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Capabilities for circular economy innovation: Factors leading to product/service innovations in the construction and manufacturing industries

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ABSTRACT

As companies in the manufacturing and construction industries strive to meet the EU circular economy (CE) targets, they need to develop new capabilities to implement CE activities that can positively influence their product/service innovations. However, companies in both industries, and beyond, still struggle to develop internal capabilities to innovate products and services that would help them in implementing CE principles and move towards the CE. The objective of this research is to analyze the types of innovation capabilities that are needed to enable CE implementation and achieve product/service innovations in two different industrial sectors. Prior research has focused on innovating and implementing circular business models and elaborated less on the innovation capability types. We collected survey data in December 2021–January 2022 that consists of responses from companies operating in Germany (n = 177), including employees in manufacturing (n = 87) and construction companies (n = 90). The results from the partial least squares structural equation modeling (PLS-SEM) based on measurement models from the literature indicate that employees in both sectors overall perceive higher levels of CE implementation capability as important for the company's product/service innovations. Furthermore, the results reveal differences in the way CE innovation capability and IT resource orchestration capability influence CE implementation and product/service innovations in the two sectors. Our study offers theoretical implications on how dynamic capabilities are associated with CE innovations and how they influence companies' product/service innovations based on empirical evidence from two industrial sectors. Those capabilities that are crucial for circular product/service innovations need to be associated with CE implementation capabilities. The results further advise practitioners in the development of CE innovation and CE implementation capabilities and how they are linked to IT resource orchestration capability and provide evidence on their relevance to creating product/service innovations.

1. Introduction

Despite the fact that a transition toward a circular economy (CE) is considered to be a widely accepted target within the EU, the actual development and implementation of circular product and service innovations still remains a challenge for the majority of companies (Blomsma et al., 2019; European Commission, 2020a; Haas et al., 2015) and there is a need for new CE related innovation capabilities. In previous literature, CE innovation capabilities have been grounded on the theory of dynamic capabilities theory (da Nascimento et al., 2023; Dangelico et al., 2017) based on Teece (2007) and Teece et al. (1997). In this case, dynamic capabilities reflect the ability of a company to further develop its capabilities as a response to change happening outside the company, on the markets, and in the environment (Fernandez de Arroyabe et al., 2021; Zahra et al., 2006). Recent research in Europe has found that companies can still face major challenges in distinguishing between the main resources and capabilities they should develop and in determining how to implement them when adopting CE practices

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(Kristoffersen et al., 2021a). When companies develop and launch circular products and services, they need to start implementing circular business models (CBM) that indicate how to propose, create, and capture value from circularity (Urbinati et al., 2017). To ensure that the targeted product/service innovations of the CBMs are achieved, there is a need for a better understanding of the capabilities that have an impact on the CE implementation (Kaipainen and Aarikka-Stenroos, 2022; Ritzén and Sandström, 2017).

The need for capabilities to support in the implementation of CE targets is seen as crucial for particularly environmentally burdensome industrial sectors, such as the construction and manufacturing sectors. These sectors generate significant amounts of waste, which has led to the urgent need to rethink material usage and develop more sustainable production systems that are compliant with CE principles to reduce carbon footprints and minimize the usage and overexploitation of virgin material resources on a societal level (European Commission, 2020a). Considerable amounts of resources are needed for the built environment, and in 2020, the construction sector accounted for approximately 50% of all extracted material in Europe (European Commission, 2020a). It has been estimated that approximately 37% of the EU's total waste is generated in the construction sector and nearly 11%, in the manufacturing sector (Statista, 2022). The implementation of CE practices in companies will require specific innovation and digitalization-related capabilities (Neligan et al., 2022). The way these capabilities are applied in different industrial sectors can progress at different paces, and their impacts on CE implementation may vary from each other depending on the industrial sector (Lieder and Rashid, 2016).

CE innovation (CEI) capabilities can be defined as activities integrating high-level CE goals, principles, CBMs, and recovery strategies into more practical level technical and market-based innovations. The aim is to launch products and services that have been designed and produced according to circular design principles and that aim at capturing value across the full product life cycle, including potential second product life cycles (Brown et al., 2019; Kirchherr et al., 2018; Suchek et al., 2021). For an organization to innovate for the CE, it needs to develop a CEI capability that enables it to recognize and analyze the interdependencies of various stakeholders, share knowledge, and plan the supplies of materials (Blomsma et al., 2019; Kristoffersen et al., 2021a). CEI requires that companies innovate on multiple levels, including the process, product, organization, company strategy, and business models, to enable systemic change (Suchek et al., 2021). In this paper, we consider CEI capability as a dynamic capability (Teece et al., 1997; Teece, 2007) that is needed to innovate new CE practices in companies. Whereas general innovation capability is defined as a capability that is a necessary element in companies' strategies for ensuring superior and competitive performance and it is distinguished from sustainability-oriented eco-innovation capability (Fan et al., 2021; Perna et al., 2015; Peuckert, 2011; Walz, 2010; Walz et al., 2017).

The adoption of new dynamic capabilities for the CE at the company level requires innovation capabilities driven by technical and engineering solutions that are enabled by IT technology and digitalization (Antikainen et al., 2018). A study by the Organization for Economic Co-operation and Development (OECD) reports that companies that invest in data-driven innovation and data analytic capabilities tend to have a 5%–10% faster increase in productivity than companies that do not invest in such capabilities (OECD, 2015). Previous research has used the resource orchestration perspective to study capability-building processes, and their results indicate that research orchestration capabilities are crucial for improving innovations, especially when there is a need to adapt to changes in the markets (Chadwick et al., 2015; Wales et al., 2013). IT resource orchestration capability refers here to the capability building process led by managers when they are converting companies' IT resources into the form of IT capabilities (Sirmon et al., 2011).

Sehnem et al. (2022) have called for more research on types of innovation in the context of the CE, and innovation barriers within the CE, as well as required innovation skillsets for the CE. They also specifically call for comparative studies and empirical validation of innovation capabilities within the CE context. Currently there is also a research gap regarding the impact CE related innovations have on actual the CE implementation and product/service innovations, especially in engineering management contexts (Scipioni et al., 2021), CE innovation challenges related to new CBMs and their implementation (Santa-Maria et al., 2021) as well as the management of CBM design in different contexts where companies are targeting CE goals (Vecchio et al., 2022).

We aim to answer the following research question: How are different innovation capabilities influencing the CE implementation capability and product/service innovations of companies, and what is the role of IT orchestration capability in these cases? Survey data (n = 177) were collected at the end of 2021 and in early 2022. The partial least squares structural equation modeling (PLS-SEM) method is used in this paper to estimate and evaluate the theoretical model created on the basis of previous research and validated measurement models.

This paper contributes to the body of knowledge on CE innovations and capabilities development for CE implementation. In this study, the capabilities are considered as dynamic capabilities that are required to develop CE innovation practices in companies when moving towards a CE and thus it responds to the call by Sehnem et al. (2022) for further quantitative studies in this area. The focus in this research is to study the influence of different types of capabilities on the perceived product and service innovations of companies. The capabilities that we explore are general innovation capability, CEI capability, IT resource orchestration capability, and CE implementation capability.

