschooling of employees
			Increasing focus in planning phase
Facilitating the loop	Increasing responsibility of public entities	Establishing material banks	Serving multiple roles in the value chain
		Procuring materials locally	Establishing takeback systems
		Changing ownership structures	Prefabricating
		Developing material passports	Designing for disassembly
		Designing based on material availability	
		Tracing of secondary materials	
Promoting the loop	Funding support for risk takers	Changing perceived value of waste	Advising for circularity
		Starting bottom up	Changing communication strategies
		Rewarding impact through certifications	Starting with low risk projects

			Starting top down
Regulating the loop	Reducing taxes Establishing carbon tax Establishing open source data Lobbying Increasing ambition levels of policy and regulation	Changing growth parameters	Assessing Co2 emissions and other climate impacts

Appendix 7. Full list of all recommended strategies by experts to the driver categories

Driver Categories	Top 3 strategies	Level	Recommended by percentage of experts
Behavioral change	Establishing circularity oriented education	Policy	70%
	Developing common language	Industry	55%
	Increasing ambition levels of policy and regulation	Policy	45%
	Changing communication strategies	Company	45%
	Reschooling of employees	Company	40%
	Starting bottom up	Industry	35%
	Advising for circularity	Company	30%
	Changing perceived value of waste	Company	30%
	Increasing responsibility of public entities	Policy	25%
	Funding support for risk takers	Policy	25%
	Establishing takeback systems	Company	25%
	Changing growth parameters	Industry	25%
	Establishing open source data	Policy	20%
	Establishing carbon tax	Policy	20%
	Leasing models	Company	20%
	Starting top down	Company	20%
	Assessing Co2 emissions and other climate impact	Company	20%
	Changing ownership structures	Industry	20%
	Rewarding impact through certifications	Industry	20%
	Establishing sustainability committees	Industry	20%
	Lobbying	Policy	15%
	Starting with low risk projects	Company	15%

	Establishing hubs	Industry	15%
	Establishing think tanks	Industry	15%
	Reducing taxes	Policy	10%
	Increasing focus in planning phase	Company	10%
	Designing for disassembly	Company	10%
	Serving multiple roles in value chain	Company	5%
	Designing based on material availability	Company	5%
	Prefabricating	Company	5%
	Establishing material banks	Industry	5%
	Developing material passports	Industry	5%
	Procuring materials locally	Company	0%
	Tracing of secondary materials	Industry	0%
Supporting regulations	Increasing ambition levels of policy and regulation	Policy	65%
	Establishing open source data	Policy	40%
	Establishing carbon tax	Policy	35%
	Developing common language	Industry	35%
	Increasing responsibility of public entities	Policy	30%
	Reducing taxes	Policy	30%
	Changing growth parameters	Industry	30%
	Funding support for risk takers	Policy	25%
	Establishing circularity oriented education	Policy	25%
	Rewarding impact through certifications	Industry	25%
	Lobbying	Policy	20%
	Advising for circularity	Company	20%
	Increasing focus in planning phase	Company	20%
	Establishing hubs	Industry	20%

	Establishing takeback systems	Company	15%
	Serving multiple roles in value chain	Company	15%
	Assessing Co2 emissions and other climate impact	Company	15%
	Changing perceived value of waste	Industry	15%
	Changing ownership structures	Industry	15%
	Developing material passports	Industry	15%
	Establishing think tanks	Industry	15%
	Changing communication strategies	Company	10%
	Starting top down	Company	10%
	Procuring materials locally	Company	10%
	Establishing material banks	Industry	10%
	Establishing sustainability committees	Industry	10%
	Leasing models	Company	5%
	Starting with low risk projects	Company	5%
	Designing based on material availability	Company	5%
	Reschooling of employees	Company	5%
	Tracing of secondary materials	Industry	5%
	Prefabricating	Company	0%
	Designing for disassembly	Company	0%
	Starting bottom up	Industry	0%
Knowledge generation	Establishing circularity oriented education	Policy	65%
	Establishing hubs	Industry	50%
	Reschooling of employees	Company	45%
	Funding support for risk takers	Policy	40%
	Establishing open source data	Policy	40%
	Advising for circularity	Company	35%
	Developing common language	Industry	35%

	Establishing think tanks	Industry	35%
	Changing communication strategies	Company	25%
	Increasing focus in planning phase	Company	25%
	Increasing responsibility of public entities	Policy	20%
	Increasing ambition levels of policy and regulation	Policy	20%
	Establishing sustainability committees	Industry	20%
	Starting with low risk projects	Company	15%
	Serving multiple roles in value chain	Company	15%
	Starting bottom up	Industry	15%
	Establishing material banks	Industry	15%
	Rewarding impact through certifications	Industry	15%
	Lobbying	Policy	10%
	Leasing models	Company	10%
	Establishing takeback systems	Company	10%
	Assessing Co2 emissions and other climate impact	Company	10%
	Changing growth parameters	Industry	10%
	Changing perceived value of waste	Industry	10%
	Changing ownership structures	Industry	10%
	Developing material passports	Industry	10%
	Reducing taxes	Policy	5%
	Establishing carbon tax	Policy	5%
	Designing based on material availability	Company	5%
	Tracing of secondary materials	Industry	5%
	Starting top down	Company	0%
	Prefabricating	Company	0%

	Procuring materials locally	Company	0%
	Designing for disassembly	Company	0%
Sharing opportunities	Establishing open source data	Policy	65%
	Establishing hubs	Industry	45%
	Advising for circularity	Company	35%
	Developing common language	Industry	35%
	Starting with low risk projects	Company	30%
	Reschooling of employees	Company	30%
	Establishing think tanks	Industry	30%
	Establishing circularity oriented education	Policy	25%
	Changing communication strategies	Company	25%
	Establishing sustainability committees	Industry	25%
	Lobbying	Policy	20%
	Serving multiple roles in value chain	Company	20%
	Assessing Co2 emissions and other climate impact	Company	20%
	Increasing responsibility of public entities	Policy	15%
	Funding support for risk takers	Policy	15%
	Establishing takeback systems	Company	15%
	Changing perceived value of waste	Industry	15%
	Changing ownership structures	Industry	15%
	Establishing material banks	Industry	15%
	Leasing models	Company	10%
	Starting top down	Company	10%
	Developing material passports	Industry	10%
	Increasing ambition levels of policy and regulation	Policy	5%
	Increasing focus in planning phase	Company	5%

	Changing growth parameters	Industry	5%
	Rewarding impact through certifications	Industry	5%
	Tracing of secondary materials	Industry	5%
	Reducing taxes	Policy	0%
	Establishing carbon tax	Policy	0%
	Designing based on material availability	Company	0%
	Prefabricating	Company	0%
	Procuring materials locally	Company	0%
	Designing for disassembly	Company	0%
	Starting bottom up	Industry	0%
Collaboration and partnerships	Establishing hubs	Industry	70%
	Changing ownership structures	Industry	40%
	Increasing responsibility of public entities	Policy	35%
	Funding support for risk takers	Policy	30%
	Establishing think tanks	Industry	30%
	Establishing open source data	Policy	25%
	Changing communication strategies	Company	25%
	Serving multiple roles in value chain	Company	25%
	Advising for circularity	Company	25%
	Establishing material banks	Industry	25%
	Establishing sustainability committees	Industry	25%
	Developing common language	Industry	20%
	Establishing circularity oriented education	Policy	15%
	Establishing takeback systems	Company	15%
	Starting with low risk projects	Company	15%
	Increasing focus in planning phase	Company	15%

	Reschooling of employees	Company	15%
	Starting bottom up	Industry	15%
	Lobbying	Policy	10%
	Leasing models	Company	10%
	Starting top down	Company	10%
	Developing material passports	Industry	10%
	Reducing taxes	Policy	5%
	Increasing ambition levels of policy and regulation	Policy	5%
	Designing based on material availability	Company	5%
	Assessing Co2 emissions and other climate impact	Company	5%
	Changing growth parameters	Industry	5%
	Changing perceived value of waste	Industry	5%
	Rewarding impact through certifications	Industry	5%
	Establishing carbon tax	Policy	0%
	Prefabricating	Company	0%
	Procuring materials locally	Company	0%
	Designing for disassembly	Company	0%
	Tracing of secondary materials	Industry	0%
Increase of demand	Funding support for risk takers	Policy	55%
	Increasing ambition levels of policy and regulation	Policy	50%
	Establishing material banks	Industry	45%
	Reducing taxes	Policy	40%
	Changing growth parameters	Industry	40%
	Advising for circularity	Company	35%
	Increasing focus in planning phase	Company	35%
	Establishing carbon tax	Policy	30%

	Developing common language	Industry	30%
	Designing based on material availability	Company	25%
	Changing perceived value of waste	Industry	25%
	Establishing hubs	Industry	25%
	Developing material passports	Industry	25%
	Rewarding impact through certifications	Industry	25%
	Establishing circularity oriented education	Policy	20%
	Establishing takeback systems	Company	20%
	Starting with low risk projects	Company	20%
	Assessing Co2 emissions and other climate impact	Company	20%
	Reschooling of employees	Company	20%
	Increasing responsibility of public entities	Policy	15%
	Lobbying	Policy	15%
	Leasing models	Company	15%
	Changing communication strategies	Company	15%
	Procuring materials locally	Company	15%
	Establishing open source data	Policy	10%
	Prefabricating	Company	10%
	Starting bottom up	Industry	10%
	Changing ownership structures	Industry	10%
	Tracing of secondary materials	Industry	10%
	Starting top down	Company	5%
	Designing for disassembly	Company	5%
	Establishing think tanks	Industry	5%
	Serving multiple roles in value chain	Company	0%

	Establishing sustainability committees	Industry	0%
Cost and competition benefits	Changing communication strategies	Company	55%
	Changing growth parameters	Industry	40%
	Funding support for risk takers	Policy	35%
	Establishing circularity oriented education	Policy	35%
	Reschooling of employees	Company	35%
	Reducing taxes	Policy	30%
	Increasing ambition levels of policy and regulation	Policy	30%
	Advising for circularity	Company	30%
	Starting with low risk projects	Company	25%
	Serving multiple roles in value chain	Company	25%
	Increasing focus in planning phase	Company	25%
	Changing ownership structures	Industry	25%
	Changing perceived value of waste	Industry	20%
	Establishing hubs	Industry	20%
	Rewarding impact through certifications	Industry	20%
	Lobbying	Policy	15%
	Establishing open source data	Policy	15%
	Starting top down	Company	15%
	Assessing Co2 emissions and other climate impact	Company	15%
	Establishing material banks	Industry	15%
	Developing common language	Industry	15%
	Increasing responsibility of public entities	Policy	10%
	Establishing carbon tax	Policy	10%
	Leasing models	Company	10%

	Establishing takeback systems	Company	10%
	Designing based on material availability	Company	10%
	Prefabricating	Company	10%
	Procuring materials locally	Company	10%
	Designing for disassembly	Company	5%
	Developing material passports	Industry	5%
	Establishing think tanks	Industry	5%
	Tracing of secondary materials	Industry	5%
	Starting bottom up	Industry	0%
	Establishing sustainability committees	Industry	0%
Grand societal challenges	Changing growth parameters	Industry	50%
	Designing based on material availability	Company	45%
	Changing perceived value of waste	Industry	45%
	Lobbying	Policy	35%
	Assessing Co2 emissions and other climate impact	Company	35%
	Increasing ambition levels of policy and regulation	Policy	30%
	Establishing carbon tax	Policy	30%
	Changing communication strategies	Company	30%
	Reschooling of employees	Company	30%
	Changing ownership structures	Industry	30%
	Increasing responsibility of public entities	Policy	25%
	Establishing circularity oriented education	Policy	25%
	Procuring materials locally	Company	25%
	Establishing material banks	Industry	25%

	Developing common language	Industry	25%
	Reducing taxes	Policy	20%
	Establishing hubs	Industry	20%
	Rewarding impact through certifications	Industry	20%
	Establishing open source data	Policy	15%
	Starting top down	Company	15%
	Serving multiple roles in value chain	Company	15%
	Prefabricating	Company	15%
	Increasing focus in planning phase	Company	15%
	Establishing sustainability committees	Industry	15%
	Funding support for risk takers	Policy	10%
	Establishing takeback systems	Company	10%
	Advising for circularity	Company	10%
	Designing for disassembly	Company	10%
	Developing material passports	Industry	10%
	Leasing models	Company	5%
	Starting with low risk projects	Company	5%
	Establishing think tanks	Industry	5%
	Tracing of secondary materials	Industry	5%
	Starting bottom up	Industry	0%

6. ARTICLE C

Title: Circularity and Resilience in Entrepreneurial Ecosystems – How Circular and Linear Startups Nurture Their Ecosystems

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Abstract

Despite the recent upsurge of scholarly studies on resilience in entrepreneurial ecosystems, there is a lack of theoretical consensus regarding how startups with different business models can nurture their entrepreneurial ecosystem to increase resilience in the face of crises. With the impending material crisis heavily impacting the built environment's material prices, material supply and project demand, startups aiming to gain a foothold in the industry are challenged. Using a qualitative approach grounded in case studies, this study examines four circular and four linear startups from the built environment that are part of the same entrepreneurial ecosystem: the Bloxhub ecosystem in Denmark. The study draws on theories of complex adaptive systems and panarchy and uses the four phases of the adaptive cycle model (exploitation, conservation, release and reorganization) to investigate the startups' resilience trajectory. The findings from this study contend that circular and linear startups differ fundamentally in how they nurture their ecosystems. As a result, their trajectories throughout the adaptive cycle and their resilience are affected differently. This study holds implications for policymakers, researchers and entrepreneurs wanting to secure startup resilience to crises through leveraging entrepreneurial ecosystems.

Keywords: Resilience, Entrepreneurial ecosystems, Panarchy, Crisis, Circular entrepreneurship, Circular business models.

1. Introduction

The notion that crises can provide opportunities is not new (Brockner & Erika, 2008). As Intel's former CEO Andy Grove put it:

> *"There is at least one point in the history of any company when you have to change dramatically to rise to the next performance level. Miss the moment and you begin to decline. Emotionally, it's easier to change when you are hemorrhaging." (O'Reilly and Tushman, 1997, p. 44)*

The built environment industry is confronted by a number of challenges. By 2030, three billion people around the globe will require new housing and, simultaneously, the Paris Agreement urges the industry to achieve carbon neutrality by 2050 (UN-Habitat, 2018). Currently, the industry is also struggling to operate normally as a raw material crisis has struck. This crisis stems from the shifting global conditions in recent years. Specifically, in the wake of the COVID-19 pandemic, industries worldwide experienced supply chain disruptions, production delays, and labor shortages (KPMG, 2022).

Moreover, in March 2021, the traffic in the Suez Canal, one of the busiest shipping routes globally, was declared suspended due to high winds with a cargo ship going aground (Lee & Wong, 2021). This resulted in global trade losses ranging from $6 billion to $10 billion (Allianz, 2021), as well as increased delivery delays and shipping costs (Li, 2023). Starting from February 2022, the Russian invasion of Ukraine has led to tens of thousands of deaths and instigated the largest refugee crisis in Europe since World War II. The supply bottlenecks that had formed during the pandemic were increasingly challenged by this invasion, particularly due to the rising energy and commodity prices that came as a result (Dabrowski, 2022; Hutter & Weber, 2022). At the same time, in February 2022, the world's advanced economies reached the highest levels of inflation since the early 1980s (Dabrowski, 2022). In June 2022, the EU's construction output was 2.3% lower than in February before the invasion of Ukraine. Moreover, many building materials have seen an increase in price since the outbreak of the COVID-19 pandemic, for instance, in normally stable materials such as concrete and brick, due to rising energy prices (ING, 2023). The supply chain disruptions and increase in energy prices have led to higher material prices and pressured construction firms to either increase their prices or find alternative solutions for building within their budgets (ING, 2022). As many as 50% of construction firms in the EU planned to increase their prices in 2022, the highest number since 1985 (ING, 2022). With a current loss of consumer purchasing power and higher mortgage rates, the contractors and developers will have less wiggle room to increase house prices due to the material cost increase (ING, 2022). In August 2022, 23% of the EU construction firms could report having production problems by virtue of a shortage of materials and many of the contractors were experiencing purchasing problems (ING, 2022).

As the material crisis intensified, affecting even the most resilient incumbent organizations in the built environment, it forced the industry to look for alternative ways to source materials and construct buildings and infrastructure. Interestingly, the material crisis presents an opportunity for circularity-oriented startups (from now on called 'circular startups') to increase their market presence, given the rising demand for circularity-oriented solutions and materials (e.g., reclaimed wood or reused brick and metal). However, circular startups also report unfavorable effects from the material crisis, such as reduced availability of secondary materials due to halted building projects, and decreased investments in the built environment. To leverage the material crisis, startups should know the most effective strategies to implement.

One concept offered in literature as an approach for organizations to deal with crises is resilience (Gunderson & Pritchard, 2002). Some authors contend that the most resilient organizations are better equipped to discover ways to take chances and benefit from a situation, or crisis (Aldianto et al., 2021). To develop resilience, a startup's entrepreneurial ecosystem and ecosystem agents can be critical (Khurana et al., 2022). The concept of entrepreneurial ecosystems is new and aims to offer a "systematic view of entrepreneurship" (Cavallo et al., 2018). When faced with a crisis, the connections formed in the entrepreneurial ecosystem can be used to build resilience, and the ecosystem can have a crucial impact on new ventures' emergence, growth and innovation efforts (Khurana et al., 2022; Acs et al., 2017; Bogers and West, 2012). However, there is no theoretical consensus regarding how startups, specifically circular startups, nurture their entrepreneurial ecosystems to gain resilience and, thus, to overcome crises and strengthen their position in the market. This study adds to this debate by addressing the following research question:

How can circular and linear startups nurture their entrepreneurial ecosystems to gain resilience in response to crises?

To address this research question, we utilized a multiple case study method, examining four circular and four linear startups in the built environment. All these startups are part of the same entrepreneurial ecosystem: the Bloxhub ecosystem in Denmark. This ecosystem is a viable context for this study as it connects 350 science institutions, organizations, and public bodies across the Nordics. It provides a physical community space in central Copenhagen, in which all ecosystem agents work to envision an urban future. This study examined how startups operate within this entrepreneurial ecosystem and how the material crisis impacts their resilience. We conducted semi-structured interviews with representatives from the eight startups, and the data collected exposed how the level of ecosystem nurturing has separated the circular and linear startups into two subsystems. They portrayed how these two subsystems impacted the entrepreneurial ecosystem's overall resilience.