The major contribution of this study is the linking of different types of CE related innovation capabilities to the dynamic capabilities research stream and analyzing their impacts on the CE implementation capability and product/service innovations in two different kinds of industrial sectors. Based on the literature, we have created a conceptual model that we have tested by conducting PLS-SEM analysis with empirical data. The findings of this study show that there are clear differences in the way employees in manufacturing and construction companies perceive how IT resource orchestration capability and CE innovation capability influence the CE implementation and product/service innovations of their companies. Another contribution of this research lies in providing a cross-industrial comparison regarding the manner, in which CE implementation capability and product/service innovations are influenced by the three different capabilities (i.e., general innovation capability, CE innovation capability, and IT resource orchestration capability). The findings provide evidence of the need to analyze the specific challenges of individual industrial sectors and offer opportunities to share cross-sectoral learning from CE-related capability development initiatives conducted in different industrial sectors. The resulting model can be used in future research as a base model when analyzing the influence of innovation, CE innovation, and IT resource orchestration capabilities on CE implementation activities and on product/service innovations. The latter ultimately influences the sustainable long-term competitiveness of companies.

The paper is structured in the following way. The first section describes the theoretical background on which the hypotheses development and conceptual model are based. The following section presents the methodology, data collection, and results from the quantitative data analysis conducted using the PLS-SEM approach. The final section discusses the implications of the research findings and the limitations of the study, and suggests future research areas.

2. Theoretical background and hypotheses development

2.1. Product/service innovations

Prior research has shown that product/service innovation is one of the major sources of competitive advantage (Blichfeldt and Faullant, 2021; Lau et al., 2010). Close interaction and collaboration with suppliers are essential for improving product/service innovations and enable green supply chains implemented with a life cycle approach for a circular economy (Xing and Liu, 2023), which can then result in increased competitiveness (van Echtelt et al., 2008). Product/service innovations (P/SI) can be measured with company-level performance in relation to its former performance and competitors' performance. Sustainable competitiveness is seen as one dimension in addition to environmental performance, financial performance, and corporate reputation (Khan et al., 2020; Kristoffersen et al., 2021a). In previous research, it has been measured by employees' self-assessment of how their company is capable of introducing innovative products and services, improving the quality of their products/services, improving the brand value of products/services, and gaining access to new markets (Kristoffersen et al., 2021a).

The development and innovation of novel products and services need to be integrated as core components of the business models of the companies. In the manufacturing sector, products/service innovations may include larger sets of connected equipment and possible services and in some cases manufacturing companies are even offering 'products as services' (Vaillant et al., 2023). In the construction sector, the P/SI are more related to the production of building components that are the products in the constructions sector (such as floors, walls, roofs, beams), and extending life cycles of the building components (Murphy et al., 2015). CBMs that consider the circularity of the product design and have new kinds of services to extend life cycles, are essential for companies and their supply chains to ensure future competitiveness in a business environment where waste and natural resource depletion are risks for production systems (Nandi et al., 2020). Responding to these growing risks, CBMs are already increasingly being introduced as solutions for companies to stay competitive when moving towards a CE (Lüdeke-Freund et al., 2019; Pieroni et al., 2019).

The practical implementation of CBMs has been fairly slow in many companies (Guldmann and Huulgaard, 2020). Some of the reasons for the slow implementation include the varying tracking of ideation and development, limited resources in new product development and process development, and unsuccessful business experimentation (Geissdoerfer et al., 2018). Therefore, we argue that the success of CBMs are linked to CE implementation that can be measured by the level of P/SI, which is considered a dimension of competitiveness.

2.2. Circular economy implementation capability

CE implementation can be defined as the company-level ability to apply CBMs in its value chain (Kristoffersen et al., 2021a). Prior literature has focused on innovation in the context of CBMs, whereas the actual practical activities and capabilities from an engineering perspective across supply and value chains still require more empirical research (Nandi et al., 2020). Company-level CE implementation requires activities and capabilities for developing practical technical solutions to create sustainable product value. The formulation of CBMs and their implementation are crucial for improving companies' environmental and financial performance, competitiveness, and corporate reputation (Blomsma et al., 2019). Incumbent companies and especially small and medium-sized enterprises (SMEs) face challenges in the implementation of CBM innovations due to resistance to change and often only explore novel CBMs on a small scale (Bocken et al., 2019).

The level of CE implementation reflects how successfully companies have been able to revise and redesign their business models to circular ones and also modify their supply/value chains to include loop closing, slowing and/or narrowing, so that they abide to CE requirements (Aarikka-Stenroos et al., 2022; Blomsma et al., 2019; Kristoffersen et al., 2021a). CE implementation here refers to sourcing secondary and recycled and/or renewable materials, ensuring lean and clean production, optimizing product use, developing operations to extend the product life, minimizing energy use, and if possible, ensuring ways to increase product utilization, extending existing use-cycles of products and parts, and also extending products and parts to new use cycles, and lastly having implemented activities for extending the lifespan of materials (Blomsma et al., 2019; Kristoffersen et al., 2021a). Companies should also build more internal dynamic capabilities that will enable them to adapt more effectively to the conditions, restrictions, and requirements arising from the ecological and social environments (Allen and Tomoaia-Cotisel, 2021). On a practical level, CE implementation can be actualized by various CE product/service design principles or so-called R's highlighted in the CE literature (e.g., reduction, recycling, reuse, refurbishment, and remanufacturing; Kirchherr et al., 2017). For most of these principles, some engineering is required, especially in the manufacturing and construction sectors (Dey et al., 2022).

CE implementation is dependent on the industrial sector and institutional context shaping the business environment; thus, CE implementation needs to be analyzed within the context of the industrial sector to find unique characteristics on a company level (Nandi et al., 2020; Ranta et al., 2020). We therefore look at data from two industrial sectors in this study. The practical implementation of CE-compliant products, services, and production processes necessitates the development of technical processes as well as new capabilities (Bertassini et al., 2021). Required technical and engineering solutions for CE implementation consist of sourcing recycled and renewable materials, operating with clean production processes, optimizing the use of energy, supporting the extended use of products, and promoting product designs that support repairability, reusability, and re-manufacturability (Blomsma et al., 2019).

So far, few studies have compared different industrial sectors, such as the manufacturing and construction sectors, to better understand what capabilities influence CE implementation and how these, in turn, influence innovations on the level of services and products (Bertassini et al., 2021). Despite the efforts to improve environmental performance in the last years companies are not yet achieving the desired financial performance and return on investment in the expected time; however, companies may progress quicker by developing capabilities, more specifically their dynamic capabilities (Khan et al., 2020). The theory of dynamic capabilities (Teece, 2007) is often referred to in corporate sustainability studies due to the way it can be used to sense and seize opportunities and threats and while maintaining competitiveness by enhancing and reconfiguring the intangible and tangible assets of companies (Khan et al., 2020). These dynamic capabilities are distinct skills, processes, and organizational activities (Teece, 2007). In the context of this paper, CE innovation capabilities are seen as dynamic capabilities that are impacted by innovation, CE innovation, and IT resource orchestration capabilities.

For CE implementation capabilities, creativity at the operations level and in the innovation of new products and services are essential factors in the development of CE value chains and in applying CE knowledge for innovations (Fan et al., 2021; Santa-Maria et al., 2021). The implementation of products and production processes for CE markets requires companies to change their operations and ways of working based on new CBMs (Bertassini et al., 2021; Fan et al., 2021) that account for these CE capabilities. Based on the above literature, the following hypothesis is formulated:

H1. Higher levels of perceived *CE implementation capability* have a positive influence on a company's perceived *product/service innovations*.

2.3. General innovation capability

In this paper, the general innovation capability is distinguished from sustainability-oriented eco-innovation capability and CEI (Peuckert, 2011; Walz, 2010; Walz et al., 2017). Innovation is considered as one dimension of an entrepreneurial orientation that enables organizations to explore new business opportunities, adapt to new market opportunities, and inspire more technological solutions (Wales, 2016). Innovation results in companies being able to perform better and creating sustainable growth, and it can even be considered as an inherent condition within companies that are successful in launching successful product innovations (Avlonitis and Salavou, 2007). Previous research has recognized general innovation capability as an internal driver of successful new product development (Menguc and Auh, 2010; Najafi-Tavani et al., 2018).

General innovation capability covers both the perspectives of product and process innovation capabilities. It is understood as including the development of new products and processes, as well as significantly modifying and changing existing products and processes (Camisón and Villar-López, 2014). Product innovation capability refers to a company's capacity and ability to launch new products or services successfully based on market needs (Slater et al., 2014). Process innovation is more related to incorporating new elements or subprocesses on the operations level, such as new materials, tasks, workflows, and tools that are used to manufacture products and improve the output quality and cost efficiency of the production (Frishammar et al., 2012).

General innovation capability has been found to have a significant impact on organizational performance and to moderate different kinds of performance antecedents, such as an organization's learning capability (Alegre and Chiva, 2008). A successful company often has an innovative research and development (R&D) department responsible for regularly introducing novel innovative products/services to the market (Fan et al., 2021; Lin, 2007). When companies possess innovation capability, they are capable of experimenting with new business models. In the context of implementing CE requirements and innovating new products/services for CE, organizations are required to change and adopt new capabilities and competences to develop and adapt their businesses (Bertassini et al., 2021).

In previous studies, general innovation capability has been operationalized with items measuring both the product and process innovation capabilities of a firm (Fan et al., 2021; Lin, 2007). These studies measured employees' perceptions of the extent to which their companies were able to constantly generate new product/service ideas, search for new ways of working, implement creativity on the operations level, serve as market pioneers, and develop R&D functions capable of introducing innovations frequently (Fan et al., 2021), as well as how often companies attempt to introduce novel ideas and innovations to the market (Lin, 2007).

We test the following hypotheses:

H2. Higher levels of perceived *innovation capability* have a positive influence on the perceived *product/service innovations* of a company.

H3. Higher levels of perceived *innovation capability* have a positive influence on the perceived *CE implementation* capability of a company.

2.4. IT resource orchestration capability

According to a study conducted by McKinsey & Company for the European Commission, 93% of executives in the EU consider improved data access as important for their companies, and 40% even indicated that it was very important (European Commission, 2020b). The EU drives digitalization in association with the transition to CE; this will require high-capacity digital infrastructure, innovative technologies, and new kinds of digital and IT capabilities that will permit energy-saving and climate-neutral processes (European Commission, 2020b). The analysis of existing data is crucial for implementing CE innovations and the way companies can use their IT resources for optimizing their internal processes will help to accelerate the CE implementation activities (Ranta et al., 2021). The development of new CE implementation-related processes with digital tools and solutions in different industrial sectors will require employees to be trained to use the tools that are needed to implement new IT capabilities (European Commission, 2022). Resource orchestration is critical for reducing internal conflicts within an organization, ensuring that resources are matched to needs, and enabling the dynamic capabilities required for sustainability-oriented and green innovations (Wang et al., 2020).

Kristoffersen et al. (2021a) applied a combined framework that included resource-based, resource management (Sirmon et al., 2007), and IT resource orchestration perspectives (Helfat et al., 2009) to describe IT resource orchestration capability. In this framework, managers are seen to be in a key position to transform companies and managing resources to achieve improved competitive performance, for example, in supply chain management (Gong et al., 2018), SME performance (Wales et al., 2013), and green innovation (Wang et al., 2020). The combined framework describes the activities for structuring, bundling, and leveraging resources that managers need to consider when developing and improving organizational performance. Resource orchestration capability is considered as being among the most important capabilities within a company if the company has any resource-related issues or challenges (Kristoffersen et al., 2021a). This is often the case for circular economy practices, as companies need to re-innovate for circular solutions. Resource orchestration capability involves expertise with which a company can effectively structure, bundle, and leverage both current and new resources when attempting to maximize performance (Choi et al., 2020).

The sub-capabilities grouped under the top-level resource orchestration capability that are the most relevant for innovation for the CE include capabilities to effectively bundle and leverage IT resources. The activities described under the *bundling* sub-capability include the following activities: the integration of IT resources for the purpose of building high-level IT capabilities, the extension of existing IT capabilities with new IT resources, and the creation of new kinds of IT capabilities (Kristoffersen et al., 2021a). The *leveraging* sub-capability has been described as including the activation of IT capabilities for a common vision, coordination of IT capabilities, and the deployment of IT capabilities to gain market advantage (Kristoffersen et al., 2021a). However, in the context of P/SI outcome levels, the structuring of IT capabilities, which is part of the resource orchestration capability construct developed by Kristoffersen et al. (2021a), is not relevant in this case because the IT structures are assumed to be in place.

For implementing the CE as well as enabling P/SI, Industry 4.0 and digitalization are considered critical tools for the management of production economics and operations (Lopes de Sousa Jabbour et al., 2022). The current production systems have for the most part been created for the linear economy and cannot capture potential circular value, as the recycling, reuse, and remanufacturing processes have not been incorporated on the product nor the process level. In the context of big data analytics, IT resource orchestration capability is key to developing organizational-level competences and capacity to utilize resources strategically (Cragg et al., 2011; Mikalef et al., 2018; Wang et al., 2012). With the utilization of IT resources, the flows of materials and products can be monitored in real time, which enables supply chain actors in production planning to increase the efficiency and resilience of production and operations (Lu, 2017).

Digitalization can help improve recycling management, as sensors and robots enable a more efficient sorting of items and improved recycling rates (Lopes de Sousa Jabbour et al., 2022), and in the construction sector, digitalization can have a large effect, as it facilitates the location of materials and through building information modeling (BIM) allows for recycling of materials in the future (Kovacic and Honic, 2021). The IT capabilities of companies play a key role, and especially the management and orchestration of the IT resources are crucial for utilizing digitalization in the implementation of CE (Bressanelli et al., 2018). The development and adoption of CE innovation capabilities internally within the organization and externally can be accelerated with digital tools (Lardo et al., 2020).