Based on our findings, we make three core contributions. First, we present how the startups in this specific entrepreneurial ecosystem have grown into two separate subsystems due to their business model (circular or linear). Second, we employ a complexity lens to present how the circular startups have nurtured their ecosystem to gain resilience and, thus, to overcome the material crisis. Third, we present our theoretical model, which extends Holling's (1986, 2001) adaptive cycle model to four levels (startup, subsystem, ecosystem and industry level) to investigate how start-up-level resilience impacts the subsystem, entrepreneurial ecosystem and the industry levels.

This article continues as follows. Section 2 presents the existing literature on resilience in startups, circular entrepreneurship, entrepreneurial ecosystems, as well as complexity and panarchy theories, thereby illuminating the open discourses in the literature that this study aims to solve. Section 3 presents the methodology employed in this study. Section 4 presents the empirical findings. Section 5 discusses these findings and the study's implications on theory, practice, and policy, whereas Section 6 presents the study's conclusions, limitations, and suggestions for future studies.

2. Theoretical background

This section presents the theoretical background guiding this study, first by introducing the theory on resilience in startups and then introducing the literature on circular entrepreneurship. Further, it provides theoretical background on entrepreneurial ecosystems and connects it to the literature on resilience at the ecosystem level. Finally, to dive deeper into the discourse on resilience, this article adopts a complexity lens, by expounding on complexity theory, which then branches out into explaining the panarchy theory.

2.1 Resilience in startups

In literature, resilience is a concept that has been employed in a broad range of fields and disciplines, spanning from strategic management to ecology and focusing on various organizational and geographical settings (Williams & Vorley, 2014). Although the majority of studies on resilience have in the past focused on resilience at the individual or managerial level, an increasing amount of literature has recently focused on resilience as organizations' and societies' ability to anticipate, avoid, adjust and respond to possible risks or threats, for instance due to natural disasters (Howard et al., 2022; van der Vegt et al., 2015; Ortiz-de-Mandojana & Bansal, 2016; DesJardine et al., 2019). Gunderson and Pritchard (2002, p. 6) define resilience at the firm level as 'the ability of a system to persist despite disruptions and the ability to regenerate and maintain existing organization'. Ortiz-de-Mandojana and Bansal (2016) argue that resilient firms are sometimes required to endure short-term financial losses to realize longer-term benefits. Aldianto et al. (2021) state that a truly resilient organization will always discover ways to take chances and benefit from a good or bad situation.

When faced with crises or changing conditions, small businesses are more vulnerable and less prepared than larger ones, and tend to be hit the hardest (Kuckertz et al., 2020; da Paixão de Oliveira et al., 2023; Runyan, 2006; Rebmann et al., 2013; Turner & Akinremi, 2020). However, small businesses also tend to be particularly responsive to exogenous shocks as they are more adaptive, adjustable and innovative than large businesses (Williams & Vorley, 2014; Aldianto et al., 2021). Startups can be considered a subgroup of SMEs, primarily including young firms performing entrepreneurial activities (Aldianto et al., 2021; Petersen et al., 2007). The difference between startups and large firms mainly revolves around the accessibility to resources, revenue, leadership styles, organizational structure, and reactions to its external and internal contexts (Turner & Akinremi, 2020; Aldianto et al., 2021; Ghezzi & Cavallo, 2020). Runyan (2006) presented various reasons why startups tend to be hit the hardest when facing crises, including higher vulnerability, reliance on local government and institutions, lower levels of preparedness, and greater physiological and financial strain on business owners (Aldianto et al., 2021). Some authors argue that external shocks and crises can pose opportunities for entrepreneurs and firms if they can take advantage of periods of market and economic disequilibrium (Williams & Vorley, 2014; Cowling et al., 2014). Even though it has been argued that startups are particularly affected by crises and thus require organizational resilience, the studies focused on organizational resilience tend to be focused on large firms and well-established SMEs (Runyan, 2006; Aldianto et al., 2021; da Paixão de Oliveira et al., 2023; Ates & Bititci, 2011; Burnard & Bhamra, 2011; Demmer et al., 2011; Sullivan-Taylor & Branicki, 2011).

2.2 Circular entrepreneurship

An emerging concept at the intersection between entrepreneurship and circular economy literature streams is the concept of circular entrepreneurship (Zucchella & Urban, 2019; Cullen and de Angelis, 2021). Circular entrepreneurship is defined by Cullen and de Angelis (2021) as the process of exploring and exploiting opportunities in the circular economy domain. Zucchella and Urban (2019, p. 195) present a more detailed definition, referring to "the processes of formation and exploitation of opportunities, using both commercial and ecological logics to address environmental challenges with the aim of closing, slowing, and narrowing the loop of resources and regenerating/reconstituting natural capital". To date, most of the empirical literature on circular entrepreneurship is focused on large firms (Zamfir et al., 2017; Ünal et al., 2019; Cullen & De Angelis, 2021). However, the concept of circular economy is currently paving the way for new entrepreneurial opportunities across industries. The theoretical foundations of the circular economy are also found in industrial ecology and its related concepts (Ghisellini et al., 2016; Blomsma & Brennan, 2017). Even though the circular economy, similar to ecosystem theory, relates to ecological theory, the studies on ecosystems tend to relate to business ecosystems (Iansiti & Levien, 2004), industrial symbiosis (Chertow, 2007), industrial ecology (Ashton, 2008) and sustainable business models (Bocken et al., 2019). However, limited research has focused on this ecosystem perspective in the current circular economy literature (Kanda et al., 2021).

2.3 Entrepreneurial Ecosystems

The concept of business ecosystems describes the interconnected web of firms that collectively construct an integrated system ultimately creating value for customers and clients (Mäkinen & Dedehayir, 2012; Bahrarni & Evans, 1995; Teece, 2007). The metaphor of the ecosystem (ecological system) relates back to ecological sciences (Mäkinen & Dedehayir, 2012) and similarly to an ecological system in nature, with its diversity of interdependent species, the business ecosystem describes inter-reliant networks of organizations (Mäkinen & Dedehayir, 2012). Business ecosystems have gained popularity in strategy, innovation, management and entrepreneurship research (de Vasconcelos Gomes et al., 2018; Kanda et al., 2021). Within an ecosystem, firms may collaborate to deliver services or products, and all members of the ecosystem depend on other members for their survival and must contribute to the wellbeing of the ecosystem (Mäkinen & Dedehayir, 2012). Iansiti and Levien (2004) argue that the success and survival of the members of an ecosystem are affected by the ecosystem as a holistic entity that is in constant evolution.

Every industry contains ecosystems that each require knowledge, technical skills and financial support (Mathews, 1997; Zacharakis et al., 2003), and multiple authors, including Moore (1996), Zacharakis (2003) and Bahrarni and Evans (1995) pinpoint the various constituents of a business ecosystem based on their relation to a focal firm. First, the literature presents the actors responsible for the core value creation, consisting of the main suppliers and distribution channels. Followingly, the extended actors are described as the suppliers of secondary products or services, or suppliers' suppliers. Ultimately, the extended ecosystem is described as comprising the firms that affect the context, including the governmental agencies, authorities, universities and research institutions, customers, investors, venture capitalists and competitors (Bahrarni & Evans, 1995; Zacharakis et al., 2003; Pierce, 2009; Mäkinen & Dedehayir, 2012). In many ecosystems, the members compete for the same customers, but each core firm differentiates itself based on its product and service offerings (Pierce, 2009).

As startups tend to be more vulnerable than other firms (Runyan, 2006), ecosystems may be particularly important. In the last 15 years, the number of studies focused on entrepreneurial ecosystems has increased drastically (Theodoraki et al., 2022). Brown and Mason (2017. p. 5) define entrepreneurial ecosystems as "a set of entrepreneurial actors, entrepreneurial organizations, institutions, and entrepreneurial processes which formally and informally coalesce to connect, mediate and govern the performance within the local entrepreneurial environment". The entrepreneurial ecosystem perspective has gained popularity among scholars (e.g., Acs et al., 2017; Autio et al., 2014; Spigel and Harrison, 2018), policymakers and practitioners as a means to explain the complex interdependencies between different actors and activities which leads to new ventures' entry, growth and exit (Abootorabi et al., 2021). Some authors argue that the entrepreneurial ecosystem profoundly affects a startup's growth and development (Acs et al., 2017); thus, research is particularly important to advance knowledge on the topic. However, although the value of applying the notion of ecosystems to entrepreneurship has become increasingly supported in the literature, the literature stream has focused on conceptual advancement and framing. It lacks empirical studies (Abootorabi et al., 2021). Moreover, Mack and Mayer (2016, p. 2118) contend that a main limitation of existing literature on entrepreneurial ecosystems is its focus on "documenting the presence of system components, [with] little understanding of interdependencies between components." Roundy et al. (2018) also argue that studies on entrepreneurial ecosystems have principally concentrated on identifying the core attributes of well-established ecosystems (e.g., Klingler et al., 2016; Spigel, 2016). Therefore, this study aims to contribute to the gap in the literature which concerns that the academic research on the topic is mostly conceptual, and there is a limited number of empirical studies on how entrepreneurs and startups can employ ecosystems to improve their standing in the market they operate in.

2.4 Resilience through entrepreneurial ecosystems

As aforementioned, to overcome or exploit crises, the literature suggests that organizations require resilience. Existing literature has investigated resilience particularly at the individual level (i.e., the entrepreneur) or examined inter-organizational resilience (Khurana, 2022). Khurana (2022) argues that in times of crisis, ecosystem level partnerships are expected to intensify to build resilience, and Santoro et al. (2020) find that entrepreneurs who have formed strong stakeholder partnerships also have strong entrepreneurial resilience, indicating the importance ecosystems can play in new venture's resilience. Supporting the ecosystems' importance on new ventures' resilience, Roundy and Fayard (2019) find that vibrant ecosystems allow entrepreneurs to become more capable of sensing, seizing, and reconfiguring resources and opportunities. To date, studies have primarily focused on how crises or disruptions can challenge the resilience of business ecosystems (Ramezani & Camarinha-Matos, 2020) but limited research has examined how ecosystems may boost resilience, particularly at the startup level.

2.5 Complexity theory

Complexity theory has been identified to bridge natural and social sciences (Ison et al., 1997) and has led to developing social-ecological systems approaches and (Berkes & Folke, 1998; Berkes et al., 2003). Complexity theory deals with systems with complex structures (Lissack, 1997) and 'provides appropriate language, metaphors, and tools to examine how systems adapt and cope with conditions of uncertainty' (Ramezani & Camarinha-Matos, 2020. p. 17). It shows that self-organization will emerge by bringing organizations to the edge of chaos. Such entrepreneurial ecosystems' evolutionary dynamics are useful for uncovering the complex nature of an entrepreneurial ecosystems' adaptability and resilience.

Roundy et al. (2018. p.2) suggest that entrepreneurial ecosystems 'are best treated as systems and that systems theory, an analytical approach representing phenomena as sets of stocks and flows regulated by interactions (e.g., Hartvigsen et al., 1998), might provide an appropriate lens for understanding' entrepreneurial ecosystems. Past studies have identified the entrepreneurial ecosystem components and examined the connections between them (Roundy et al, 2018). However, scholars have argued that investigating the entrepreneurial components separately, the completeness of entrepreneurship is overlooked, and by isolating the individual parts of the system it is not revealing the causal mechanisms in the system (Anderson et al., 2012; Roundy et al., 2018).

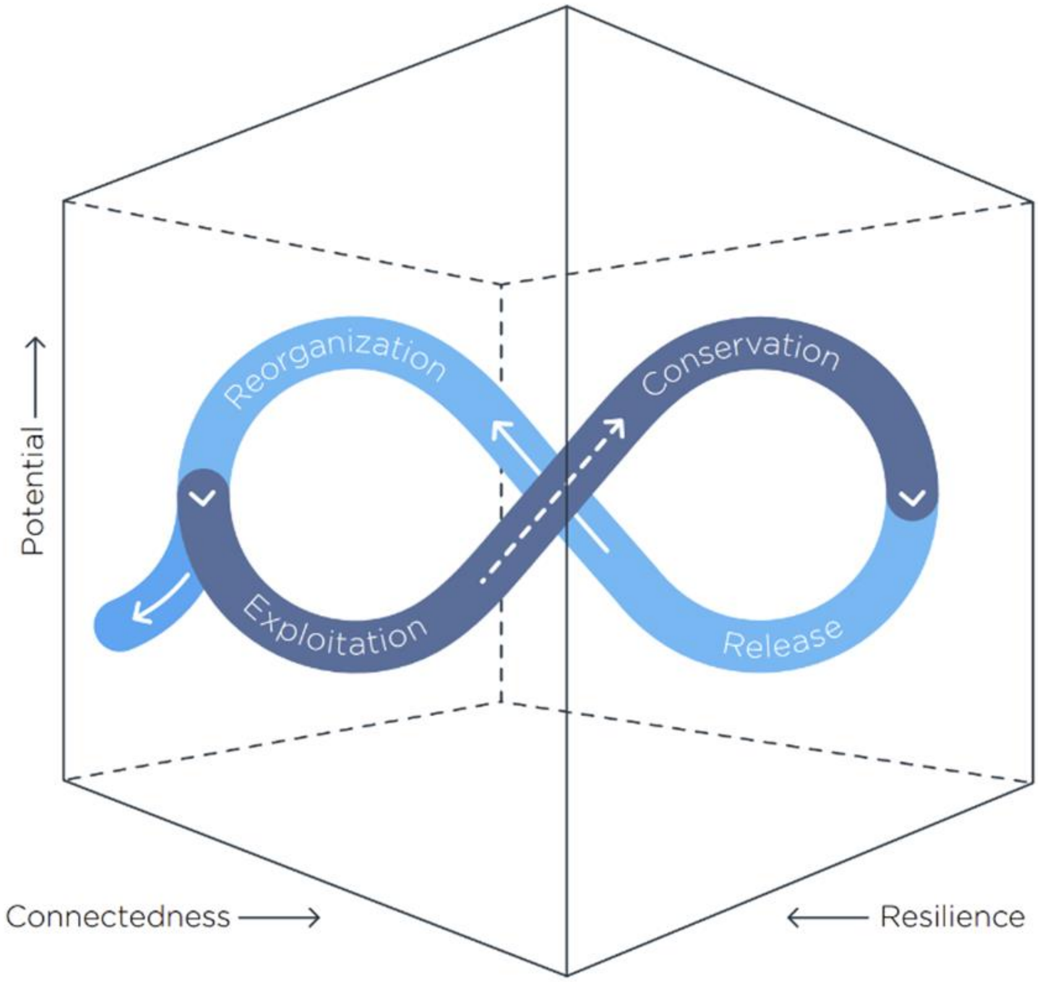
Studies examining systems theory have employed two approaches, in which one supposes that systems are commonly in, or near, equilibrium (Roundy et al., 2018). This approach refutes that there is a need for assessing dynamic relationships and nonlinear interactions between the elements in the system, and rather concentrates on separating and parameterizing stable, individual components (Manson, 2001; Roundy et al., 2018). Moreover, the second approach suggests that there exists a subgroup of non-equilibrium systems – complex adaptive systems (CAS) – which do not operate in equilibrium, and that these systems cannot be explained using general systems theory (Roundy et al., 2018). This lens, called complexity theory, has been tied to resilience by multiple scholars, particularly, Cumming et al. (2005) employ resilience to investigate core dimensions of complexity and change, and propose that a given system's resilience is dependent on four elements:

1. Components which make up the system, for instance the particular ecosystem types/habitats, species (e.g., consumers and producers), and biophysical features (geomorphology, soil structure, topography) (Cumming et al., 2005);
2. Relationships among components which involve nutrients and biogeochemical cycles, trophic interactions and food webs which link organisms to each other and their biophysical environment (Cumming et al., 2005);
3. Diversity (specifically biological) which is a main source of innovation and renewal within the system, including response diversity (the diversity of responses to environmental change between species adding to the same ecosystem function (see Elmqvist et al., 2003) (Cumming et al., 2005); and
4. Ecological memory and continuity which offers a surrogate of the ability of the system to self-maintain through space and time and continue to self-organize (Cumming et al., 2005).

2.6 Panarchy

A facet of complexity theory is panarchy, which concerns the dynamics of complex adaptive systems and their resilience in a fast-changing world. It is an aspect of complexity science that is rooted in resilience theory and it describes the hierarchical organization, connectedness of scales, and dynamic system structure (Gunderson & Holling, 2002; Allen et al., 2014). Panarchy argues that complex adaptive systems follow the movement along four phases of development (exploitation, conservation, release and reorganization), and transition from one phase to the other follows the pattern of an adaptive cycle (Figure 1). The adaptive cycle was originally conceptualized by Holling (1986, 2001) to construe the dynamics of complex ecosystems in response to change.

Figure 1. The adaptive cycle, own illustration adapted from Holling, (1986, 2001)



As illustrated in Figure 1, the adaptive cycle represents the development of complex adaptive systems and ecosystems and comprises four phases (Gunderson & Holling, 2002):

1. Rapid growth and exploitation: periods of exponential change in which resources are easy to attain, and capital is accrued.
2. Conservation: periods of increase in rigidity in which resources become increasingly hard to attain.
3. Collapse or release: periods of readjustment and ruin characterized by rapid capital loss.
4. Reorganization or renewal: periods of reorganization and renewal in which novelty wins.

Figure 1 also depicts the three salient dimensions that determine change in an adaptive cycle: potential, connectedness and resilience (Gunderson and Holling, 2002). The potential dimension defines “the inherent potential of a system that is available for change” (Holling 2001, p 393). The connectedness dimension represents a system’s ability to internally control its destiny (Holling, 2001). Lastly, the resilience dimension concerns the whole system’s capacity to absorb disturbances while maintaining its function and control (Gunderson & Holling, 2002). Panarchy theory focuses on the sustainability of an ecosystem, which entails the ecosystem’s continuous adeptness to reach its equilibrium state or several equilibrium states when confronted with severe shocks (Boyer, 2020). Chikumbo and Norris (2015, p. 115) argue that panarchy encapsulates the “notion that complex systems are not static, and change through a cycle of growth, accumulation, destruction, and renewal”. Table 1, below, presents the characteristics for each phase of the adaptive cycle (exploitation, conservation, release and reorganization), and have been derived from existing literature (Auerswald & Dani, 2017; Boyer, 2020; Fath et al., 2015; Wieland, 2021).