Based on the above literature, the following hypotheses are formulated:

H4. Higher levels of perceived *IT resource orchestration capability* have a positive influence on the perceived *product/service innovations* of a company.

H5. Higher levels of *IT resource orchestration capability* have a positive influence on the perceived *CE implementation* capability of a company.

2.5. Circular economy innovation capability

The skills and competencies that are at the core of CEI capabilities are those required by designers to enable and envision new kinds of products/services, aid in product life-cycle assessments (LCA), and understand their impacts on the system level (Brown et al., 2019). CEI capabilities also require that actors are able to develop and collaborate internally and externally with different roles and align their activities at the system level (Rizos et al., 2016).

The coupling of CE targets with CEI capability may require firms to promote more exploratory innovation capabilities that have been found to aid in the adoption of rapid changes, which is not the case for a mere exploitative approach, where the focus is on launching improved products or services for existing customers or markets (Benner and Tushman, 2003; Carrillo-Hermosilla et al., 2010). In fact, it has been demonstrated that exploratory and exploitative innovations do not necessarily have the same outcomes: exploratory innovation capabilities ensure survival and long-term competitiveness that are hard to imitate by competitors (Mueller et al., 2013); exploitative innovation capabilities, on the other hand, focus more on developing and commercializing improved products/services to meet already existing customer needs (Benner and Tushman, 2003). Furthermore, to develop CE innovations into a competitive advantage, companies need to develop dynamic capabilities to perform continuous innovations and conduct follow-up studies on the actual adoption of CE (Berrone et al., 2013).

The target of sustainable innovation is quite similar to that of CEI, where the goal is also to improve the ecological performance with CE targets regarding the environmental impacts of the production systems (Carrillo-Hermosilla et al., 2010). CE is a major transition for businesses and impacts the production systems of manufacturers and the consumption patterns of consumers, while responding to ecological and societal needs (Prieto-Sandoval et al., 2018). There is strong motivation for businesses to exploit their innovative capabilities in order to adopt CE-related innovations (Jakhar et al., 2019). The CEI capabilities of firms are key to the adoption of wide-scale advanced CEI and practices (Berrone et al., 2013).

CEI capability ensures that companies' have high-level competences related to CE implementation, and it enables them to translate their CE strategies and visions into practice. The product design phase (den Hollander et al., 2017; Moreno et al., 2016) and the creation of organizational capabilities to implement experimentation and value chain innovation are also critical for CEI capability development (Chiappetta Jabbour et al., 2019; Weissbrod and Bocken, 2017). CEI capability can also be supported by a company culture that integrates the company's CE strategy and principles into product, technical, and market level innovations that create sustainable value; this is enabled by sustainable resource management in the development of processes, products/services, as well as business models (Kristoffersen et al., 2021a). These capabilities are also developed based on the knowledge produced via collaboration, for example, to create value offerings with decoupling from material use (Pouwels and Koster, 2017).

CEI capability requires tight collaboration among different stakeholders to deliver EU-level CE targets and create radical sustainable innovations that will reduce environmental impacts (Sautter, 2016). CEI capability is an antecedent of CE implementation activities and a prerequisite for being able to do the implementation. Company managers and CEOs are conscious of the fact that they are obligated to improve their innovation capabilities, so they are in line with CE requirements. CEI capabilities will enable industries to improve their ecological efficiency and develop new CE-compliant products and services with market value (Jakhar et al., 2019). To promote CEI and develop CEI capabilities that support innovative CE strategies, companies need to manage and engage with internal and external stakeholders to create value in various parts of the value chain (Watson et al., 2018).

In previous literature, there are no direct references to the linking of these capabilities to P/SI. However, the dynamic capabilities view has been used as a theoretical lens to analyze CE implementation in companies from different innovation perspectives, including: digital business transformation (Belhadi et al., 2022), CE business model innovation (Bocken and Konietzko, 2022; Elf et al., 2022; Fernandez de Arroyabe et al., 2021; Santa-Maria et al., 2022), factors impacting the acquisition of innovation capabilities to implement CE (Arranz et al., 2023; Mondal et al., 2023a), role of eco-innovation capability in CE implementation (Bag et al., 2022), compared to open innovation (Köhler et al., 2022), sustainability-driven innovation (da Nascimento et al., 2023), and CE implementation principles (Wade et al., 2022) (Table 1).

In both the manufacturing and construction sectors, the operations environment can require complex development initiatives and configurations to make the companies' products and processes CE compliant (Blomsma and Brennan, 2017). Product-service systems (PSS) allow direct reuse, repair, refurbishment, remanufacturing, and recycling of materials, which will require companies to be innovative in new ways, and in such cases companies will need to create CEI capabilities to provide the workforce with insights and conditions to develop circular configurations (Blomsma et al., 2018, 2019). Special design expertise and creativity may be required when exploring methods to extend products by offering new kinds of product support during their lifetime. This may entail not granting customers any ownership of physical products but instead allowing users access to products for a certain period of time for a certain price (Tukker, 2004). Based on the above literature and gaps in previous research, we hypothesize that:

H6. Higher levels of perceived *CE innovation capability* have a positive influence on the perceived *product/service innovations* of a company.

H7. Higher levels of *CE innovation capability* have a positive influence on the perceived *CE implementation* capability of a company.

Based on the literature, we have created the following conceptual model that we further test by conducting PLS-SEM analysis with empirical data. See Fig. 1 for the hypotheses in the conceptual model.

3. Method

3.1. Constructs and operationalization

The constructs and their relationships in our conceptual model (Fig. 1) are based on the theoretical background described above. Previous studies have validated the measurement models of the constructs and thereby confirmed their validity and reliability (Table 2). The constructs in our research were operationalized using reflective measurement models that each included multiple measurement items (Sarstedt et al., 2022b). The measurement items relate to the way companies' employees perceive capabilities in terms of general innovation, CE innovation, IT resource orchestration, and CE implementation, as well as the product/service innovations of their company. All measurement items in the conceptual model are listed in Table 2.

The measurement items were measured on a 7-point-Likert scale with response options ranging from "Do not agree at all" to "Fully agree." In addition, the response option "I don't know" was included to allow respondents who did not deal with certain elements in their positions to still answer all questions in the survey.

3.2. Sample

The data collection was conducted with an online survey in Germany between December 2021 and January 2022 and distributed via a market research panel consisting of companies from the manufacturing and

Table 1
Categorization of CE innovation and implementation related dynamics capabilities based on previous literature.