Table 1. The adaptive cycle - phase characteristics (derived from Auerswald & Dani, 2017; Boyer, 2020; Fath et al., 2015; Wieland, 2021)

Adaptive cycle phases	Characteristics of phases from literature
Exploitation	- New players arise, which strengthens the ecosystem - Environment becomes healthier and more predictable - Connectivity increases - Complex relationship between cooperation and competition are shaped - Self-organized relationships are formed - High return on investments - Orchestrators emerge to improve coherency - Competitive processes fosters new monopoly/oligopoly situations which harms diversity in the ecosystem - Connectivity is strengthened due to clustering processes - Exploitation of technological fields or new markets - Ecosystem operates at full speed

	- Ecosystem becomes increasingly attractive to investors, entrepreneurs and talent - Core-business and target markets are well identified
Conservation	- Initially significantly low growth rate that declines or goes into zero - Ecosystem gets increasingly fragile and vulnerable to shocks because of low resilience - Ultimate utilization of a technological cycle - Hyper-specialization - High degrees of connectivity among the actors - A fitting institutional environment is shaped - Competitive advantage via differentiation or cost - Technological waves that support competitiveness decrease - Relationships become increasingly hierarchical and formal - Firms might become rigid and bureaucratic
Release	- Crisis disturbs the state of ecosystem - Market changes impact agents - New technological changes - Connections are broken - Regulatory mechanisms weakened - Conditions for chaotic behavior are reached - Value capture of incumbent firms reached through monopoly or oligopoly positions is destroyed - Perceptions of being in a situation of uncertainty - Trust and confidence breaks down - Control mechanisms are weakened - Social boundaries divides firms - Delocalization of firms and industrial activities - Decline of foreign investment - Loss of competitiveness - Drop in sales - Drop in value - Emergence of other firms offering higher quality at lower cost
Reorganization	- Diversity is essential - The communities exploit the opportunities of harsh conditions - Agents develop new relationships to strengthen each other - Future is starting to look more predictable - Future seems less inflicted by crisis outside of ecosystems' control - Co-creation - Regeneration - Restructuring of the ecosystem - Exploration

	- Need for creative class - Disruptive innovations are developing from pre-existing niches - Risk takers are more likely to expand - Conditions for a good environment for startups are met - Fosters development of new products and services - Establishment of new business models - Establishment of new markets to capture value - Success stories are generated and create confidence - Fosters more complex relationships - Attraction of new developer communities and business opportunities - Actors position in the ecosystem is changing - Ecosystem is stable enough for stakeholders to move forward together - Material flow is becoming more secure

3. Methodology

3.1 Data collection

The empirical investigation of this study aims to examine how circular and linear startups can nurture their entrepreneurial ecosystem to gain resilience in response to crises. We have selected a qualitative multiple case study method for the data collection (Eisenhardt, 1989). This method is particularly fitting as case studies in organizational research elucidate the appearance and withdrawal of activities, structures, and resources which may reveal organizational inaction and the change of contextual circumstances (Dougherty, 2002; Hofman & zu Knyphausen-Aufseß, 2022). Moreover, the use of case studies allows in-depth collection of data, and particularly, the multiple case approach permits the researchers to contrast and complement between the individual findings from each case (Yin, 2014). The multiple case study method is thus an appropriate approach for under-explored topics, as the one examined in this study.

The unit of analysis in this study is the startup that is embedded in an entrepreneurial ecosystem. Therefore, the data has been collected across four circular startups and four linear startups in the Bloxhub entrepreneurial ecosystem in Copenhagen, Denmark. The case selection process was based on purposive sampling principles, and we selected eight cases as the sample for our study. Eisenhardt (1989) argues that despite there being no ideal amount of cases, between four to ten case companies are recommended as it is strenuous to generate a strong theory with less than four cases, and onerous to manage the amount of data that comes with more than 10 cases (Eisenhardt, 1989; da Paixão de Oliveira et al., 2023). To select our case studies, we adhered to the following criteria: i) there should be an even split between startups with linear and circular business models in the final sample; ii) the startups must be based in Europe; iii) the startups should operate within the built environment; iv) for each startup being part of the sample at least three individuals with insights on the startup's entrepreneurial ecosystem should be available for interviews; and vi) the startups should belong to the Bloxhub entrepreneurial ecosystem. The reasoning behind selecting only Europe-based startups was that the material crisis is currently predominantly affecting the construction industry in Europe. We included a criterion stating that a minimum of three representatives from each focal firm and its surrounding ecosystem needed to be available to partake in our study, to ensure covering a sufficient understanding of each startup's role in the entrepreneurial ecosystem. By adhering to these criteria, we tapped into Bloxhub's databases to identify relevant cases, reaching out to startups within this entrepreneurial ecosystem. Initially, four circular startups and three linear startups consented to participate. However, we secured participation from an additional linear startup using the snowballing technique.

The primary data in this study was collected through semi-structured interviews, and this approach was selected as it enabled us to pose the same set of interview questions to each interviewee while also enabling us to ask follow-up questions and clarifications when necessary and collect detailed insights (Bryman & Bell, 2015). Since we aimed to analyze the ecosystem's resilience, we synthesized the ecosystem from the perspective of multiple ecosystem agents for each case company (e.g. founders, board members, civil servants, researchers). The interview participants were asked to identify the ecosystem agents with which they collaborate the most frequently, and the snowballing technique was used to recruit further interview participants until reaching the data saturation point in which new data tend to be redundant (Saunders et al., 2018; Grady, 1998). The primary data from the semi-structured interviews were complemented and triangulated by three on-site visits to the Bloxhub facilities and a collection of publicly available secondary data. The interviews lasted between 30 and 60 minutes and were conducted and recorded on Microsoft Teams. We collected data until reaching the data saturation point (Saunders et al., 2018; Grady, 1998), and the semi-structured interviews were all transcribed verbatim within 24 hours to codify the data. Table 2 presents the overview of the interview participants from each case company and the forms of secondary data collected.

Table 2. Case study participant overview

Ecosystem	No. of interviewees	Interview Participants	Secondary data
Circular startup 1	5	Co-founder (Participant 1)	- Company website - Bloxhub website - Video - Social media posts - Pitch decks
		Director (Participant 2)	
		Board member (Participant 3)	
		Innovation hub partner (Participant 4)	
		Director of co-creating startup (Participant 5)	
Circular startup 2	4	Director (Participant 6)	- Company website - Bloxhub website - Social media posts - Pitch decks
		Board Member (Participant 7)	
		CEO of co-creating startup (Participant 8)	
		Civil servant (Participant 9)	
Circular startup 3	4	CEO (Participant 10)	- Company website - Bloxhub website - Social media posts - Pitch decks
		COO (Participant 11)	
		Materials and implementation manager (Participant 12)	
		Civil servant (Participant 13)	
		Co-founder (Participant 14)	- Company website

Circular startup 4	5	Co-founder (Participant 15)	- Bloxhub website - Social media posts
		Co-founder (Participant 16)	
		Academic researcher - Building innovation (Participant 17)	
		Civil servant (Participant 18)	
Linear startup 1	4	Founder (Participant 19)	- Company website - Bloxhub website - Video - Social media posts
		Co-founder (Participant 20)	
		Academic researcher (Participant 21)	
		End customer (Participant 22)	
Linear startup 2	4	CEO (Participant 23)	- Company website - Bloxhub website - Social media posts
		Innovation hub partner (Participant 24)	
		Civil servant (Participant 25)	
		Academic researcher (Participant 26)	
Linear startup 3	4	Manager (Participant 27)	- Company website - Bloxhub website - Video - Social media post - Pitch decks
		Civil servant (Participant 28)	
		Academic Researcher (Participant 29)	
		Innovation hub partner (Participant 30)	
Linear startup 4	4	Co-founder (Participant 31)	- Company website - Bloxhub website - Video - Social media posts
		Co-Founder (Participant 32)	
		End customer (Participant 33)	
		Civil servant (Participant 34)	

3.2 Data analysis

This study has employed an abductive approach (Dubois and Gadde, 2014) to enable the extension of already existing knowledge and to allow to introduce new ideas (Barron & Pereda, 2020). This was deemed applicable for this study as the data analysis was steered by the existing theoretical knowledge on Panarchy and the phases of the adaptive cycle to identify the emergent themes in the case companies, and for performing a cross-comparison of the cases. The data that was collected through the 34 semi-structured interviews was coded, and subsequently analyzed iteratively and abductively through thematic coding, guided by the existing literature on Panarchy and the conceptual model ‘the adaptive cycle’. The abductive thematic coding was conducted through an iterative six-step process proposed by Kiger and

Varpio (2020). The first step recommended to thematically code data by Kiger and Varpio (2020) is to transcribe the data and familiarize with the entire data set shortly after transcription to search for meaning in the narratives (Kiger & Varpiom 2020; Thompson, 2022). At this stage, we took notes to observe potential codes and patterns in the data (Thompson, 2022). Followingly, the second step as proposed by Kiger and Varpio (2020) is to generate the initial codes. In this round we analyzed each of the transcripts in detail, in NVivo, and assigned codes to the relevant data. A code is described by Saldaña as “a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data” (Saldaña, 2015, p. 3-4), and this first round of coding led to a development of 163 codes. Subsequently, the third step which Kiger and Varpio (2020) recommends is to search for themes, and this step is concerned with the identification of the emerging themes of broader significance by examining the relationships between the codes (Thompson, 2022). In this step we iteratively derived the codes into 80 themes by analyzing and comparing how the codes were related to each other. The fourth step which Kiger and Varpio (2020) propose is then to iteratively review the generated themes. As this study followed an abductive approach, this step entailed that the clustering and explanation of the themes were guided by the existing theory on the characteristics of the adaptive cycle model (Thompson, 2022). Subsequently, the fifth step entailed finalizing the themes, in which we assessed the relationship between the data and the phases of the adaptive cycle to analyze the thematic categories and cross-compare the eight cases through the lens of each category (Eisenhardt, 1989; Williams & Moser, 2019). In this step, we derived 68 thematic codes across the four phases of the adaptive cycle and cross-compared each case company dependent on their respective themes related to the existing knowledge on the adaptive cycle phases. The sixth, and final step recommended by Kiger and Varpio (2020) is then to produce the manuscript, guided by the five earlier steps in which we had collected notes, codes, themes and had cross-compared the cases iteratively to existing literature on Panarchy and the adaptive cycle (Liu et al., 2021).

For the purpose of the data analysis, NVivo was selected as the software for the coding, and each case company was studied separately to familiarize us with each case as a stand-alone entity (Hofmann, 2021; Eisenhart, 1989; Eisenhardt & Graebner, 2007). We triangulated the primary and secondary data from various sources, resulting in a detailed case description (Fiss, 2009; Ridder, 2017). The secondary data were collected through firms' websites, press articles, and social media posts and videos to enrich the body of data with complementary sources. Additionally, we conducted three site visits with observations at the entrepreneurial ecosystem's headquarters, Bloxhub's headquarters in Copenhagen. This allowed us to study the workspaces and the facilities where the startups interact and triggered discussions with the ecosystem agents about how they perceive the ecosystem's culture.

3.3 Sample

This section presents an overview of the four circular and four linear startups examined in this study.

Circular startup 1 aims to scale circular construction by offering the industry a digital material bank platform for repurposing and reusing materials. The startup was founded in 2020 by a team of matured entrepreneurs with decades of experience in the built environment. Today the startup consists of a team of 9 experts and is taking their solution out of the early stage and testing, into the growth stage. The material crisis has offered this startup an opportunity to grow as the industry's need for assistance to perform material exchanges has increased.

Circular startup 2 is an online registry for materials and products used in real estate and infrastructure. The startup creates the registry based on material passports developed for the objects. The startup was founded 5 years ago and now employs 13 specialists from the built environment industry across Europe. The material crisis has led to increased interest in the startup's offerings as it allows actors in the construction industry to gain data about materials, which they can then use to understand which materials are best suited to be repurposed and reused.

Circular startup 3 offers a membership platform that matches excess materials with members who can utilize them. The startup was founded in 2020 and employs 10 professionals with a wide array of backgrounds and experience levels. Shortly after the material crisis hit, the startup experienced a decrease in project requests and membership sign-ups. However, after several months, the membership requests increased as the need for sourcing secondary materials within projects that were preliminary planned to only be using new materials increased.

Circular startup 4 is a real estate firm that employs circular practices in developing new buildings to meet affordable housing needs. The startup was founded two years ago by an experienced team of entrepreneurs and experts from the construction industry, and has grown into a team of around 20 professionals. The material crisis has negatively and positively impacted circular startup 4. The negative impact is that the prices and availability of secondary materials have increased, leading to sourcing issues. However, the material crisis has also positively affected the startup, particularly as their investors see a market opportunity for construction firms that employ circular practices and solutions.

Linear startup 1, is a two-year old startup that has already attained a leading status within 3D printed construction solutions. The startup is run by a team of 10 experts with diverse backgrounds ranging from architecture and construction engineering to law and entrepreneurship. The material crisis has hit the startup, particularly increased material prices and reduced innovation investments in the construction industry.

Linear startup 2 consists of two founders who have developed a patented technology for improving the properties of wood materials. The startup was founded four years ago and is currently testing its minimum viable product with clients. The startup has been negatively impacted by the material crisis and experienced difficulty in securing further funding due to decreased investments in the construction industry.

Linear startup 3 has developed pioneering robot technology which can be used in construction and allows the construction industry to reduce the need for manual labor and develop more innovative construction designs. The startup was founded 9 years ago and today employs 39 experts. The startup is currently transitioning toward the expansion phase and a scaleup status. However, the material crisis has heavily impacted the startups' progress with risks of project delays and terminations.

L*inear startup 4* is an architecture firm focused on developing housing for the future and reaching social sustainability goals through design. The startup employs 19 experts, primarily architects, and utilizes the latest technological tools within design. During its four-year lifespan, the startup has attained project collaborations and partnerships with incumbent organizations. The material crisis has negatively impacted the startup due to the increased raw material prices. However, the startup also gained collaboration opportunities during the crisis due to the Russian invasion of Ukraine and the need to reconstruct Ukrainian infrastructure and housing.

3.4 Research reliability and validity

When working with case studies, it is important to consider rigor to ensure reliable results (Voss et al., 2002; Gibbert et al., 2008). Particularly, exploratory case studies must ensure to have: (i) construct validity, which ensures the correct measures for the studied concepts (Voss et al., 2002); (ii) external validity, which concerns the generalization of the results to reach circumstances beyond the situation which was analyzed (Gibbert et al., 2008; Yin, 2018); and

(iii) reliability, ensuring that other researchers can reproduce the same case study and find the same results (Gibbert et al., 2008; Yin, 2018). Table 3 represents the activities performed in this study to reach research validity and reliability.

Table 3. Research validity and reliability activities performed

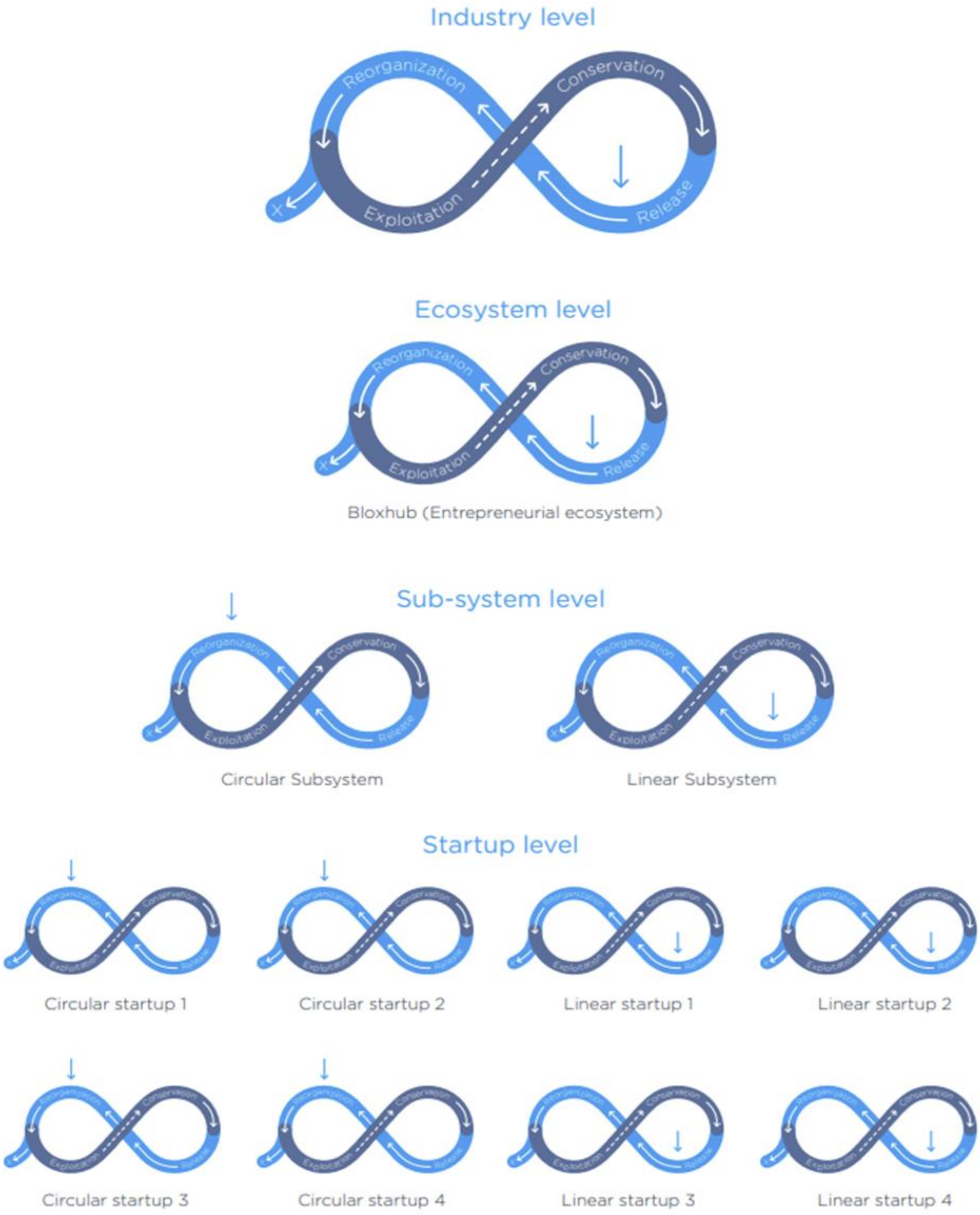
	Explanation	Activities performed	Activity description
Construct validity	The degree to which the test precisely measures what it is aimed to	Multiple sources of evidence	Both primary data in the form of semi structured interviews and secondary data by way of company websites, site visits and videos were collected in this study for validation of results and to enhance data triangulation (Neuman, 2003)
		Diversity in participants	We ensured to seek a diverse spread in participants from each startup considering factors as age, gender, ethnicity, race etc. Diversity increases the generalizability of the study and ensures that the study can reflect the diversity of the culture and conditions (UCSF, 2023)
		Testing of the interview guide with experienced researchers	A pilot test was conducted to attain validity of the instruments and detect errors (Dikko, 2016; Majid et al, 2017; Aung et al., 2021)
External validity	The level to which the study findings can be generalized to other settings, people or measures	Iteration between the theory and the results	As this study employed a complexity theory and panarchy lens, the characteristics for each of the stages of panarchy were used when codifying the data collection and iterated between when analyzing the data (Eisenhardt, 1989)
Reliability	The level to which the research method creates steady and reliable results and can be reproduced with the same results repeatedly	Establishing interview protocol and mostly keeping to the protocol	The data in this study were collected following a semi-structured interview protocol, and although the semi structured interview allows the researcher to stray away from the interview protocol if deemed useful, we tried to remain close to the interview guide to ensure comparability between the interviews (Deakin University, 2023)
		Recording and notetaking throughout every interview	Each of the interviews were video-recorded and transcribed verbatim within 24 hours to reduce systematic bias and research rigour (Rutakumwa et al., 2019)

	Triangulating between primary data and secondary data	We triangulated between the data collected through the semi-structured interviews and publicly available data to produce a more comprehensive set of findings (Fraser & Greenhaigh, 2001; Kuper et al., 2008; Noble & Smith, 2015)

4. Findings

This study investigates how circular and linear startups can nurture their ecosystem to increase resilience in response to the material crisis. By employing the lens of complexity theory, particularly panarchy, we examined the trajectory of four circular and four linear startups from the same entrepreneurial ecosystem in the phases of the adaptive cycle: exploitation, conservation, release, and reorganization. This section presents the findings from the semi-structured interviews conducted with the startups. Based on the NVivo coding of the semi-structured interviews, we found evidence that substantiated how resilience differed at the startup, subsystem, and entrepreneurial ecosystem levels, ultimately impacting the industry level. Figure 2 illustrates the different levels' trajectories through the adaptive cycle and the next subsections explicate the findings for each of these four levels.

Figure 2. The startup, subsystem, ecosystem and industry level moving through the adaptive cycle



4.1 Startup level

When coding the interviews with the participants from the four circular and four linear startups, it became evident that the startups subsisted in different phases of the adaptive cycle. Table 4 depicts the findings from the interviews, exemplifying how the different startups described their situations with characteristics typical of distinct phases of the adaptive cycle.

Despite belonging to the same entrepreneurial ecosystem, our findings suggest that the startups are going through different phases of the adaptive cycle. However, all the startups were either in the release or reorganization phase.

Table 4. Cross comparison of case startups – abductively coded guided by existing theory on the characteristics of the adaptive cycle and occurring themes from data analysis process

Startup	Exploitation	Conservation	Release phase	Reorganization phase
Circular startup 1	1. Environment is becoming increasingly predictable	2. Great level of connectivity between actors		3. Connects with ecosystem multiple times a day 4. Complex relationships in ecosystem, collaborating with competitors 5. Risk willing ecosystem where they are not scared of being each other's supporters and first clients/ testers 6. Stable ecosystem that moves forward together 7. Dividing roles in ecosystem to collaborate better 8. Actively nurturing the ecosystem 9. Actively exploiting harsh conditions 10. Co-creates with ecosystem daily
Circular startup 2	1. Complex relationship between cooperation and competition 2. Connectivity is strengthened due to	3. Great level of connectivity between actors	4. Impacted by uncertainty and difficulty to source secondary materials due to material crisis	5. Risk willing (Taking risk because they want to speed up the process and expand the market) 6. Co-creation as basis of expanding into new countries

	clustering processes			7. Connects with ecosystem multiple times per day 8. Deliberately has built an ecosystem and building ecosystems has been a part of their strategy 9. Actively seeks for diversity in the ecosystem 10. Stable ecosystem that moves forward together 11. Role division to collaborate better in ecosystem 12. Actively nurturing the ecosystem 13. Actively exploiting harsh conditions 14. New relationships
Circular startup 3	1. Self-organized relationships are forming	2. Great level of connectivity between actors	3. Market changes	4. Actively exploiting harsh conditions 5. Collaboration multiple times per day 6. Complex relationships where there is a lot of co-creation 7. Stable ecosystem that moves forward together 8. Co-creates with ecosystem daily 9. Predictable future 10. Increasing market value 11. Actively nurturing their ecosystem
Circular startup 4		1. Great level of connectivity	3. Uncertainty due to impact of the increased material prices	4. Developed a new business model 5. Collaborate multiple times a

		between actors 2. Hyper-specialization		day with the ecosystem 6. Co-creation across the ecosystem often 7. Stable ecosystem that moves forward together 8. Nurturing their ecosystem 9. Actively exploiting harsh conditions
Linear startup 1			1. Price increase of materials 2. Does not actively exploit harsh conditions 3. Delocalization of activities 4. Not actively nurturing ES 5. Risk averse 6. Less than weekly connections with the ecosystem	7. Co-creates with ecosystem occasionally
Linear startup 2	1. Competitive processes create new monopoly/oligopoly situations harming ecosystem's diversity	2. Hyper-specialization 3. Ecosystem is getting increasingly fragile and vulnerable to shocks because of low resilience	4. A decline in investment to linear startups 5. Connectivity to ecosystem is decreasing 6. Decline in trust 7. Loss of competitiveness 8. Increasing levels of uncertainty 9. Withdrawals from the ecosystem 10. Less than bi-monthly connections with the ecosystem	11. Co-creates with ecosystem occasionally
Linear startup 3		1. Ecosystem is getting increasingly fragile and vulnerable	2. Weekly or bi-monthly collaboration 3. Market changes that negatively	8. Co-creates with ecosystem occasionally

	to shocks because of low resilience	impact the startup 4. Uncertainty (projects not being finalized or uncertainty that partners will agree to project due to change in prices) 5. Decline in investments 6. Have become more risk averse 7. Uncertainty (Lack of continuity)	
Linear startup 4	1. Hyper-specialization	2. Connects with the ecosystem less than every week 3. Not seeing potential in material crisis 4. Price increases on necessitated materials leading to project threats 5. Not actively nurturing the ecosystem 6. Unpredictable future 7. Market changes	8. Co-creates with ecosystem occasionally 9. Attraction of new developer communities and business opportunities

4.1.1 Startups in the release phase

When describing their current circumstances, Linear startups 1, 2, 3 and 4 reported characteristics typical of the release phase. One of these characteristics of the release phase is sharp declines in investments, in which for instance Linear startup 2 reported being impacted by, and Practitioner 23 stated, “Money and investments are not that loose anymore as it was six months ago. And this issue is still there. It’s just growing.” Linear startup 3 substantiated this statement and added that they see more investments for firms with sustainable offerings: “We see more struggle to raise money, and we know that green areas raise more money” (Practitioner 19). Not only is the decline in investments typical of the release phase, but it is often accompanied by a loss of competitiveness. Linear startup 2 revealed that a loss of competitiveness had impacted them. Participant 23 argued, “The ability to compete is highly affected by the end price. And we have had a few incidences where prices have gone up.” Linear startup 1 harmonized and argued that the crisis has pushed them to rely on technology to compete, and participant 19 stated, “I think the opportunity we have now can be cheap and available digital manufacturing software which were not possible some years ago, and the old companies are a little too slow or scared to start doing.” New technological changes are another characteristic of the release phase and constitutes one of the main disruptive elements to this phase.

Several startups also shared that, due to the material crisis, they had been affected by greater uncertainty, which typifies the release phase. Linear startup 3 argued to be affected by uncertainty concerning projects. Participant 27 exemplified, “By April 2021, the market went nuts, and everything went sideways and had massive impacts on the project (…) and how we should approach the use of materials throughout the project.” Linear startup 3 also unfolded their experience of the material crisis, along with the uncertainty of current circumstances and a lack of continuity, “To give continuity to something. That is what is missing now. I also see that in my project currently, we are not sure will happen to the result and if it will actually be used" (Participant 29). Linear startup 2 substantiated this impression of being in an uncertain situation and revealed being financially affected by uncertainty. Particularly, Participant 23 stated, "There's so much insecurity out there. So, money is really not that loose anymore as it was six months ago, and we feel it." Linear startup 4 further explained that the uncertainty has led to a "fear for startups in the industry of not moving forward" (Participant 32), which might signify confidence breakdowns in the ecosystem which are typical of the release phase.

4.1.2 Startups in the reorganization phase

The remaining four startups (Circular startup 1, 2, 3 and 4) reported characteristics related to the reorganization phase. For instance, all the circular startups reported co-creation as an important facet to their connection with their ecosystem. Circular startup 2 also explained how they use co-creation as the basis for their expansion into new countries. Participant 6 stated, "We build a network or ecosystem for two years in each country we want to expand in, where we work with them together to enter that market". A complex relationship between cooperation and competition is typical of the reorganization phase. Participant 1 argued to co-create even beyond competition: "You might be developing something that's similar to ours or there's an overlap, but we help each other and create a market that we can all benefit from, and the planet can benefit from."

Moreover, actively exploiting harsh conditions is another characteristic of the reorganization phase and Circular startup 2 argued that the harsh conditions are the reason for their existence. Particularly, Participant 7 exemplified, "We are really focused on the opportunities slash the risks related to the crisis, a full 100%. So, without the risks or opportunities related to resource or climate issues, we would not be here, period. We exist, because these risks are there and if the awareness of these opportunities or risks increases, we will flourish." Participant 1 from Circular startup 1 also expressed a strategic choice for the firm to leverage challenging conditions. This was done not just to benefit the startup, but also to boost resilience within their ecosystem. The participant stated: "we're trying to turn it around, and see what are the opportunities instead of the material crisis, because we can use the material crisis to become more confident and our ecosystem to become more resilient".

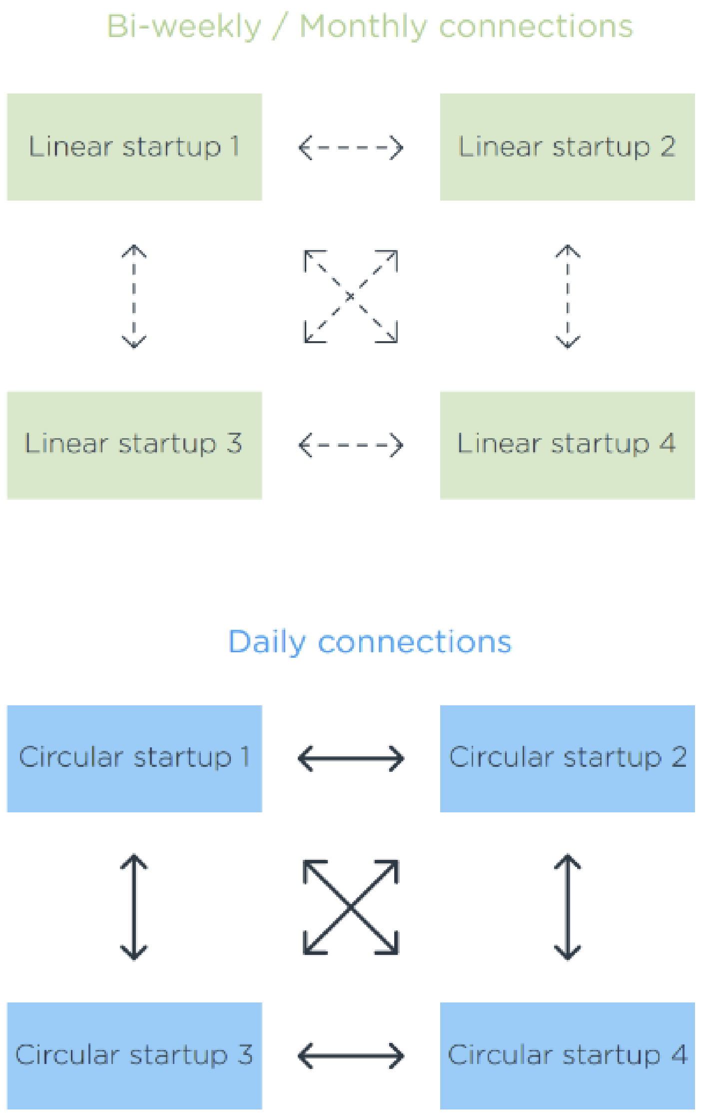
Additionally, a characteristic distinguishing the reorganization phase is the future becoming increasingly predictable and stable, which Circular startup 3 reported seeing impacting their business. Participant 10: "I see that handling waste is going to become at least just as big as the healthcare or food sector and demands a lot of different systems working together to tackle the needs. (…) And it will positively benefit from the rising raw material prices as well because it becomes more valuable than it was just two years ago". The circular startups also reported that they believed the current market changes due to the material crisis to be a growth opportunity if they acted adeptly. Participant 2 remarked, "Because of the crisis there's a new industry booming up, meaning that there are new business opportunities, and the market is still emerging but you have to act". Market changes are a characteristic of the release phase. Still, new market developments which lead to value capture are a characteristic of the reorganization phase and justifies the circular startups 1, 2, 3, and 4 classifications into the reorganization phase of the adaptive cycle.

4.2 Subsystem level

4.2.1 Two subsystems within the entrepreneurial ecosystem

Our analysis revealed that in the entrepreneurial ecosystem studied, there was separation between the linear and circular startups, in which the circular startups connected more frequently with each other (multiple times a day), and the linear startups connected with the other linear startups, but at a less frequent rate (maximum weekly). Consequently, upon examining the entrepreneurial ecosystem, we discerned that it comprises two distinct sub-systems within the overarching ecosystem, each operating differently. These two subsystems diverge based on their business models: circular and linear. Notably, all startups in the circular subsystem are currently in the reorganization phase, while those in the linear subsystem are in the release phase. Figure 3 provides a visual representation of how these two subsystems emerged from our analysis.

Figure 3. Startups dividing into subsystems of the same entrepreneurial ecosystem due to differing connectedness to the system



One of the most fundamental differences between the circular and linear subsystems determining their trajectory through the adaptive cycle was their connectedness to the ecosystem. The circular subsystem reported to connect daily, and even multiple times per day. When explaining their collaboration with the circular subsystem, participant 10 reported, “We connect with them all the time, every day”. In contrast, the linear subsystem described to connect weekly at most, and Participant 31 argued this to be a result of time constraints: “At the end of the day, there are only so many hours in 24 hours, and if I could, I would check in with all my partners once a week”. Participant 23 argued that the connectedness to the ecosystem is currently decreasing and that some ecosystem agents are starting to withhold information due to the ongoing crisis and stated: “Others are really starting to hold their parts to themselves in the industry and ecosystem because of the crisis” (Participant 23). The circular subsystem, however, which connects daily, made their connectedness to the ecosystem a strategic investment. Practitioner 12 made clear, “Working with our ecosystem is all we do basically, we are building a community (…) my main job right now is to assist the ecosystem, so there's a lot of interaction”. Increasing levels of connectedness where new relationships form characterizes the reorganization phase, whereas decreasing connectedness to the ecosystem is typical of the release phase.

Possibly explaining their strong connectedness, participants from the circular subsystem argued to actively treat their ecosystem like a living organism and Participant 7 argued that “[e]cosystems need to be like living creatures and must be nurtured, they need food. You need to put something in, to get something out” (Participant 7). Interviewees highlighted the circular subsystem’s willingness to nurture their ecosystem as a strategic endeavor and Practitioner 16 commented, “Some companies stick to their own or do not share anything, but we do because without it, it is not really a way to go or be part of this ecosystem, because by yourself it is not going to lead to a powerful outcome.” By investing in the ecosystem, the circular subsystem argued to benefit positively but also to have greater levels of stability. Participant 11 argued, "Because of our ecosystem, if we have a partner that cannot deliver a material, we can fairly easy find other partners likely to be able to deliver the same or similar material".

A stable and healthy ecosystem that moves forward together is a characteristic of the reorganization phase of the adaptive cycle, and the circular subsystem contended to be willing to take risks due to their stable ecosystem foundation. In contrast, the linear subsystem reported increasing risk aversion and ecosystem withdrawals, which are distinctive to the release phase. Practitioner 23 explained: "Because in crisis, if you are in fear or trouble of some kind, you withdraw from these ecosystem activities. Even when we all need to be innovative, but in crisis you do what you do on a daily basis and tend to escape from that innovative process". These broken connections to the system occur in the release phase and can signify a system that struggles to move to the next phase together with all its components.

The crisis and the lack of stability in the ecosystem is also argued by the participants from the linear subsystem to have been a cause to them becoming increasingly risk averse. Participant 27 argued the current uncertainty related to the increasing costs of materials is a cause to risk aversion: "We cannot predict what the actual cost of a project is, as we could pre-2021. So now, within our contracts, we have a lot higher focus on material costs, material usage, we take certain considerations when we're making an offer to decrease risks". The decrease in trust is also highlighted by participants when asked about the linear subsystem and Participant 23 expounded, "The material prices mean that we are starting to see some firms around us literally hawking the materials that are scarce and then drive the prices even further up and then we basically have a bigger crisis or almost a geopolitical crisis". A breakdown of trust and confidence are typical signs of a system in a release phase and can signify a possible threat to an ecosystem's survival (Boyer, 2020).

The circular subsystem appears to be exhibiting indicators of good health as they are experiencing greater levels of stability and connectedness, becoming less risk averse, and moving forward together as a unit. This might be attributed to the proactive efforts invested by members of the circular subsystem. They actively nurture their environment, highlighting a deliberate emphasis on fostering a system characterized by diversity and complexity, both of which are crucial aspects of the reorganization phase. Participant 7 argued, “We want our ecosystem to be diverse and also focus on being both hyperlocal and hyperglobal”. Moreover, the circular subsystem expressed complex relationships within their system focused on maintaining a system where agents both give and take. Participant 6 explains:

> “We have an ecosystem for likeminded companies that can make use of everything that we as a company do and produce, but in return, we highly appreciate the fact that they also support us and are ambassadors of what we do in their own ecosystems. I think that’s the main feature of our ecosystem that in a crisis will help us get through it (…) and as long as they keep supporting us, we can overcome any crisis.” (Participant 6)

The circular subsystem reports having faith that they cannot only overcome the crisis but that they can also benefit from it as explained by Participant 2: “The crisis is an opportunity for a mindset change and more sustainable business. In that sense, the crisis works on our behalf at a business level, but we exploit it because we are truly concerned about the climate crisis, biodiversity, and resource density. So, the main driver for us is not the business opportunity but hoping to help solve some of these issues.” By perceiving their system as healthy and stable, the circular subsystem is therefore more willing to engage in risk. It allows them to be open to actively exploit the harsh conditions of the material crisis. However, it is also to be argued that the material crisis favors the circular subsystem and Participant 7 observed: “The awareness of dependency upon resources has increased. Awareness that resource scarcity might drastically change the economic game has also increased. And I think the awareness that measures must be taken has also increased." This mindset change throughout the society and industry enforces the market change that the circular subsystem aims to exploit, pushing their trajectory through to the reorganization phase.