How dynamic capabilities (DC) have been applied in CE implementation	Linking to innovation	Industrial sector (s)	References
Combines institutional theory with DC approach to analyze the effect of institutional pressures on the adoption of CE in firms	Combination of innovation and financial support policies can enhance the acquisition of capabilities to enable CE implementation	EU CE database, firms in different sectors in 27 EU member states	Arranz et al. (2023)
Identifies DC that enable to advance circular economy practices.	CE Business model innovation and adoption	Sustainable fashion design and fashion micro, small and medium enterprises (MSMEs)	Elf et al. (2022)
Analyzes digital business transformation, organizational ambidexterity, and circular business models on the relationship between Industry 4.0 capabilities and sustainable performance.	General innovation capability linked to digital business transformation, organizational ambidexterity link to exploitation-exploration innovation	Manufacturing companies and their supply chains	Belhadi et al. (2022)
Categorizes green entrepreneurship enablers of the CE that improve firms' DC.	Availability of capital to carry out innovative initiatives drives R&D related innovation capability	Manufacturing MSMEs	Mondal et al. (2023b)
Applies the DC to analyze the relationships between eco-innovation, green supply chain management and CE.	Focusing on eco-innovation capability to enable CE in the context of manufacturing processes, use of products, business models, networks, etc.	SME companies	Bag et al. (2022)
Analyzes the practices and tools used in firms to build dynamic capabilities during circular business model innovation	Circular business model innovation process	Fashion, furniture and health technology industries	Bocken and Konietzko (2022)
CE business model development is analyzed from the DC perspective.	CE development in firms requires firm innovation capabilities that are aligned via a dynamic process.	EU CE database, firms in different sectors in 27 EU member states	Fernandez de Arroyabe et al. (2021)
evelopment of a collaboration framework for CE by combining DC with open innovation to understand cross-sectoral collaborative efforts.	Innovation capability is related to open innovation, that helps the sharing of knowledge to gain advantages across an entire network, while dynamic capabilities focus on competitive advantages.	Construction sector	Köhler et al. (2022)
Introduces the DC approach to analyze technology development, operations, management, and transaction capabilities that enable and to deal with sustainability issues.	Introduce three dimensions to innovation capabilities: social, environmental, and economic.	Small-sized enterprises in the fashion, furniture, renewable energy, and hotel industry	da Nascimento et al. (2023)
Describes dynamic capabilities for sustainability-oriented business model innovation, sustainable/circular innovation processes and their micro-foundations	Proposes practices for circular business model innovation processes.	Manufacturing and service industries	Santa-Maria et al. (2022)
Examines the CE implementation principles within organizations and the role of DC in turning waste into a resource.	Presents experimentation as one of the most important innovation capabilities for succeeding in radical innovations.	Mining	Wade et al. (2022)

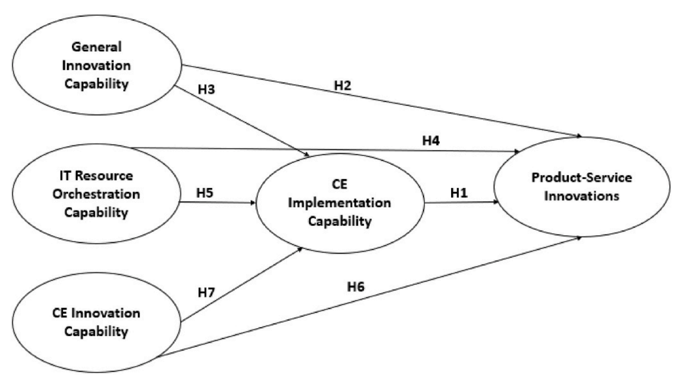

Fig. 1. Conceptual model with hypotheses.

construction sectors as well as snowball sampling to ensure a more even distribution between construction and manufacturing companies (Parker et al., 2020). The online survey was set up with the Limesurvey tool by the researchers. The survey included statements based on the measurement items for the constructs in the conceptual model. Respondents were asked to self-report their industry affiliation. The responses were submitted and handled anonymously. We used the Nomenclature of Economic Activities (NACE) European statistical classification of economic activities Rev. 2 classification to select members in manufacturing companies (n = 87; Section C, Subsections 26, 27, 28, 29 & 301) and construction companies (n = 90; NACE Section F,

Table 2
Measurement items for the constructs.

Construct	Item	References
General Innovation Capability (IC)		
ICI1	There is constant generation of new product or service ideas in this firm.	Fan et al. (2021)
ICI2	We constantly search for new ways of doing things.	Fan et al. (2021)
ICI3	There is creativity in our methods of operation.	Fan et al. (2021)
ICI4	This firm is usually a pioneer in the market.	Fan et al. (2021)
ICI5	This firm's R&D supports the frequent introduction of new products or services.	Fan et al. (2021)
ICI6	Our company tries to bring new ideas and innovations to the market.	Lin (2007)
IT Resource Orchestration Capability (IT ROC)		
Bundling		
ROB1	We are effective at integrating IT resources/assets to build IT capabilities.	Kristoffersen et al. (2021a); Choi et al. (2020); Sirmon et al. (2011); Wang et al. (2020)
ROB2	We are effective at enriching or extending existing IT capabilities with new IT resources/assets.	
ROB3	We are effective at pioneering or creating new IT capabilities.	
Leveraging		
ROL1	We are effective at mobilizing our IT capabilities towards a common vision.	Kristoffersen et al. (2021a); Choi et al. (2020); Sirmon et al. (2011); Wang et al. (2020)
ROL2	We are effective at coordinating or integrating our IT capabilities.	
ROL3	We are effective at deploying our joint IT capabilities to take advantage of specific market opportunities.	
Circular Economy Innovation Capability (CEIC)		
CEInv_1	We provide value offerings that are decoupled from material use (e.g., abandoning physical product for digital service).	Blomsma et al. (2019); Kristoffersen et al. (2021a)
CEInv_2	We support products during their lifetime through providing spare parts and/or repair services as separate sales offerings.	Blomsma et al. (2019); Kristoffersen et al. (2021a)
CEInv_3	We provide the result or performance of a product as a service instead of selling the physical product (e.g., performance-based business models).	Blomsma et al. (2019); Kristoffersen et al. (2021a)
CEInv_4	We provide the access or usage of a product as a service instead of selling the physical product (e.g., usage-based business models).	Blomsma et al. (2019); Kristoffersen et al. (2021a)
CEInv_5	We design for easy disassembly.	Jakhar et al. (2019)
Circular Economy Implementation Capability (CE IMP)		
CE-RRA1	We source secondary, recycled, and/or renewable materials (e.g., industrial symbiosis, using ocean plastics, non-toxic materials, or biodegradable materials).	Blomsma et al. (2019); Kristoffersen et al. (2021a)
CE-RRA2	We run a lean and clean production (e.g., use less energy and materials, treat wastes, rework).	Blomsma et al. (2019); Kristoffersen et al. (2021a)
CE-RRA3	We optimize product use and operation to extend the product life, minimize energy use, and/or increase product utilization.	Blomsma et al. (2019); Kristoffersen et al. (2021a)
CE-REC1	We provide activities for extending the existing use-cycles of products and parts (e.g., upgrade, repair, maintenance).	Blomsma et al. (2019); Kristoffersen et al. (2021a)
CE-REC2	We provide activities for extending products and parts to new use-cycles (e.g., reuse, refurbish, remanufacture).	Blomsma et al. (2019); Kristoffersen et al. (2021a)
CE-REC3	We provide activities for extending the lifespan of materials (e.g., recycle, cascade, energy recovery).	Blomsma et al. (2019); Kristoffersen et al. (2021a)
Product/service Innovations P/SI		
PER-CO1	We have increased capability to introduce innovative products/services.	Khan et al. (2020); Kristoffersen et al. (2021a)
PER-CO2	We have improved quality of products/services.	Khan et al. (2020); Kristoffersen et al. (2021a)
PER-CO3	We have improved brand value of products/services.	Khan et al. (2020); Kristoffersen et al. (2021a)
PER-CO4	We have increased accessibility to new markets.	Khan et al. (2020); Kristoffersen et al. (2021a)