4.3 Entrepreneurial ecosystem level

The release phase is characterized by external disturbances to the ecosystem's initial equilibrium (Boyer, 2020). For the Bloxhub entrepreneurial ecosystem, these external disturbances were the cascading effects of the material crisis, which impacted the whole ecosystem and its agents. The ecosystem agents' response to the material crisis has led to the emergence of two distinct subsystems within the entrepreneurial ecosystem. Consequently, the entrepreneurial ecosystem struggles to cohesively transition from the release phase to the reorganization phase. This division, with the two subsystems operating at two different speeds and thus are in different phases of the adaptive cycle (release and reorganization), influences the overall progression of the entrepreneurial ecosystem through the adaptive cycle stages.

Our study revealed that the release phase represented a pivotal moment in the adaptive cycle for the entrepreneurial ecosystem. Within this context, the ecosystem grappled with advancing cohesively due to internal disparities and tensions between the subsystems. The inherent business model of the agents within the ecosystem emerged as a divisive element, thus challenging the ecosystem's resilience. The circular subsystem advanced more rapidly to the reorganization phase – where resilience peaks, according to Boyer (2020) – leaving the linear subsystem in the release phase. This dynamic has fostered an internal divide within the entrepreneurial ecosystem. The way in which the agents have dealt with this crisis, however, has resulted in the emergence of two separate subsystems within the entrepreneurial ecosystem and the ecosystem as a whole is therefore struggling to move beyond the release phase into the reorganization phase. Given the divide between the two subsystems being in two different phases of the adaptive cycle (release and reorganization), the entrepreneurial ecosystem's overall trajectory through the phases of the adaptive cycle is impacted. In our study, it became evident that the release phase substantiated a crossroad in the adaptive cycle for the entrepreneurial ecosystem in which the ecosystem struggled to move ahead as a singular unit due to internal differences and frictions between the subsystems. The inherent business model of the ecosystem agents became a dividing factor in the ecosystem and the resilience of the ecosystem is therefore currently challenged. The circular subsystem has processed faster through to the reorganization phase in which resilience is at its highest (Boyer, 2020), leaving the linear subsystem behind in the release phase. This has created internal separation in the entrepreneurial ecosystem.

Moreover, analyzing the different ways the two subsystems nurture their ecosystem, the entrepreneurial ecosystem struggles to move ahead. When talking with the ecosystem agent representatives, it became clear that the entrepreneurial ecosystem as a whole (Bloxhub) is also experiencing withdrawals from ecosystem agents, and Participant 23 argued, “Because in crisis, if you are in fear or you are in trouble of some kind, you withdraw from these activities. Even when we all need to be innovative, but in crisis you do what you do on a daily basis, then you tend to escape from that innovative process”. Ecosystem agents’ withdrawals might signify that the whole entrepreneurial ecosystem may still lag in the release phase. However, interestingly only participants from the linear subsystem had noticed ecosystem withdrawals, which may further signify this divide the entrepreneurial ecosystem is experiencing between the circular and linear subsystems.

Another explanation for why the release phase presents a crossroad for the entrepreneurial ecosystem is the nature of the crisis favoring circular business models and operations. None of the linear startups reported the material crisis to offer a business opportunity for their business, and Participant 31 confirmed this by stating, “I don’t think that any opportunities have or can come to us due to the material crisis”. On the contrary, all the circular startups reported that despite the crisis hinders their potential business success due to difficulties in sourcing secondary materials, limited availability of used materials and limited projects and resources, they all strategized to capitalize on the material crisis. Participant 10 observed: “The crisis is definitely something that we notice and that obstructs our work as well. But in our case, we can actually turn it into something positive because it makes the companies search for alternative materials. And that’s where we can offer our alternative and more sustainable solution.”

The reorganizing of the ecosystem is likely to foster new markets and additional products and services that can create value for the ecosystem agents. If the ecosystem aims to move to the reorganization phase, it is necessary to have successful initiatives and success stories. This can regenerate confidence in the system, necessitating cooperation, collaboration, and the clustering process (Boyer, 2020). The participants from the entrepreneurial ecosystem argue that success stories exist, but these are currently reflecting solely the circular operations within the entrepreneurial ecosystem. Participant 2 expounded, “We can see that if we close down traditional businesses, there will be new businesses who emerge that can fuel the economy. So, the crisis is an opportunity for sustainable businesses”. The current lack of success stories from the linear operations of the entrepreneurial ecosystem can therefore challenge the ecosystem’s process toward the reorganization phase.

4.4 Industry level

An entrepreneurial ecosystem holds the potential to influence its industry significantly. Many participants in this study noted increased interest in their business solutions, offering alternative materials or guidance to clients and customers affected by the material crisis. Notably, the circular startups observed a shift in the built environment industry's perspective toward their circular solutions. These participants suggested that the material crisis propels society toward a more circular approach. Participant 27 elaborated:

> "The crisis offers potential to change the financial incentive towards rethinking material use. We saw it in the 1970s, where the greatest costs of building were material costs and people were very cautious with material use. Since the 1990s, the material costs have been so small compared to labor costs, but now that has been completely inverted again which incentives us as an industry and a society to think differently".

Despite the material crisis offering an opportunity for an industrial and societal reset on material usage, some participants argued that this transition towards sustainability is happening at a low rate due to the rigid structures and established patterns of the system. The industry is therefore not showing signs of entering the reorganization phase. The participants also argued that the industry is currently struggling to exploit the harsh conditions of the material crisis and that risk aversion is suppressing the industry. Participant 23 expounded, "The risk in the industry is about who dares to be first mover, who is willing to take that risk?"

The risk of project delays or possible project cancellations is also hindering the industry from overcoming the material crisis, and Participant 17 explained, "It affects every project in the industry. It is either a delay, or the project is completely stopped. Meaning that maybe stakeholders do not want to get involved either, so we just cannot take any risks". The decline in investments and broken relationships with stakeholders also signifies a system in the release phase. It can suggest a system losing confidence and trust internally and with its stakeholders.

The participants also highlighted the industry's uncertainty as a hindering factor to overcoming the material crisis and Participant 17 argued, "Because of the crisis it has affected the decision-making process and because of material prices and labor shortages leading to project delays and cancellations the uncertainty is high and people just do not want to risk anything". Uncertainty is another characteristic of the release phase which the interview participants argued to currently impact the built environment industry. The participants also argued that the industry is currently undergoing a positive change due to the material crisis which concerns increased awareness regarding the potential of secondary materials. This change in attitude toward circular solutions is opening new markets for value capture, which is a characteristic of a system in the reorganization phase. However, although the participants described the built environment as currently holding certain characteristics related to the reorganization phase, most of the characteristics the participants explained illustrate a system in the release phase (e.g., high levels of uncertainty, risk aversion, rigid industry structures).

5. Discussion

This study explores how circular and linear startups can nurture their ecosystems to increase resilience in response to crises. A cross-case comparison with eight startups enabled us to examine how startups with different business models (circular and linear) belonging to the same entrepreneurial ecosystem (Bloxhub) impact the ecosystem's trajectory through the adaptive cycle and, thus, its resilience.

Our study offers three important theoretical contributions. First, we present how an entrepreneurial ecosystem can function of subsystems, and we identified two subsystems based on the inherent startups differing business models. Moreover, we highlight how the startups that actively nurture their subsystem process faster through the release phase onto the reorganization phase in which resilience is higher. Third, we present a model, which applies Holling's (1986, 2001) adaptive cycle model to four separate levels (startup, subsystem, ecosystem and industry level) to investigate how resilience at the startup level impacts the subsystem level, which then again affects the overall entrepreneurial ecosystem, ultimately impacting the industry in which the entrepreneurial ecosystem operates.

In our findings, we presented how an entrepreneurial ecosystem may be challenged to pass through the adaptive cycle as a united system due to inherent differences between the ecosystem agents' business models. Our findings exposed that the entrepreneurial ecosystem studied, Bloxhub, consisted of two subsystems that operated differently. The most prevalent distinguisher between the two subsystems is their business models: four startups were linear and four were circular. As this study was designed to examine four circular and four linear startups, we expected to see differences between the circular and linear startups. Still, we did not foresee that the entrepreneurial ecosystem had started to operate with two subsystems. Although the different business models are the main separator between the startups examined in this study, what separated them into two subsystems was also their dissimilar strategy concerning how they nurture their ecosystem, and how they have been affected by the material crisis.

First, the greatest difference between the circular and linear subsystems at Bloxhub was their approach to nurturing their ecosystem. We found that the circular subsystem keenly nurtured its ecosystem to the point where it considered it a living organism in need of food and care to be in optimal health. The circular subsystem nurtured its ecosystem by sharing data and projects, dividing roles and opportunities for commercial purposes and a "give and take" mentality. On the other hand, we found that the linear subsystem considered their ecosystem a "good to have but not a must have" (Participant 31) and did not consider the ecosystem crucial for their survival. The linear subsystem, therefore, did not actively maintain its ecosystem and was less concerned with its health. While the linear subsystem may not rely heavily on its ecosystem, the circular subsystem expressed significant dependence on theirs as they have strategically leveraged their ecosystem to seize opportunities. It can be argued that cross-collaboration is the essence of circularity, and the circular subsystem thus nurtures their ecosystem not only for their ecosystem's survival but for their startups' survival.

Second, we discovered a remarkable disparity between the two subsystems regarding their connectedness within their subsystem. Each startup in the circular subsystem connected daily, with each other, but also with other ecosystem agents beyond our data sample. This connectedness consisted of co-creating, conversing, and collaborating. Conversely, the linear subsystem connected less than weekly, and argued their limited joining with their ecosystem to be due to time restraints and the impact of the crisis leading to ecosystem withdrawals, decreased trust and a breakdown of confidence in the ecosystem's health and stability. The interviewees representing the circular startups argued that the close connection with their ecosystem was key to their success and a principle of the circular economy. We thus argue that the subsystem with circular business models may be more apt to proceed through the adaptive cycle as circularity is heavily focused on cross-company collaboration due to the need for an ever-lasting exchange of previously used products and materials. This can suggest that startups with business models dependent on strong ecosystem connectedness are better suited to survive a release phase and pass through to the reorganization phase in which connectedness to the ecosystem is rapidly growing.

The success and survival of ecosystem members are influenced by the ecosystem's holistic nature, which is constantly evolving (Iansiti & Levien, 2004). Our findings corroborate this, showing that this entrepreneurial ecosystem is having difficulties functioning as a unified entity, which in turn challenges its resilience in addressing the material crisis. By evaluating the trajectories of the startups, the subsystems, and the overall ecosystem through the adaptive cycle, it is clear that the linear startups remained locked in the release phase. In contrast, the circular startups and their corresponding subsystem advanced to the reorganization phase, which is identified as the stage with the highest resilience in the adaptive cycle (Boyer, 2020).

5.1 Key takeaways for policy

The findings of this study are valuable to policymakers who facilitate and participate in entrepreneurial ecosystems and highlight the need for constant attention to an ecosystem's health and to the connectedness and dedication of ecosystem agents. This study has presented how an ecosystem can struggle to progress as a unit through the adaptive cycle due to differences between the ecosystem agents. We found that the development of subsystems inflicted a strain on the entrepreneurial ecosystem and can threaten the ecosystem's overall resilience to overcome crises as a unit. However, the emergence of the circular subsystem which has moved to the reorganization phase can also positively impact the entrepreneurial ecosystem by 'showing the ropes' on how to nurture the ecosystem to transition toward the reorganization phase. Therefore, by investing in the facilitation of entrepreneurial ecosystems and education on the importance of ecosystem health and nurturing, entrepreneurial ecosystems may increase their chances for survival through crises.

Furthermore, as the material crisis currently impacts the built environment and it is in the interest of policymakers on a local and national level to assist startups in their survival, the findings of this study can be employed as a guide to how startups nurture their entrepreneurial ecosystem are progressing at a greater rate than those who do not.

5.2 Key takeaways for research

This study contributed to the rapidly growing academic research on resilience in entrepreneurial ecosystems. It opened the discussion on how entrepreneurial ecosystems can be crucial for individual startups' resilience to survive crises. Until now, studies have primarily focused on how crises or disruptions can challenge the resilience of business ecosystems (Ramezani & Camarinha-Matos, 2020). However, limited research has examined how ecosystems may be a tool to increase and build resilience, particularly on the startup level. Moreover, existing literature concerned with resilience has investigated resilience predominantly at the individual entrepreneur and new venture level and examined how these levels can impact the ventures' survival (Khurana, 2022). This study extends the academic understanding of the impact on resilience to the subsystem, entrepreneurial and industrial levels and argues that the entrepreneurial ecosystem can consist of multiple subsystems that are worth examining and understanding further.

Moreover, past studies on entrepreneurial ecosystems have identified the components of entrepreneurial ecosystems and examined the connections between them. Employing the complexity lens has led scholars to suggest that by investigating the entrepreneurial components in isolation from each other, we overlook the wholeness of entrepreneurship, and isolating individual parts of the system hinders researchers from revealing the causal mechanisms in the system (Anderson et al., 2012; Roundy et al., 2018). Although we examine multiple levels, this study maintains this statement. It suggests that the entrepreneurial ecosystem has meso and macro level implications that can benefit both the entrepreneur and the stakeholders in increasing awareness.

Furthermore, this study extends the adaptive cycle which construes the dynamics of complex adaptive systems in response to change and explains the movement of complex adaptive systems and ecosystems along four phases: exploitation, conservation, release and reorganization. This study illustrates that the adaptive cycle can also be employed at the startup, subsystem and industry level and provides an applicable lens to investigate how the various levels' trajectory through the adaptive cycle has "trickle-up" effects.

5.3 Key takeaways for practice

The findings of this study are particularly relevant for entrepreneurs operating with circular and linear business models. Through the investigation of four circular and four linear startups belonging to an entrepreneurial ecosystem, we discovered that the startups actively nurturing their ecosystem experienced greater levels of stability and resilience. This finding suggests that the startups investing in their ecosystem can experience benefits beyond sharing experiences and knowledge, but overall survival and resilience. The startups that joined this study suggested investing in sharing data and resources, sharing project and collaboration opportunities, and sharing project roles and time.

The study findings are concerned with an entrepreneurial ecosystem in the built environment. However, the findings may also be applicable across industries, innovation ecosystems, and other business ecosystems. Also, as adaptation and survival are key for startups, the findings of this study can guide entrepreneurs wishing to overcome crises by altering the maintenance of their ecosystems. We believe that the findings may indeed be widely applicable to different crisis contexts and can assist startups contending with, for instance, the environmental crisis, the global energy crisis, the global supply chain crisis or other crises at the local, national or global scale.

6. Conclusion

This study examined how circular and linear startups belonging to the same entrepreneurial ecosystem can nurture their ecosystem to increase resilience in response to crises. By cross-comparison of four circular and four linear startups in the Bloxhub entrepreneurial ecosystem, it became evident that the ecosystem was divided into two subsystems: one consisted of startups with a circular business model and the other involved startups with a linear business model. The impending material crisis impacted the entrepreneurial ecosystem as with the rest of the built environment. The existence of the two subsystems challenged the entrepreneurial ecosystem from progressing as a unit in the adaptive cycle from the release phase through to the reorganization phase in which resilience is at its highest. Our study indicates that the circular subsystem which their inherent startups actively nurtured, had progressed through the reorganization phase and perceived their ecosystem as stable and healthy enough to capitalize on the material crisis. The linear subsystem, however, was experiencing its subsystem as disintegrating and reported ecosystem withdrawals, lack of trust and risk aversion. It can thus be argued that to tackle an ensuing crisis. Startups should be recommended to advance their nurturing of the ecosystem. Moreover, our study finds that the adaptive cycle can be employed as a lens to examine resilience not only at the entrepreneurial ecosystem level, but also at the startup level, subsystem level and overarching industry level.

6.1 Limitations of the study and future research

When interpreting the results of this study, four limitations should be considered. The first is that the study has solely analyzed qualitative data, for which it is more difficult to maintain, assess and demonstrate methodological rigor. Due to the time-consuming process of collecting qualitative data, it also limits the spread and diversity of the responses. Future research should therefore collect quantitative data through surveys to examine how multiple entrepreneurial ecosystems might have sub-systems dependent on ecosystem agents' respective business models, and how that affects the ecosystems' trajectory throughout the adaptive cycle.

The second limitation of this study regards the data collection undertaken in three months, thus not reflecting the development of the ecosystem and the circular and linear subsystems. Therefore, our findings do not allow this study to follow the entrepreneurial ecosystem's trajectory throughout the adaptive cycle. Future studies should focus on longitudinal data collection to examine the entrepreneurial ecosystem and its subsystems' full evolution through the adaptive cycle over time. Future studies can also extend the findings of this study through longitudinal studies and a comparative case analysis of multiple entrepreneurial ecosystems to investigate how various entrepreneurial ecosystems in the built environment are processing through the adaptive cycle, for instance employing the material crisis as their crisis context. Perhaps a longitudinal study could also examine startups, subsystems, or ecosystems in each of the four phases of the adaptive cycle to reveal the measures each system takes to progress to the next phase.

The third limitation of this study is that it is constructed around a relatively rich number of interviews, but with only four or five representatives from each startup and their surrounding ecosystem. This limits the study's representation and the possibility of a complete understanding of the ecosystem, particularly from the viewpoint of ecosystem agents' end clients or policymakers involved. Future studies should therefore increase this study's extensiveness by including a broader spectrum of stakeholders, clients, competitors, and associated actors and policymakers.

Finally, the fourth limitation of this study is that our findings only describe startups that are currently in either the release or reorganization phase of the adaptive cycle, but not startups in either the exploitation or conservation phase, as the sampled startups did not occur to be in those phases. This, therefore, limits the study's generalizability and applicability to ecosystems currently experiencing the exploitation or conservation phase. We, therefore, suggest future studies to further expand upon the findings of this study and apply a complexity lens to examine resilience in entrepreneurial ecosystems', by investigating the impact of having startups in each phase of the adaptive cycle.

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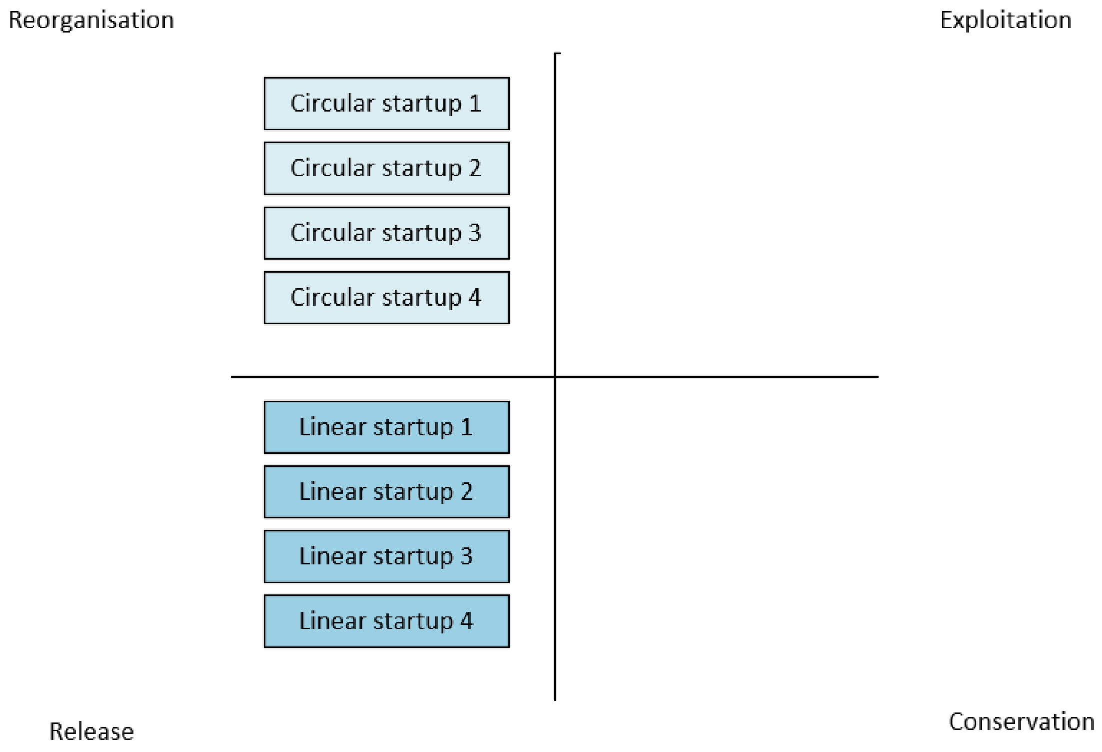
Appendix

Appendix 1. Overview of startups coded into the four phases of the adaptive cycle



Appendix 2. Overview of the systems' discourse in the adaptive cycle across startup, subsystem, entrepreneurial ecosystem and industry level

Level	Adaptive cycle phase	Network actors	Discourse	
			From	To
Industry	Release	Contractors, architects, engineers, material suppliers, organizations, government, banks, entrepreneurial ecosystems etc. that are interconnected	Capitalist/ financial growth	A world that falls apart
Entrepreneurial ecosystem	Release	Startups that are connected through the Bloxhub entrepreneurial ecosystem	Product 1	Product 2
		Subsystem level		
Circular sub system	Reorganization	Employees from circular startups that are connected	Product 1 (circular)	Product 2 (circular)
Linear sub system	Release	Employees from linear startups that are connected	Product 1 (linear)	Product 2 (linear)
		Startup level		
Linear startup 1	Release	Employees that are connected	Product 1 (linear)	Product 2 (linear)

Linear startup 2	Release	Employees that are connected	Product 1 (linear)	Product 2 (linear)
Linear startup 3	Release	Employees that are connected	Product 1 (linear)	Product 2 (linear)
Linear startup 4	Release	Employees that are connected	Product 1 (linear)	Product 2 (linear)
Circular startup 1	Reorganization	Employees that are connected	Product 1 (circular)	Product 2 (circular)
Circular startup 2	Reorganization	Employees that are connected	Product 1 (circular)	Product 2 (circular)
Circular startup 3	Reorganization	Employees that are connected	Product 1 (circular)	Product 2 (circular)
Circular startup 4	Reorganization	Employees that are connected	Product 1 (circular)	Product 2 (circular)

7. DISCUSSION

This chapter summarizes the articles included in this thesis—first individually and then as a collected body of work. Subsequently, this chapter discusses the contributions of the findings of this thesis to theory and practice.

The thesis aimed to gather the conditions and strategies that lead to CBM adoption and CBMI, and to investigate the resulting effects on resilience in the built environment. Table 2 presents the research gaps and research questions that the articles in this thesis have aimed to answer, the research methods that were employed, and the theoretical and practical contributions of each article.

Table 2. Research overview

	Article A	**Article B**	**Article C**
Research gaps	Lack of new knowledge and systematic reviews on the institutional, organizational, and individual determinants, driving or hindering CBM adoption	Lack of research on the drivers and barriers to CBMI in the built environment, and strategic recommendations for practitioners to employ in their own business models and organizations	Limited understanding of how startups—and particularly circular startups—nurture their ecosystems to gain resilience to overcome crises
Research questions		**RQ1**. What are the existing drivers of, and barriers to, circular business model innovation in the built environment? **RQ2**. What strategies can be employed to capitalize on the drivers of, and overcome the barriers to, circular business model innovation in the built environment?	**RQ1**. How can circular and linear startups nurture their entrepreneurial ecosystems to gain resilience in response to crises?
Research method	Systematic literature review of the literature on determinants to CBM adoption	Delphi study with 25 experts providing rich qualitative data on drivers, barriers, and strategies to CBMI in the built environment	Multiple case study, cross examining startups belonging to one entrepreneurial ecosystem, identifying gaps in the literature on the effect of CBMs on resilience across levels

Theoretical contribution	Holistic overview of the determinants of CBM adoption	Holistic overview of drivers and barriers to CBMI in the built environment and categorization of strategies to change resource loops	Introduction of the effect of CBMs on resilience in entrepreneurial ecosystems and across levels
Practical contribution	Framework for practitioners to identify determinants driving or hindering their CBM adoption	Common language of barriers and drivers to CBMI in the built environment, and practical strategies and categories for practitioners to employ to deal with them	Introduction of the effect of post-adoption of CBMs on resilience, and a showcasing of CBM startups' innate motivation to nurture ecosystems

7.1 Article summaries

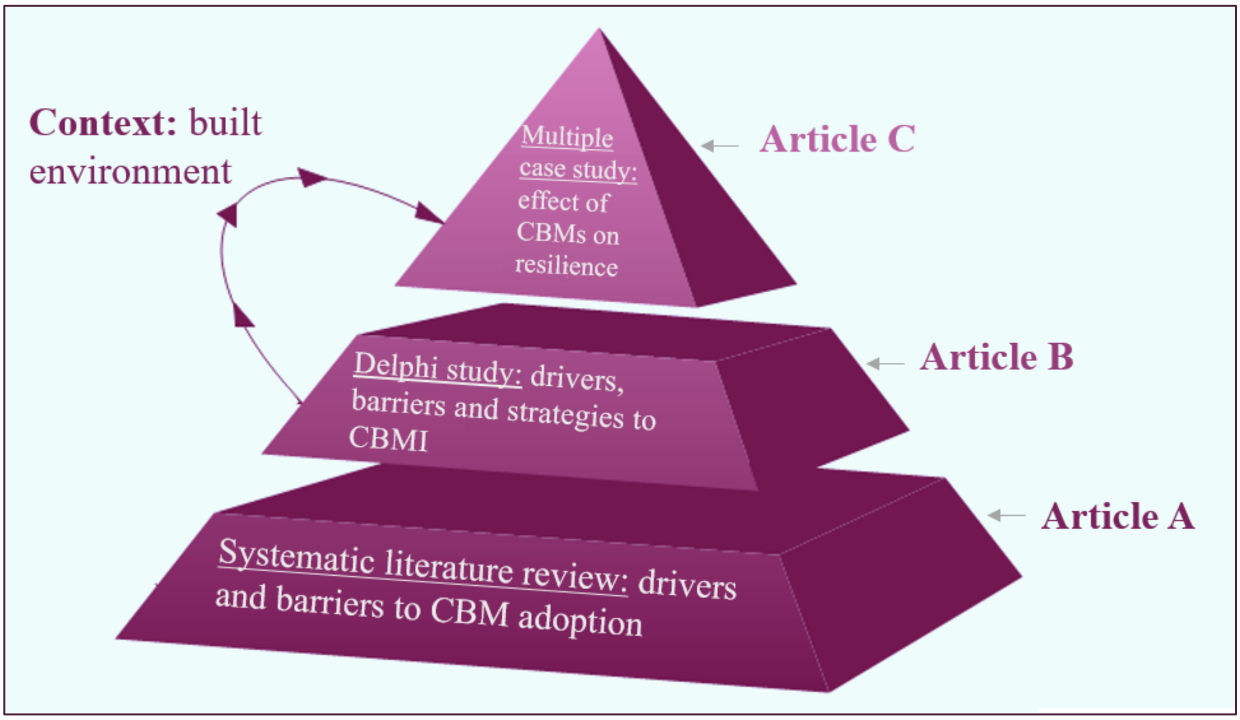
This thesis wove together three articles. The first article (Article A) uncovered a collection of determinants that create the conditions that drive or hinder firms' adoption of CBMs. This article presented a holistic overview of the state-of-the-art determinants of CBM adoption by way of a systematic literature review of 67 articles. As a result, Article A identified 54 different categories of determinants, which were grouped into eight separate macro categories: culture, regulation, market, strategy, business case, collaboration, operations, and knowledge. As listed, one of the determinant categories which the article exposed was 'Culture,' which we considered to be the most external condition determining the CBM adoption. When examining the literature, several cultural determinants appeared, including the 'Industry culture,' which also highlighted a determining factor to be "Conservatism and reluctance of the industry when it comes to the green transition" (Assmann et al., 2023, p. 3; Rizos et al., 2016). The built environment industry has been characterized as slow to change (Gambatese & Hallowell, 2011), and multiple scholars report a lack of innovativeness in the industry (Brockmann et al., 2016; Koskela & Vrijhoef, 2001; Laborde & Sanvido, 1994). The context of the built environment was therefore selected for narrowing down our research, going into the second article, as we believed it to be a fitting context in which to examine CBMI in a traditional industry.

The second article (Article B) therefore set out to investigate the connection between innovation and lack of innovativeness, using the built environment as its research context. The article found that although the built environment was still considered by the experts to be conservative, there were a plethora of drivers toward CBMI, and the experts argued that CBMI was increasing owing to a growing amount of drivers. As there has been limited research on the application of CBMI in the context of the built environment, particularly concerning studies that provide strategic recommendations for practitioners to apply to their own business models and organizations (Adams et al., 2017), Article B aimed to fill this gap. Therefore, this article conducted a Delphi study with 25 international experts within circular economy, CBMs, and the built environment. The data gathered through the Delphi study allowed the authors to identify the barriers and drivers that the experts considered imminent in the industry, and 34 strategies that can be used to tackle these and stimulate CBMI in the built environment. Next, we classified these strategies and proposed four categories in which strategies for circularity can be organized: 'Understanding the loop,' 'Facilitating the loop,' 'Promoting the loop,' and 'Regulating the loop.' From the findings in Article B, it emerged that the experts believed conservative behavior in the industry is one of the greatest barriers to CBMI, and 'Lack of collaboration' was one of the most frequently highlighted barriers by the experts. This, therefore, became the starting point when designing our framing of Article C.

The third article (Article C) was thus designed to build on Article A and B, and we took an even narrower perspective by investigating how circular and linear startups nurture their entrepreneurial ecosystem to increase resilience in response to crises. Specifically, we used the context of the impeding material crisis, which has intensified in the built environment as building materials have seen a dramatic increase in price following the COVID-19 pandemic, the Russian invasion of Ukraine, and the rising energy prices. The ecosystem perspective was selected as the findings from both Article A and B revealed that partnerships and collaborations are strong enablers of CBM adoption and CBMI, and embracing the ecosystem lens therefore was a fruitful avenue of investigation. Moreover, the justification behind opting to investigate the entrepreneurial ecosystem setting was to investigate how the stakeholders within the built environment that tend to be considered the most innovative, i.e., the entrepreneurs, are nurturing their ecosystems to become more resilient when faced with the increasingly challenging environment firms in the built environment operate in.

In combination, these three articles create a pyramid presented in Figure 2, in which Article A provides the central foundation that is used to frame Article B, which applies a narrower industry perspective and gives foundation to Article C, which further narrows the scope to examine the impact of adopted CBMs on startups in the built environment on entrepreneurial ecosystem resilience.

Figure 2. Article pyramid overview



7.2 Theoretical contributions

This thesis has contributed to theory by proposing holistic overviews of the conditions driving or hindering CBM adoption and CBMI, providing strategies to reaching CBMI in the built environment and identifying the effect of CBMs on resilience across levels in the built environment.

7.2.1 Contributions to the CBM literature

First, this thesis by way of Article A extends the existing literature on CBM adoption by providing novel empirical insights. These insights offer a deeper theoretical understanding of the driver and barrier conditions that influence firms in their adoption of CBMs. Existing literature on CBM adoption has primarily focused on the current barriers without examining the drivers, and these studies have mostly adopted a case study methodology (Aid et al., 2017; Kazançoğlu et al., 2020; Singh & Giacosa, 2018; Tura et al., 2019; van Loon & Van Wassenhove, 2020; Werning & Spinler, 2019). Utilizing a sample of 67 journal articles, Article A identified 54 different determinants and classifies them into eight macro categories: culture, regulation, market, strategy, business case, collaboration, operations, and knowledge. Article A thus fills this research gap by providing an industry-wide overview to determinants that create the hindering and driving conditions to CBM adoption by utilizing a systematic literature review approach.

Second, adding to the CBM adoption literature stream, in Article A we exposed a need for knowledge and innovation on the topic of CBM adoption and circular economy practices, to allow firms to partake in the circular transition (e.g., Bocken et al., 2018; Lehtimäki & Piispanen, 2020). In Article A, we found that some firms were unable to adopt CBMs owing to a lack of resources and knowledge on the topic. Thus, we call for future research to focus on those factors that promote firms' adoption of CBMs, as CBM adoption remains scarce in practice. Article B concurs with this finding and stresses the need for knowledge generation and knowledge sharing in order to enhance CBMI. The findings of Article B uphold that academic research and public disclosure of academic results are required, and suggest that increased sharing of knowledge between academia, policy, and practice is mandatory to achieve CBM adoption.

Third, by way of Article A, we find that collaboration between academic institutions and firms wishing to adopt CBMs can prove influential in enhancing the CBM adoption rate. Collaboration with academic institutions can benefit firms wanting to experiment with CBMs and can resultingly lead to an increase in the CBM success and adoption rates, whilst also benefiting the CBM research field through data-gathering opportunities in firms experiencing the CBM adoption practices and processes.

7.2.2 Contributions to CBMI in the built environment literature

This thesis also adds to the literature stream on CBMI, which has remained under-studied in academic research, particularly regarding the issues related to the process of innovating business models toward circularity (Bocken et al., 2018; Guldmann & Huulgaard, 2019, 2020; Linder & Williander, 2017; Urbinati et al., 2017). This thesis addresses this critical literature gap, and its contribution is threefold.

First, in Article B we add to CBMI theory by presenting 34 strategies that change the resource loop. We classify these strategies into four categories: 'Understanding the loop,' 'Facilitating the loop,' 'Promoting the loop,' and 'Regulating the loop.' These four categories that we propose are nondependent on industry, and this categorization builds on and complements the circular economy principles (narrowing, slowing, closing, or regenerating resource loops) that are already accepted and widely employed in CBMI literature (Çetin et al., 2021; Nußholz, 2018; Tunn et al., 2019). We therefore advance CBMI literature by offering a categorization that is widely applicable across industries and allows other scholars to develop strategies fitting into the categories and to further advance the theory to close resource loops.

Second, limited academic research has disclosed the application of CBMI to the context of the built environment, especially providing strategic recommendations for practitioners to use when innovating toward CBMs in this industry (Adams et al., 2017). This thesis responds to this research gap and contributes to an updated and expanded academic comprehension of the conditions that determine CBMI in the built environment and why this transition remains slow (Article B). Further, Article B provided 34 strategies that can particularly assist in fostering CBMI in the built environment, guided by recommendations from the 25 Delphi study experts.

Third, this thesis by way of Article B, emphasizes the need for knowledge generation and knowledge sharing on CBMI—between academia, policy, and practice—in order to advance CBMI in firms. The findings thus propose a need for academic research and the public disclosure of academic results to drive CBMI. Moreover, Article B presents a necessity for devising relevant higher education to expand the knowledge required to undertake CBMI and circular strategies. Particularly, Article B finds that academia holds a significant position in driving awareness and mindset change—also within industries and organizations—and the thesis demonstrates a potential for academic studies and theoretical progression to further promote CBMI.

7.2.3 Contributions to resilience theory

This thesis also contributed to resilience literature, which is a fast-expanding academic research stream. The findings from Article C extend the theoretical discussion about entrepreneurial ecosystem resilience and presents how startups with CBMs can be more apt than linear startups to advance resilience by being innately connected with and nurturing of their ecosystem. Thus, this thesis extends the literature on how resilience can be gained for entrepreneurial ecosystems in the built environment, which is crucial for the ecosystems to survive the increasingly unstable environment in which businesses operate. To date, scholarly studies on ecosystem resilience have mainly concentrated on how crises or disruption can challenge ecological ecosystems' or business ecosystems' resilience (Ramezani & Camarinha-Matos, 2020). However, there has been a lack of studies unveiling how nurturing of entrepreneurial ecosystems can be a tool for building resilience, and Article C aimed to fill this gap by presenting how startups with CBMs may be more apt to nurture their entrepreneurial ecosystems and thus can drive resilience across levels.

Further, Article C answers to the call for studies investigating resilience across different levels to investigate how resilience at one level can impact other levels' resilience (Kennedy & Linnenluecke, 2022). In Article C, we performed a multiple case study of four circular and four linear startups belonging to one entrepreneurial ecosystem, and found that investigating resilience across four levels (startup, subsystem, entrepreneurial ecosystem, and industry level) can provide a suitable lens through which to examine the varying degrees of resilience across the different levels and their effect on each other. In Article C, we find that there are trickle-up effects from the resilience at the startup level affecting the subsystem, entrepreneurial ecosystem and the overarching industrial system level. This finding suggests that to unleash the potential which scholars have proposed that the built environment holds on social ecological system resilience (Lloyd-Jones, 2006; Bosher, 2008; Dainty & Bosher, Haigh & Amaratunga, 2010; Hassler & Kohler; 2014); efforts must be made to increase resilience also employing a "bottom up" approach by starting at startup level. That way, resilience can trickle up and advance the entrepreneurial ecosystem resilience, which then affects the industrial system resilience, which again, due to the built environment's potential can deliver important effects on the social ecological system resilience.