Subsection 41) operating in Germany.[1]

The self-reporting of the respondents indicates that 73% of the companies included in the analysis mostly incorporated CE orientation in their strategy to some degree (on a small scale or as a core element). To avoid common method bias, attention checks were incorporated into the survey (i.e., some items were reverse-coded). In the final phase, before the data analysis the quality of the responses was checked and the respondents for which the response time was below 4 min were removed from the data set. After data cleansing to remove responses with too many missing values (>15%) and suspicious response patterns, our final sample consisted of 177 responses. The final dataset consists of survey data (n = 177) from both manufacturing companies (n = 87) and construction companies (n = 90) operating in Germany. Table 3 provides an overview of some of the descriptive sample characteristics. The majority of the companies included in the analysis reported incorporating a CE

Table 3
Descriptive statistics for the final dataset (n = 177).

Industry	Sample (n = 177)	Percentage (%)
Construction	90	51%
Manufacture of machinery and equipment n.e.c.	48	27%
Manufacture of computer, electronic and optical products.	20	11%
Manufacture of electrical equipment	2	1%
Manufacture of other transport equipment	14	8%
Manufacture of motor vehicles, trailers, and semi-trailers	3	2%
Number of employees		
1–9	24	14%
10–49	43	24%
50–249	41	23%
250–500	20	11%
>500	49	28%
Ownership structure		
Publicly owned	22	12%
Family owned	62	35%
Privately owned	85	48%
State-owned	8	5%

[1] 26) Manufacture of computer, electronic and optical products, 27) Manufacture of electrical equipment, 28) Manufacture of machinery and equipment n.e.c., 29) Manufacture of motor vehicles, trailers, and semi-trailers, 30) Manufacture of other transport equipment, 41) Construction of buildings. (https://ec.europa.eu/eurostat/documents/3859598/5902521/KS-RA-07-015-EN.PDF).

orientation into their strategy to at least some degree (on a small scale or as a core element). In the dataset, 73% of the companies have CE incorporated into their strategy, and 27% reported that they had yet to incorporate CE into their core strategy.

3.3. Model estimation

The conceptual model's relationships are based on constructs and their hypothesized relationships. We estimated our model by using composites (Sarstedt et al., 2016) and the causal-predictive PLS-SEM method (Lohmöller, 1989; Wold, 1982). The results can be used to support causal explanations and to assess the model's predictive capabilities (Chin et al., 2020). Hence, PLS-SEM allowed us to analyze the relationships in our model with a prediction angle (Hair et al., 2022), especially when focusing on the key target construct (i.e., product/service innovations). Another important characteristic is the method's capability to provide results for complex models (Hair et al., 2019; Wold, 1982). The PLS-SEM approach has been used extensively in social science disciplines, such as marketing research (Guenther et al., 2023; Hair et al., 2012; Sarstedt et al., 2022a). In engineering sciences, it has been used for empirical analyses of primary and secondary data, software engineering research (Russo and Stol, 2022), and construction management research (Zeng et al., 2021).

For the estimation of our model with our dataset, we used the SmartPLS 4 software (Ringle et al., 2022). Bootstrapping with 10,000 subsamples, the percentile approach, and a two-tailed test (and a one-tailed test for HTMT) allowed us to determine the significance of results based on 95% confidence intervals. The evaluation of the results used the procedure proposed by Hair et al. (2022), the recommended criteria for PLS-SEM, and their established evaluation measures and thresholds (Ringle et al., 2023; Sarstedt et al., 2022b, 2023). Accordingly, we first start with the evaluation of the measurement models and then evaluate the results of the structural model.

4. Results

The assessment of reflective measurement models includes item-level reliability, internal consistency (composite reliability), convergent validity (average variance extracted; AVE), and discriminant validity (heterotrait-monotrait ratio of correlations; HTMT). Only two item loadings were slightly below the recommended threshold of 0.708 (i.e., ICI3 with 0.634 and CE-INV2 with 0.676). As all the other loadings were above the threshold, indicator reliability was confirmed (Sarstedt et al., 2022b). The composite reliability ρ_A indicates the constructs' internal consistency reliability. For all constructs, the ρ_A criterion was between the required thresholds of 0.7 and 0.95 (Hair et al., 2019), and the AVE is above the threshold of 0.5, which supports the convergent validity of all constructs (Table 4).

The heterotrait-monotrait ratio of correlations (HTMT) indicates the discriminant validity of the constructs (Henseler et al., 2015; Ringle et al., 2023). In this study, the HTMT values (Table 5) are all below the conservative threshold of 0.85 and significantly below the more liberal threshold of 0.90 (Franke and Sarstedt, 2019; Hair et al., 2022). Hence, we concluded that discriminant validity was established.

The variance inflation factor (VIF) provides an indication of collinearity in the structural model. For the assessed model, the VIF values ranged from 2.347 to 3.065, which was below the conservative threshold of 3.3. Therefore, we argue that collinearity does not substantially affect the estimated coefficients of the structural model.

For the full dataset, all the path coefficients were significant, except for the relationship between IT ROC and P/SI (Fig. 2). However, they become significant when considering CE innovation capability (CEIC) as a mediator. The overall model explains 69.5% of the variance in product/service innovations ($R^2 = 0.695$).

We also analyzed the datasets from the construction and manufacturing sectors separately. In manufacturing companies, employees perceive that IT ROC has a significant influence on CE IMP [H5] (β = 0.569; $p = 0.000$), but its influence is not significant on P/SI directly [H4] (β = −0.130; $p = 0.495$). By contrast, in construction companies, IT ROC does not have a significant influence on either of the

Table 4
Item loadings, reliability and validity of constructs (N = 177).

Construct	Item	Loading	ρ_A	AVE
CEIC	CE-INV1	0.795	0.848	0.621
	CE-INV2	0.676		
	CE-INV3	0.809		
	CE-INV4	0.833		
	CE-INV5	0.821		
CE IMP	CE-REC1	0.853	0.925	0.722
	CE-REC2	0.868		
	CE-REC3	0.838		
	CE-RRA1	0.804		
	CE-RRA2	0.849		
	CE-RRA3	0.886		
IC	ICI1	0.855	0.919	0.668
	ICI2	0.732		
	ICI3	0.634		
	ICI4	0.874		
	ICI5	0.884		
	ICI6	0.893		
P/SI	PER-CO1	0.878	0.901	0.769
	PER-CO2	0.887		
	PER-CO3	0.901		
	PER-CO4	0.843		
IT ROC	ROB1	0.876	0.956	0.817
	ROB2	0.928		
	ROB3	0.894		
	ROL1	0.931		
	ROL2	0.898		
	ROL3	0.896		

Note: Two-tailed test. AVE = Average variance extracted. ρ_A = Composite reliability.