Taken together, Articles A, B and C in this thesis therefore assists in advancing the literature on CBMs, and CBMI in the built environment and CBMs' impact on resilience across levels, with its methodological and empirical contributions. The research has been motivated by the aim of providing other researchers involved in the field of CBM adoption and CBMI in the built environment with state-of-the-art overviews of conditions that drive or hinder CBM adoption and CBMI. Moreover, the aim has been to present the recommendations from experts to provide strategies that can advance CBMI in the built environment, and to present the benefit of CBMs by exhibiting how CBMs' innate nature to nurture their ecosystems can allow reaching greater levels of resilience, across levels.

7.3 Practical contributions

Following the theoretical implications of this thesis, our findings have multiple implications for practitioners:

- Two holistic overviews which practitioners can use to assess the conditions that drive or hinder them in adopting or innovating toward CBMs
- 34 strategies practitioners in the built environment can employ to overcome the hindering conditions and capitalize on the driving conditions to CBMI
- Four categories for strategies to close resource loops through CBMI: 'Understanding the loop', 'Facilitating the loop', 'Promoting the loop', and 'Regulating the loop'
- Recommendation for practitioners to partake in collaboration and nurture relationships to reach CBMs and resilience across levels

The findings from Articles A, B, and C woven together in this thesis speak to managers and decision makers in several organizational settings who wish to drive the circular transformation in their firms' business models. Particularly, the insights are relevant to circular entrepreneurs, sustainability experts, internal decision makers, strategic consultants and managers of sustainability and transformation teams, and C-level executives.

First, this thesis allows practitioners to enhance their contextual understanding by advancing their knowledge on the conditions that can drive or hinder the adoption of CBMs and CBMI. By using the findings from this thesis, practitioners can assess the conditions that their firms are experiencing in their adoption and innovation processes toward CBMs. This thesis presented both a holistic overview of the conditions covered in the literature that determine CBM adoption, and a narrower overview of the conditions that impact CBMI in the built environment. I propose that these overviews can be used as frameworks, which practitioners can employ to analyze the conditions affecting their business. These categories are not solely applicable to firms operating in the built environment but can also be useful for firms operating in other resource-consuming industries, such as the fashion, food, paper, and medical industries. By acknowledging the situational conditions, companies can take one step further toward developing and adopting strategies to tackle them.

Therefore, to further extend this thesis' contributions to practice into concrete actions that practitioners may consider, it provided strategies that firms in the built environment could use to capitalize on the drivers and overcome the barriers to CBMI. At a practical level we presented 34 strategies, and nudge practitioners to employ these after having assessed which of the barriers and/or drivers their firm is experiencing. These strategies are matched to the exact barrier or driver conditions that they can tackle, and I therefore invite practitioners to use the findings in this thesis (Article A and B) to perform an assessment of which drivers and barriers their firm is affected by, and then employ the strategies recommended by the experts (Article B) to innovate their business model toward circularity. However, for firms that find these strategies do not fit their driver or barrier conditions, I suggest that developing strategies which aim to overcome particular drivers or barriers may be a more precise and advantageous way to increase CBMI and CBM adoption. I also propose practitioners to employ the proposed strategy categories: ‘Understanding the loop’, ‘Facilitating the loop’. ‘Promoting the loop’, and ‘Regulating the loop’ as a guide when developing strategies to reach CBMI and close resource loops.

Lastly, the findings in this thesis from Article A, B, and C strongly suggest a need for partnerships and collaborations as important enablers of CBM adoption and CBMI. Article A highlighted that the literature regards the partnership and collaboration determinants as strong drivers to CBM adoption, and we thus recommend that practitioners collaborate to overcome the barriers in unity. Subsequently, in Article B, 40 percent of the Delphi study experts ranked ‘Collaboration and partnerships’ as one of the greatest drivers to CBMI, and Article C highlighted that the startups that made the greatest effort to nurture their ecosystem had the highest resilience when faced with disruption and crises. Thus, on this basis, I recommend that practitioners should nurture their relationships with their collaboration partners and ecosystems and use collaboration as a strategy to reach CBMs and greater levels of resilience as a consequence.

This thesis started out with a wide focus, concentrating on CBMs across all firm types and industries. The research was then narrowed to focus on all firm types but in one specific industry: the built environment. Lastly, we confined our focus further to startups belonging to one entrepreneurial ecosystem in the built environment. The findings from our research reveal that all types of organizations—nondependent on their experience, size, or starting point—are likely to experience an abundance of both driving and hindering conditions to CBM adoption and CBMI. Therefore, to deal with this, this thesis has aimed to develop a common understanding between academia and practice in relation to the CBM concept and conditions that affect CBM adoption and CBMI, and their effect on resilience across levels when successful. Bridging this gap between academia and practice was important as business models are primarily concerned with firms, and therefore this thesis set out to ensure the involvement of practitioners in the majority of the research. Article A presents a translation to practitioners of the latest advancements in the literature in terms of determinants driving or hindering CBM adoption. Article B presents the aspects that the experts in the built environment reached consensus on regarding CBMI, and Article C presents the extent to which the startups that use CBMs from the outset are experiencing resilience as a consequence.

I hope that the insights from this thesis can serve practitioners in steering the transition toward sustainable development and resilience by (1) providing a deeper understanding of the conditions that impact CBM adoption and CBMI, and (2) giving practitioners a set of strategies, which can be used to tackle these conditions in the built environment context. The ultimate goal is to assist practitioners in driving the change toward a built environment that meets the needs of the population whilst ensuring a sustainable and circular socioeconomic system.

8. CONCLUSION

The world is changing radically, and an increased number of crises, hazards, and risks are now not only to be expected, but also inevitable. The dread of this dooming development, however, might be a do-or-die chance to compel the built environment—acknowledged to be one of the least willing industries to innovate and adopt change—to substantively transform their operations and adjust to the business models of the future, which can assist the efforts to reach resilience across levels, and ultimately affect the social-ecological system resilience (Brockmann et al., 2016; Koskela & Vrijhoef, 2001; Laborde & Sanvido, 1994).

Accordingly, this thesis set out to respond to this need for transformative change in the built environment and to provide practitioners with a scientific overview of the conditions that drive and hinder overall CBM adoption and CBMI, with strategies that practitioners in the built environment can employ to take advantage of, or overcome, these conditions. Further, this thesis aimed to demonstrate how CBMs can allow firms to gain greater resilience, which is sorely needed in the increasingly changing environment in which they operate. This thesis wove together three core articles focused on CBM adoption, CBMI in the built environment, and the resilience gained from CBMs across levels, and proposed two overarching research questions:

RQ 1: What conditions and strategies lead to CBM adoption and CBMI?

RQ 2: What are the resulting effects of CBMs on resilience across levels in the built environment?

Aiming to respond to the first research question (RQ 1), Article A involved a systematic literature review, building on a sample of 67 journal articles, and identified 54 distinct determinants to CBM adoption, and then further classified them into eight macro categories: culture, regulation, market, strategy, business case, collaboration, operations, and knowledge.

Further extending this discussion on driving and hindering conditions to CBMs, Article B employed a Delphi study method involving 25 experts, and developed an extensive overview of the drivers and barriers to CBMI in the built environment. In this article, we developed eight driver categories: ‘Behavioral change,’ ‘Supporting regulation,’ ‘Knowledge generation,’ ‘Sharing opportunities,’ ‘Collaboration and partnerships,’ ‘Increase in demand,’ ‘Cost and competition benefits,’ and ‘Grand societal challenges.’ Moreover, we also developed eight barrier categories: ‘Conservative behavior,’ ‘Politics and regulation,’ ‘Lack of knowledge and data,’ ‘Shared responsibility and liability conflicts,’ ‘Sourcing of secondary materials,’ ‘Lack of scalability,’ ‘Finance,’ and ‘Complexity and risk.’ These categories were subsequently linked to a development of 34 strategies to capitalize on the drivers and overcome the barriers, and these strategies were classified into four categories based on their contribution to closing resource loops by reaching CBMI: ‘Understanding the loop,’ ‘Facilitating the loop,’ ‘Promoting the loop,’ and ‘Regulating the loop.’

Therefore, by way of both Article A and B, it can be argued that there exists a rich multitude of conditions that impact firms when wanting to innovate toward and adopt CBMs—also for firms operating in the built environment. These conditions can be divided into drivers and barriers and examined from a wider macro level, as in Article A, to the narrower meso level shown in Article B.

Furthermore, this thesis aimed to investigate the resulting effects of CBMs on resilience across levels in the built environment and to answer the second research question:

RQ 2: What are the resulting effects of CBMs on resilience across levels in the built environment?

Article C employed a qualitative approach grounded in case studies to examine four circular and four linear startups from the built environment belonging to the same entrepreneurial ecosystem. This article examined how the levels of resilience differed in the circular and linear startups and revealed that the circular startups had attained greater levels of resilience owing to their innate nature to nurture their ecosystems. Moreover, by cross-comparing the startups in the entrepreneurial ecosystem, it became evident that the entrepreneurial ecosystem had become divided into two subsystems: one consisting of startups with a circular business model, and the other involving startups with a linear business model. This separation had developed not only as a result of the various business models of the startups, but also because of the differing connectedness of those startups to their ecosystem. By way of the findings in Article A, B, and C, we argue that a crucial facet to CBMs is the necessity to attain, or surrender, secondary materials as part of the continuation of the resource loop, and thus, collaboration, connectedness and co-dependency on other ecosystem agents becomes imperative. This attentiveness and investment that the circular startups have made in nurturing their entrepreneurial ecosystem paid off in gained resilience. The article found that the circular startups had formed a circular subsystem which keenly nurtured its ecosystem to the point where it considered it a living organism in need of food and care to maintain optimal health. This happened through daily connections and co-creation, data and knowledge sharing, and a ‘give and take’ mentality in which commercial opportunities and roles were divided equally between ecosystem agents. As a consequence, the circular subsystem experienced a stable and healthy ecosystem that could move together as a (holistic) whole and was capable of exploiting harsh conditions.

By virtue of combining Article A, B, and C, this thesis finds collaboration, partnerships and relationships to be a major driving condition toward both CBMI, CBM adoption and resilience. Considering today’s global circumstances in which resilience to crises is becoming progressively critical across firm, industry, and society level, and with the knowledge already existing in the literature regarding the potential for CBMs to be an avenue toward sustainable development in the built environment, this thesis finds that the potential drawbacks of CBMs are outweighed by their potential to advance both sustainable development and resilience. By attesting the potential for CBMs to reach sustainability and resilience, I argue that applying the theory behind CBMs to the context of the built environment is important. There is a compelling need for advancing both scholarly and practical research toward CBMs in the built environment in order for practitioners to envisage the potential benefits CBMs can offer to their firm and to resilience across levels, along with a need to devise CBM frameworks, initiatives, and strategies to abridge the adoption.

8.1 Limitations

The purpose of this thesis was to present the conditions and strategies for CBM adoption and CBMI in the built environment, and the effect CBMs can have on resilience in across levels. To do so, three distinct research methods were employed: a systematic literature review, a qualitative Delphi study with 25 experts, and a qualitative multiple case study with four circular and four linear startups. Each of these research methods have shortcomings that are, to a degree, tapered by combining them. However, several limitations are enmeshed in this thesis, and the core limitations include, but are not limited to, four factors.

First, a limitation to this thesis concerns the data sample. The two empirical articles in this thesis have focused on data gathered with 25 experts (Article B) and a multiple case study with eight startups belonging to one entrepreneurial ecosystem (Article C). Due to these data being limited to only 25 experts and one entrepreneurial ecosystem, the generalizability of the results is a limitation to this thesis as it restricts the efficacy of analytical generalizability (Voss et al., 2002).

Second, this thesis consists of two cross-sectional articles that did not study the conditions for CBMs in the built environment longitudinally. Thus, a limitation of this thesis reflects that the findings are depicting the conditions solely at the time in which the data collection was carried out. However, this thesis has not examined the ongoing developments of the conditions in the built environment, which could provide a high degree of accuracy in observing the variable changes in the conditions associated with CBMs.

Third, the research forming this thesis were primarily limited to one industry: the built environment. Hence, the findings in this thesis are not totally generalizable across industries, although the findings could be pertinent to other resource-consuming industries, such as the food and fashion industries.

Fourth, this thesis has focused on collecting qualitative data, which is regarded by some scholars as the ‘bottom of the hierarchy of evidence of informing’ (Galdas, 2017, p. 2) owing to the level of potential bias. This thesis therefore aimed to reduce the likelihood for bias as best as possible by triangulating the findings with secondary data, using the Gioia method and thematic coding to code the data, and pilot testing the interview guides with at least two experts.

8.2 Future studies

Despite the CBM field of research still being in its premature stages, the advances in scholarly studies on the topic are progressing rapidly. Simultaneously, the push from firms to take advantage of CBMs is intensifying precipitously. As a consequence, theoretical advances that can drive both the research and practical agenda on CBMs are sorely needed, and several of the contributions and limitations of this thesis unseal the potential for future studies. I propose three avenues for future studies:

First, building on the limitations of this thesis, future studies could increase the level of generalizability of this thesis' findings by undertaking longitudinal studies of the conditions for CBMs in the built environment. This research is crucial to gain knowledge on how business model conditions are prone to change, and investigating how a crisis context could spark this development could be particularly interesting in light of the increasingly changing environment the built environment is faced with. Future longitudinal studies could also benefit from examining the viewpoints of various ecosystems in the built environment, following their course of CBM adoption or CBMI, and their conditions prior, during, and post implementation. Potential research questions could be:

- *How do the conditions for CBMs in the built environment change as the material crisis influences the industry's stakeholders?*
- *How does CBMI change the industrial ecosystem in the built environment?*

Second, future studies relying on quantitative data and adopting an industry-wide perspective could provide generalized findings that could assist practitioners wanting to adopt CBMs. This could be particularly interesting for investigating how resilience could be gained through CBMs, and for understanding which business models may offer the greatest ability to increase resilience across different industries. Future research could, for example, address the following research questions:

- *What industries can make the greatest strides to net-zero through CBMI?*
- *What business models may offer the greatest ability to increase resilience across industries?*
- *What CBM drivers should firms capitalize on to create entrepreneurial ecosystem resilience?*

Third, combining a longitudinal approach to an industry-wide context could be particularly interesting to study the effect of the environmental crisis, and further studies could base their study on the following research question:

- *What business models are best suited to stand the disruptive forces of the environmental crisis by creating social ecological system resilience?*

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THESIS APPENDIX

Appendix 1. Book Chapter

Title: Circular Business Models for Digital Technologies in the Built Environment

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Abstract

Business model innovation enabled by novel digital technologies can accelerate the impact and upscaling of the circular economy in the built environment. Digital technologies not only enable highly impactful new business models but also enable innovation of existing business models. Considering the disruptive power of digital technologies, rethinking business models in the construction sector for the circular economy is vital to manage risks and capture opportunities. This chapter presents 12 real-life cases of emerging business models enabled by digital technologies that successfully narrow, slow, close, or regenerate resource loops in the construction sector. Cases are analysed regarding how they create, deliver, and capture value and how they enable circularity. Findings present different types of business models for digital technologies prevalent for narrowing, closing, slowing, and regenerating resource loops and that enabling capabilities for circularity, such as tracking, monitoring, control, optimisation, design evolution, and information exchange, are at the core of their value propositions. Industry practitioners can use findings to familiarise themselves with emerging business models and innovation opportunities.

Keywords

Circular Business Models; Business Model Innovation; Digital Technologies; Built Environment; Building Industry

Introduction

A business model is a useful management tool to analyse and design a firm's business logic (Casadesus-Masanell and Ricart, 2010) and how a company delivers, creates, and captures value (Osterwalder & Pigneur, 2010). During this process, it helps managers to focus on the most relevant building blocks for the creation of commercial value (Osterwalder et al. 2005). The business model concept in management literature originates from the time when the internet proliferated, and companies' blueprints to creating value diversified and became more complex compared with traditional business models (Osterwalder et al. 2005, Amit and Zott, 2010). Business models are considered a strong indicator of competitive advantage (Magretta 2002) because changes are harder to replicate than product innovations (Amit and Zott 2012). Thus, in order to stay successful, companies must adapt their business model over time to changing business environments (Demil and Lecocq 2010).

Technological advances since the diffusion of the internet in the 1990s have enabled new digital business models, which are now transforming industrial-age industries, such as the media, retail, financial services, and logistics sector (Veit et al. 2014). Digital business models can be defined as those that rely on digital technology and leverage the effects of digitalisation (Guggenberger et al., 2020; Bärenfänger and Otto 2015). Veit et al. (2014, p. 48) define a business model as digital "if changes in digital technologies trigger fundamental changes in the way business is carried out, and revenues are generated" of which Uber in the transport sector or AirBnB in the hospitality sector are prominent examples that have caused major disruption of previous business practices.

Even though the adoption of digital technologies in the building sector is slow compared with other sectors (ESCO, 2021), an increasing number of digital technologies and business models are proliferating. Business models are paramount for the market introduction and uptake of these technologies. Only if technologies are embedded in business models that create superior customer and business value, the technology-enabled offers can be commercialised and scaled. This is the case, for instance, in platform models, such as those operated by the Norwegian company Loopfront that enables material or second-hand product exchanges (Loopfront, 2022). Given the enormous challenges, such as stagnating productivity, high construction costs, resource intensity and scarcity paired with pending ambitious environmental regulation in national legislation (ESCO, 2021; JRC, 2019), new digital business models could provide unforeseen solutions to challenges and serve customers in radically superior ways. Digital business models are understood as innovations in business models that transform analogue, physical objects, processes, or content into primarily digital formats (Trischler & Li-Ying, 2023).

Digital technologies, such as platforms or building information modelling (BIM), enable a plethora of benefits, such as improved collaboration, easier transactions and greater control of the value chain. The Internet of Things (IoT) increases data availability and enables data-driven decision-making for more efficient operations. These developments are fundamentally changing traditional ways companies approach operations, procurement, design, and construction and engage with value chain partners (McKinsey, 2020). For example, Boston Consulting Group estimates that 10-17% of total annual spending can be saved in the operation of buildings and 13-21% in the construction phase from full digitalisation (BCG, 2016). Considering the disruptive power of digital technologies, rethinking business models and technological capabilities is vital to manage risks and capturing opportunities.

To provide an overview of the developments of digital business models in the circular built environment, this chapter presents 12 real-life cases of emerging business models enabled by digital technologies that successfully narrow, slow, close, or regenerate resource loops in the built environment. Cases are identified through desk research focusing on Europe, particularly the Netherlands, due to the authors' familiarity with this geographical context and proliferation of commercialised circular solutions in the built environment. Cases are analysed regarding how they create, deliver, and capture value, the digital technologies used, and their level of maturity. Also, their enabling capabilities to help narrow, slow, close, and regenerate resource loops in the built environment are presented. Based on the product and service offers of the case studies, several types of digital business models for the circular built environment are identified.