Table 5
Results for the HTMT criterion (full dataset).

Correlation	HTMT ratio	95% PBCI
CEIC - > CE IMP	0.823	[0.746; 0.882]
P/SI- > CE IMP	0.826	[0.742; 0.883]
P/SI - > CEIC	0.823	[0.743; 0.883]
IC - > CE IMP	0.763	[0.667; 0.839]
IC - > CEIC	0.780	[0.686; 0.855]
IC - > P/SI	0.834	[0.769; 0.886]
IT ROC - > CE IMP	0.796	[0.697; 0.871]
IT ROC - > CEIC	0.796	[0.704; 0.864]
IT ROC - > P/SI	0.748	[0.644; 0.826]
IT ROC - > IC	0.783	[0.703; 0.846]

Note: PBCI = percentile bootstrap confidence interval (one-sided test).

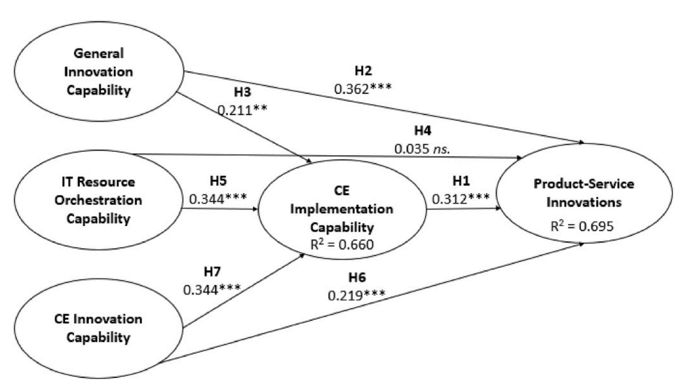

Fig. 2. PLS-SEM results for the full dataset (N = 177). Note: ***$p \leq 0.01$, **$p \leq 0.05$, *ns.* = not significant.

target constructs CE implementation [H5] (β = 0.203; $p = 0.180$) and P/SI [H4] (β = 0.176; $p = 0.089$). Another difference between construction and manufacturing companies is the way CEIC influences CE IMP [H7] and P/SI [H6]. In manufacturing companies, the CEIC is considered to have a significant influence on P/SI [H6] (β = 0.250; $p = 0.003$) but not as significantly on CE IMP [H7] (β = 0.176; $p = 0.042$). In construction companies, CEIC has a significant influence on CE IMP [H7] (β = 0.504; $p = 0.000$) but not as significant on P/SI [H6] (β = 0.176; $p = 0.089$) (Table 6).

The evaluation of the mediating effects in PLS-SEM was done based on the following criteria. First, the indirect effect is assessed, after which the strength and significance are verified using the bootstrapping procedure (Nitzl et al., 2016; Zhao et al., 2010). For the direct effects, the significance and direction of the direct effects were assessed to verify the type of mediation. The results showed an indirect effect for the full dataset as well as for the sub-samples of the construction and manufacturing sectors (Table 7).

The R^2 values indicate the in-sample explanatory power of the model. To assess the out-of-sample predictive relevance of the model for product/service innovations, we utilized the $PLS_{predict}$ procedure (Shmueli et al., 2019). The $PLS_{predict}$ results demonstrated that the $Q^2_{predict}$ values were above zero (Table 8). Since the prediction errors of the model are symmetrically distributed, PLS-SEM's RMSE values can be compared with the RMSE values of the linear model (LM) prediction benchmark. As all $RMSE_{PLS\text{-}SEM}$ values were lower than the $RMSE_{LM}$ values on the indicator level, it can be stated that the model has high predictive power for the key target construct P/S innovations (Hair et al., 2019).

As the model explains 69.5% of the variance in the target construct, that is, product/service innovations, we consider the model overall to be applicable and relevant for the combined dataset of construction and manufacturing companies.

5. Discussion

When relating the findings back to our research question on how different innovation capabilities influence the CE implementation capability and P/SI of companies, and what the role of IT orchestration capability in these cases is, we examine Table 6 that presents the hypotheses' testing results. The findings of this study show that all but one of the path coefficients in the structural model are statistically significant ($p \le 0.01$ or $p \le 0.05$) for the full dataset. In short, all hypotheses can be confirmed, except for H4 IT ROC − P/SI, which is not significant. The reason why the hypothesis H4 (Higher levels of perceived *IT resource orchestration capability* has a positive influence on the perceived *product/service innovations* of a company) was not supported, is that the capability to orchestrate IT resources on its own does not help to develop or launch any innovations. It is rather a capability for creating a more digitalized work environment that then enables the development of more sustainable CE innovations (Lardo et al., 2020).

Hypotheses H3 (Higher levels of perceived *innovation capability* have a positive influence on the perceived *CE implementation* capability of a company), H5 (Higher levels of *IT resource orchestration capability* have a positive influence on the perceived *CE implementation* capability of a company), and H7 (Higher levels of *CE innovation capability* have a positive influence on the perceived *CE implementation* capability of a company) are significant for the full dataset. This indicates that CE implementation capability is influenced by other capabilities that enable innovation, such as methods to orchestrate IT ROC, and unique CE innovation-related competences. This is understandable as the activities for CE implementation are complex and may need to be implemented with totally new processes and digital tools (Kristoffersen et al., 2021b). These processes should support the sourcing of secondary, recycled, and renewable materials; developing cleaner production; optimizing product use; extending product lives and use-cycles; minimizing energy use; increasing product utilization, and extending the lifespan of materials (Blomsma et al., 2019; Kristoffersen et al., 2021a).

Hypotheses H1 (Higher levels of perceived *CE implementation capability* have a positive influence on a company's perceived *product/service innovations*), H2 (Higher levels of perceived *innovation capability* have a positive influence on the perceived *product/service innovations* of a company), and H6 (Higher levels of perceived *CE innovation capability* have a positive influence on the perceived *product/service innovations* of a company) are also significant for the full dataset, which indicates that PS/I are positively influenced by both general innovation capabilities and CEI capability in addition to the actual CE implementation capability. This is also supported by the innovation literature, especially in the context of entrepreneurial orientation (Fan et al., 2021; Lin, 2007). This could possibly be explained by the fact that an innovative working environment with an active entrepreneurial orientation can motivate employees to explore new business opportunities devotedly and innovate (Wales, 2016). These results are further supported by the research of Kristoffersen et al. (2021a), who demonstrated the positive influence of CE implementation on firm performance. This is further confirmed by the mediating effect of CE IMP on perceived P/SI (Blichfeldt and Faullant, 2021; Lau et al., 2010). In the model created and validated in this study, P/SI was measured based on employees' self-assessment of their employers' performance and how companies were able to improve the quality and brand value of products/services and gain access to new markets (Kristoffersen et al., 2021a). The findings of our research indicate that CE implementation capability is perceived to have a positive influence on P/SI (Khan et al., 2020; Kristoffersen et al., 2021a; Pieroni et al., 2019). P/SI can lead to improvements to existing products according to CE requirements or the development of completely novel products to ensure long-term success and provide competitive advantages. We argue that our study offers empirical evidence for CEI capability as a dynamic capability (Teece et al., 1997; Teece, 2007) that companies need to learn (Zollo and Winter 2002) for CE implementation and CE-oriented P/SI.