This chapter proceeds with outlining the theoretical background of the circular business model concept (Section 2), the presentation of the case studies for narrowing, slowing, closing and regenerating resource loops (Section 3) and the discussion and conclusion (Section 4).

Circular business model innovation

A business model can be described as a conceptual tool which can assist in understanding how a company conducts business to create and capture economic value (Schaltegger et al., 2012). This chapter defines business models by three main elements: value proposition, value creation and delivery and value capture (Bocken et al., 2014; Richardson, 2008).

The value proposition concerns product/service offerings, customer segments and customer relationships of a company's business model (Boons and Luedeke-Freund, 2013). Value creation and delivery mechanisms are concerned with the activities, resources, partners, and distribution channels of a company's business model. Value capture is about the cost and revenue model, and in the case of a circular or sustainable model, it also concerns the positive value for society and the natural environment.

Business model innovation is considered to be a holistic approach that can function as an enabler to fulfil radical changes in a company's offers and value chains (Wells and Seitz, 2005, Bocken et al., 2016, Tunn et al., 2019). Innovating the business model involves either reconfiguring the main elements of the company's existing business model or developing new business models (Zott and Amit, 2010). In the context of circular economy, business models have received substantial attention in literature and industry as an avenue to achieve increased sustainability in organisations across industries. Circular business models aim to create, deliver, and capture value whilst implementing circular strategies which can close material loops and extend the useful life of products and parts (Nussholz, 2018). Adopting circular strategies usually requires radical and holistic alterations to a company's offers and value chains (Bocken & Geradts, 2022; Wells and Seitz, 2005, Nussholz, 2018).

3. Digital business models to enable circularity

Twelve business model cases enabled by digital technologies were selected to exemplify business models that are narrowing, slowing, closing and regenerating resource loops in the built environment. The following sections describe the companies' offers, how they enable circularity and the main elements of their business models. It should be noted that all cases are examples of new business models, sometimes operated through daughter companies or spin-offs and that not necessarily the whole company associated with the example is fully circular.

3.1 Digital business models for narrowing resource loops

This section discusses the companies Parametric Solutions, Philips Lighting, and EDGE Next as examples of digital business models for narrowing resource loops.

The Swedish company Parametric Solutions offers an analytics app based on a parametric design method for architectural teams to create and compare design options (Parametric Solutions, 2022a). Designs are developed based on the client's criteria and downloadable into design tools such as Revit. Optimisation criteria are, for example, space efficiency, energy efficiency, and reduced embodied carbon. As such, the main enabling capabilities of Parametric Solution’s business models for narrowing resource flows are optimisation and design evolution. Parametric Solutions, for instance, partnered with the engineering consultant COWI and architect Arkitema to generate options for building volumes for a respective site (Parametric Solutions 2022b). Parametric Solutions creates value through the development of the parametric method and customised app based on the client’s design criteria. Value is captured through users’ payments for the app license (Table 1).

Philips Lighting, with its headquarters in the Netherlands, offers an interactive IoT and Big Data System for lighting solutions. Sensors in the lighting panels are connected to interactive app-based systems that measure the occupancy, movement, and lighting levels to adjust and distribute energy usage where needed (Philips Lighting, 2022). As a result, increased user comfort is achieved and combined with a significant energy reduction for lighting. For example, energy usage decreased by 70% in the office building The Edge Amsterdam (Philips Lighting, 2022). The control application provides building managers with real-time data on operations and activities to optimise operational efficiency and provides users with the possibility of adjusting the lighting. The main enabling capabilities of Philips Lighting’s business model for narrowing resource loops are tracking, monitoring, control, and optimisation. Value is created by developing lighting panels, sensors, and a software system to monitor and control the lighting. Value is captured through the sale of the lighting system and services, while apps are offered free to users.

EDGE Next is a Netherlands-based real estate developer that also operates a service provider platform based on digital twin, sensor-based solutions, and big data analytics. EDGE Next offers different service and technology packages for various optimisation purposes, such as improved space utilisation, operational efficiency, and indoor comfort (EDGE Next, 2022a). EDGE Next's business model's main enabling capabilities for narrowing resource loops are tracking, monitoring, control, and optimisation. For the Swedish power company Vattenfall, EDGE Next developed a 22,000 m^2 office building in Berlin, using their technologies to achieve a significant reduction in energy use (EDGE Next, 2022b). Value is created through the development of the sensor systems, platform applications and user dashboards, with targeted customers being corporate real estate, portfolio managers, and human resources. Value is captured through continuous payments for different service packages.

Table 1: Examples of business models for narrowing resource loops enabled by digital technologies

Company	**Parametric Solution**	**Philips Lighting**	**EDGE Next**
Sector	Building design	Lighting	Smart buildings
Country	Sweden	The Netherlands	The Netherlands
Business model type	Analytics App developer	Light as a service	Service provision platform
Digital technologies	Artificial intelligence	IoT, big data and analytics	Digital twin, digital platform, IoT, big data analytics
Enabling capabilities	Optimisation, design evolution	Tracking, monitoring, control, optimisation	Tracking, monitoring, control, optimisation
Value proposition	• Instant creation and comparison of design options • Design optimisation based on architectural teams' criteria	• Improved lighting quality • Adjustments based on user preferences • Reduction of energy use • Real-time data on operations and	• Based on sensors, delivering data and insights for corporate real estate, portfolio managers, and human

	• Optimisationof sustainability criteria e.g., efficient space use, embodied carbon, energy consumption and efficiency, biodiversity	activities for facility managers to streamline operations	resources to optimise building performance • Optimisation of space utilisation, operational efficiency, employee wellbeing, sustainable performance
Value creation	• Developing algorithms, front and back end by team of architects and coders • Customisation of backend to customers' needs	• Developing lighting panels, sensor systems, big data system and analytics and user apps • Maintenance of lighting system	• Developing sensor systems, software, platform, dashboards apps for different optimisation targets
Value capture	Payments for license for app	Payment for products of lighting system and services	Payment per package
Company type	Start-up	Multi-national	Scale-up

3.2 Digital business models for slowing resource loops

This section discusses the companies Madaster, Rehub, and Excess Material Exchange as examples of digital business models for slowing resource loops.

The Netherlands-based Madaster operates as a digital platform offering a registry of all materials and products used in real estate and infrastructure. Madaster bases its registry on material passports developed for the objects. Amsterdam Metropolitan Area has, for instance, been involved in using Madasters's material passport to stimulate the regional circular economy (Madaster, 2022). The enabling capability of Madaster's business model is information exchange. Value is created by linking the registry to material databases of partner companies to facilitate data entry and quality. Value is captured through offering a license for use.

Rehub is a Norwegian start-up offering a material bank platform which connects the supply and demand side for the reuse of construction materials (Rehub, 2022). Rehub's business model offers the enabling capabilities of optimisation and information exchange. The value proposition is about the database for reusable materials and warranties, environmental impact analyses and assistance. Value is created through the development of the platform and data registry of the materials, and value is captured via subscription-based payments for access to the platform.

Excess Material Exchange (EME) is a Dutch start-up operating as a digital marketplace platform focused on allowing clients to find new high-value reuse options for their end-of-use materials and products (Excess Material Exchange, 2022). EME's tools are, for instance, applied in the European carpet industry to ensure that recyclable carpet tiles are matched with the demand side. The carpet tiles are given a product identification to gather all product information and allow for recyclability (Excess Material Exchange, 2019). The business model's enabling capabilities involve optimisation and information exchange. The company's value proposition is about the offering of an online material matching platform focused on selling B2B. Value is created through developing the platform, and value is captured by selling subscriptions to access the platform.

Table 2: Examples of business models for slowing resource loops enabled by digital technologies

Company	**Madaster**	**Rehub**	**Excess Material Exchange**
Sector	Buildings and infrastructure	Construction materials	Cross-industries
Country	The Netherlands	Norway	The Netherlands

Business model type	Material passport platform provider	Material bank platform provider	Marketplace platform provider
Digital technologies	Digital platform, material passports	Digital platform	Digital platform, blockchain, artificial intelligence
Enabling capabilities	Information exchange	Optimisation, information exchange	Optimisation, information exchange
Value proposition	• Registry of information on all materials and products in a building project • Circularity, embodied carbon, or toxicity assessment • Material passport for optimised end-of-use and end-of-life value management for construction materials and products	• Database for reusable material • Warranties on the material • Documenting CO_2 savings	• Online marketplace for all excess material • B2B sale by matching the supply and demand across industries
Value creation	Acquiring partner companies to facilitate data entry and data quality	Development of digital platform	Development of platform
Value capture	License for use	Subscription-based payment for platform access	Subscription-based payment for platform access
Company type	SME	Start-up	Start-up

3.3 Digital business models for closing resource loops

This section discusses the companies MetroPolder, Circularise, and Loopfront as examples of digital business models for closing resource loops.

The Dutch company MetroPolder (Metropolder, 2022a) offers a green roof with a rainwater storage system. Storage and discharge are controlled through a sensor-based software system allowing for controlled discharge of rainwater to prevent flooding and enable reuse, thereby preventing the use of drinking water. This system for control and optimisation helps close resource loops for rainwater. Through its biodiversity and cooling benefits, the green roof also fits the regenerate principle. In Amsterdam, MetroPolder's water storage system is used on the roof park/garden Babylon providing a 1500 m^2 park with a water storing capacity of 50,000 litres. Water is used for plant irrigation, for example, for the vegetable and fruit garden, enabling suitable irrigation levels (Metropolder 2022b). MetroPolder's business model creates value by developing a sensor and software system, green roof technology, an operating system, and a dashboard for users, e.g., facility managers. Value is captured through the sale of the water capture system technology and services such as construction and maintenance.

The company Circularise, based in the Netherlands, offers a blockchain-enabled software platform to help companies track products and materials and allow information exchange to enable closing loops of materials (Circularise, 2022a). Circularise partnered with the City of Amsterdam to increase traceability and transparency in their construction procurement process and gather data on environmental impact, enabling information sharing without risking sensitive data. Circularise also partnered with a concrete product company to help trace materials end-to-end throughout the supply chain, and that information can be shared without risking sensitive data (Circularise, 2022b). Circularise's business model creates value through the development of blockchain technology and the creation of data, product passports and other certificates. Value is captured through selling services and payment for licenses for software solutions.

Loopfront is a Norwegian company which offers clients working across the built environment access to a reuse platform. The digital platform offers material passports, a material bank and a survey tool and assists in closing resource loops through its enabling capabilities of optimisation, tracking, monitoring and control (Loopfront, 2022). The value is created through the development of the digital platform and is captured through selling membership packages on four different levels (Starter, Basic, Standard or Enterprise).

Table 3: Examples of business models for closing resource loops enabled by digital technologies

Company	**MetroPolder**	**Circularise**	**Loopfront**
Sector	Roofs and water management	Manufacturing and recycling	Platform developer
Country	The Netherlands	The Netherlands	Norway
Business model type	Software system provider	Software platform provider	Digital platform and surveying tool
Digital technologies	IoT	Blockchain technology, digital platform, material passports and databank	Digital platform
Enabling capabilities	Control and optimisation	Tracking and information exchange	Tracking, monitoring, control, optimisation
Value proposition	• Sensor equipped roof system with rainwater storage, for e.g., developers or facility managers • Controlled discharge of water to prevent flooding and enable rainwater use • Biodiversity benefits and cooling effects	• Blockchain technology to trace products and materials and verify their origins • Creation of product passport and certificates	• Survey tool • Material cards • Marketplace • Material passports
Value creation	Developing sensor and software system, green roof technology, operating system and dashboard	Developing software and platform solutions, including back end and dashboards	Developing and piloting material bank and material passport system
Value capture	Sale of roof systems and services, e.g., planning, construction, maintenance	Sale of services and licenses for software solutions	Sale of membership to access platform
Company type	SME	Start-up	Pilot project

3.4 Digital business models for regenerating resource loops

This section discusses the companies WASP, Lo3Energy, and AUAR as examples of digital business models for regenerating resource loops.

WASP is an Italian firm specialised in designing, developing, and selling 3D printers (WASP, 2022a). The company has succeeded in 3D printing structures that are entirely developed using reusable and recyclable bio-based materials from local soil. Specialist software allows for two printing arms to be synchronised for the construction, which allows for avoiding collisions and ensuring simultaneous operation. WASP recently created an installation for Dior in which they 3D printed two pop-up stores on Jumeirah beach in Dubai from all-natural materials (WASP, 2022b). WASP's business model creates value through the development of advanced 3D printers, whereas value is captured through the sale of 3D printers and 3D printing services.

Lo3Energy is an American company which has developed a front-end blockchain-powered platform called Pando that enables suppliers and clean energy operators to support 24/7 load matching and offers intelligent incentives to drive renewable energy use (LO3Energy, 2022). The Pando software solution has, for instance, been installed in a shopping centre in New South Wales, Australia, where it will be used to optimise renewable energy production. The company's business model's main enabling capabilities are monitoring, optimisation and information exchange, helping to regenerate resource loops. The business model is capturing value through developing a grid-edge accounting service platform that can match the production and consumption of clean energy at defined time intervals. The value is captured through payment by grid operators and energy utilities to promote their offers on the app.

AUAR is a British start-up which develops dwelling units through robotic manufacturing using bio-based materials with a zero-carbon life cycle (AUAR, 2022). It has been used in an installation at The Building Centre in London to show how it can act as a home, office, and co-working station solution (Design Boom, 2020). AUAR's business model's enabling capabilities consist of optimisation and design evolution. Value is created through the development of robotically assembled dwelling units, and value is captured through the payment for customised dwelling units on demand. The prices are dependent on the dwelling unit size and amounts of units needed.

Table 4: Examples of business models for regenerating resource loops enabled by digital technologies

Company	**WASP**	**Lo3Energy (Pando)**	**AUAR**
Sector	3D printed construction	Renewable energy	Automated architecture
Country	Italy	USA	UK
Business model type	3D printer manufacturer	Web platform provider for energy retail	Automation developer
Digital technologies	3D printer manufacturing	Blockchain technology	Additive/robotic manufacturing
Enabling capabilities	Optimisation, design evolution	Optimisation, monitoring, information exchange	Optimisation, design evolution
Value proposition	• Optimising construction to be more time and resource-efficient • Use of 100% bio-based materials	• Software platform allowing clients to forecast the availability of cheap and clean energy	• Modular dwelling units with installation that can be developed according to clients' specific needs • Zero-carbon lifecycle
Value creation	Development of 3D printers or building constructions with 100% bio-based materials for reuse and recycling	Development of grid-edge accounting service to match production and consumption of clean energy at specific time intervals	Development of robotically assembled and customised dwelling units
Value capture	Sale of 3D printers and 3D printing services	Payment by grid operators and energy utilities to promote their offers on the app	Payment for dwelling units on demand
Company type	SME	Start-up	Start-up spinout

Discussion and conclusions

This chapter has presented 12 cases of business models enabled by digital technologies that help narrow, slow, close, and regenerate resource flows in the built environment. The analysed companies were active in various sectors within the built environment, such as smart buildings, interiors, building design and construction. Business models were found to use a variety of technologies, often pairing multiple technologies such as digital twins, digital platforms, IoT, and big data analytics. No emerging business models, however, were found based primarily on BIM and Geoinformation Systems (GIS) technologies. A reason could be that these types of software are available through licenses of established companies, widely used, but in the case of GIS, also accessible open source. Both technologies however have the potential to track stocks and locations of components and materials suitable for reuse and recycling (see Chapter 2 for industry use cases of GIS).

Through developing and using digital technologies and thinking of resource efficiency and circularity in their business models, the analysed case companies make significant contributions to enabling circularity in the built environment through their offers. They capitalised on several enabling capabilities of digital technologies to realise circular resource flows. Especially tracking, monitoring, control, optimisation, information exchange and optimisation were prominent examples of how digital technologies help enable different strategies for circularity. It should be noted that some of the presented cases explicitly define themselves or their services as circular (e.g., Circularise) while most of them do not (e.g., EDGE Next).

Based on the overview of several case studies, various business model types were identified, summarising commonalities of companies' offers. Types identified were 3D printer manufacturer, platform provider (e.g., material registry, marketplace, service provision, retail), automation developer, product manufacturer, light as a service model, and analytics app developer. Especially, service offers facilitated through platforms were common even though they had a lot of variation in terms of their use and offerings. For narrowing resource loops, business model types based on software for optimisation were the most common. For slowing and closing resource loops, business model types based on platforms were dominant. For regeneration, manufacturers or providers of automation and 3D printing machinery or services dominated.

Many of the identified cases were in the Netherlands. The Netherlands has a progressive circular economy policy (Ministerie van Infrastructuur en Waterstaat, 2021) and ranks high in the Global Innovation Index (GII, 2021), which might be an explanation for the proliferation of circular start-ups in this country. However, the fact that the authors of this chapter have better insights into the developments in the Dutch built environment and might have missed cases in other countries, for example, if company websites were not available in English or less emphasis was put on communication outside of the national market, might have contributed to the dominance of Dutch case studies.

Most of the studied cases were start-ups. Some companies are already small to medium-sized enterprises, such as the digital twin and optimisation platform provider EDGE Next or the 3D printing company WASP. Many of the identified start-ups are daughter companies or spin-offs of incumbent multinationals (e.g., PolderRoof by Wavin, Rehub by Ramboll). Certainly, many digital technologies, such as parametric design, BIM, GIS are also already used by incumbents. This study presented companies with circular business models enabled by digital technologies, offering their benefits to other actors in the sector. Future research is needed to investigate potential pitfalls and uncertainties associated with digital business models for enabling circularity in the built environment, that might stem from a higher dependence on critical materials, data and technology, or environmental rebound effects. Despite these pitfalls, these developments in the uptake of digital technologies are critical as wide adoption is a prerequisite to capitalise on the improvement potential of digital technologies for circularity and other sustainability benefits (JRC, 2019).

Key takeaways

- Considering the disruptive power of digital technologies, rethinking business models in the construction sector for the circular economy is vital for companies to manage risks and capture opportunities.
- Companies considering resource efficiency and circularity in their business models and developing offers based on digital technologies can make significant contributions to enable circularity in the built environment.
- Emerging business model examples for the circular economy include: 3D printer manufacturer, platform provider (e.g., material registry, marketplace, service provision, retail), automation developer, product manufacturer, light as a service model, and analytics app developer.
- Different business model types (e.g., digital marketplaces, platforms, etc.) are suitable for enabling different circular principles (i.e., narrowing, slowing, closing, and regenerating resource loops).

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