In addition to analyzing the model with the combined dataset, we assessed the datasets from the construction and manufacturing sectors separately. As a result, the other major contribution from our research is based on the comparison of the two different industrial sectors to better understand how the supporting capabilities influence CE

Table 6
Path coefficients (β) and significance for the full dataset (n = 177), construction sector (n = 90), and manufacturing sector (n = 87).

Path		Full dataset				Construction				Manufacturing			
		β	*p* value	CI	Sig.	β	*p* value	CI	Sig.	β	*p* value	CI	Sig.
H1	CE IMP - > P/SI	0.312	0.000	[0.166; 0.454]	Yes	0.345	0.000	[0.168; 0.519]	Yes	0.321	0.025	[0.062; 0.619]	Yes
H2	IC - > P/SI	0.362	0.000	[0.264; 0.593]	Yes	0.305	0.001	[0.203; 0.531]	Yes	0.460	0.006	[0.174; 0.767]	Yes
H3	IC - > CE IMP	0.211	0.015	[0.058; 0.398]	Yes	0.169	0.195	[-0.049; 0.456]	No	0.177	0.094	[-0.014; 0.405]	No
H4	IT ROC – P/SI	0.035	0.704	[-0.043; 0.311]	No	0.130	0.141	[-0.005; 0.384]	No	−0.130	0.495	[-0.251; 0.407]	No
H5	IT ROC - > CE IMP	0.344	0.001	[0.120; 0.542]	Yes	0.203	0.180	[-0.110; 0.485]	No	0.569	0.000	[0.338; 0.743]	Yes
H6	CEIC - > P/SI	0.219	0.000	[0.210; 0.456]	Yes	0.176	0.089	[0.142; 0.526]	Yes	0.250	0.003	[0.157; 0.503]	Yes
H7	CEIC - > CE IMP	0.344	0.000	[0.177; 0.515]	Yes	0.504	0.000	[0.203; 0.758]	Yes	0.176	0.042	[0.023; 0.364]	Yes

Note: CI = 95% bootstrap confidence interval; Sig. = significant.

Table 7
Total indirect effects.

	Full dataset				Construction				Manufacturing			
	β	*p* value	CI	Sig.	β	*p* value	CI	Sig.	β	*p* value	CI	Sig.
CEIC - > CE IMP - > P/SI	0.107	0.003	[0.044; 0.184]	Yes	0.174	0.011	[0.053; 0.324]	Yes	0.056	0.141	[0.002; 0.149]	Yes
IC - > CE IMP - > P/SI	0.066	0.037	[0,017; 0,139]	Yes	0.058	0.230	[-0,017; 0,174]	No	0.057	0.187	[-0,007; 0,161]	No
IT ROC - > CE IMP - > P/SI	0.107	0.020	[0,030; 0,212]	Yes	0.070	0.225	[-0,039; 0,191]	No	0.183	0.066	[0,028; 0,411]	Yes

Note: CI = 95% bootstrap confidence interval; Sig. = significant.

Table 8
$PLS_{predict}$ analysis results.

P/S Innovations	$Q^2_{predict}$	$RMSE_{PLS-SEM}$	$RMSE_{LM}$	$RMSE_{PLS-SEM} - RMSE_{LM}$
PER-CO1	0.537	1.077	1.165	−0.088
PER-CO2	0.479	1.132	1.239	−0.107
PER-CO3	0.491	1.103	1.105	−0.002
PER-CO4	0.462	1.199	1.225	−0.026

Note: RMSE = root mean square error; LM = linear model.

implementation and furthermore how they influence innovations on the level of products and service innovations (Bertassini et al., 2021).

There are some differences in the way employees in manufacturing and construction companies perceive that IT resource orchestration capability (IT ROC) and CE innovation capability (CEIC) influence the CE implementation capability (CE IMP) and product/service innovations (P/SI) of their companies. The major difference lies in the way employees in manufacturing companies consider IT ROC as having a significant influence on CE IMP [H5], but employees in construction companies think that IT ROC does not have a significant influence on CE IMP. The reason for this could be that companies in these two sectors are in different stages of their CE implementations. Still, in both industries, companies need to develop tight and transparent collaboration with suppliers to create interorganizational CE innovation capabilities (Aarikka-Stenroos et al., 2022; van Echtelt et al., 2008).

The opportunities that emerge from the findings, indicate the possibility to accelerate the CE implementation of companies, by combining circular engineering, circular design skills and digital tools with CE innovation and CE implementation capabilities. There is the need to still develop CE-specialized capabilities within companies. The twin transition, coupling of circular engineering and digitalization, is also promoted on the European level (European Commission, 2020a). Based on the findings of our research, there could be some interdisciplinary and cross-sectoral capability development and learning opportunities for construction companies from other industrial sectors. For example, from the manufacturing sector, in the way companies manage their IT resource orchestration capabilities to support their CE implementation and find solutions to urgent societal and environmental challenges (Janssen and Abbasiharofteh, 2022). Possibly, IT ROC in the construction sector could be enhanced and improved based on the best practices already in use in some of the companies in the manufacturing sector.

Our research has managerial implications for the strategic management, business development, and R&D managers in companies moving towards CE and implementing CBMs. First, the development of CE innovation and CE implementation capabilities need to be linked to the IT resource orchestration capability to ensure that the digital tools used are suitable for circular design of new products and services. Second, especially in the construction sector, the IT resource orchestration capability could be further developed with a focus on factors related to the CE implementation, including the sourcing of construction materials, production of building components that are the products in the constructions sector and extending life cycles of the building components. In addition, for both sectors, the business development managers and training personnel should develop their CE implementation capabilities, so that the general innovation capability is upgraded and associated with the activities required for the CE innovation and CE implementation capabilities to achieve more circular product and service innovations.

One of the limitations of our study is the perceptional perspective of the employees who participated in the survey. Future research could explore how the perceptions of employees in different roles and in companies of different sizes could possibly vary in more detail. In addition, the variation of R's (reduction vs. reuse vs. recycling) or closing versus extending versus narrowing of business models and how they are influenced by the diversity of circular businesses depending on the size, age, and CE strategic approaches could be analyzed in more detail in future research. Moreover, larger sample sizes need to be used in future studies to further confirm and validate these explorative results. For the same purpose, cross-sectional data needs to be collected at different points in time to allow for the analysis of changes over time. On another note, it would be useful to collect more factual data, such as in a field experiment, rather than relying on the perceptions of respondents. Finally, as this research focused on capabilities for CE innovation and product/service innovations, future research could focus more on linking product/service innovations to CBM innovations.

6. Conclusion

This study shows how companies benefit from a set of capabilities for CE innovation that support their CE implementation and result in product/service innovations. When moving towards a CE, companies need to pay attention to technological innovation that may require substantial investments to ensure competitiveness in the market. CE implementation, hence, requires investments in technology development, including IT resources, as well changes in business models, but this ultimately results in product/service level innovations (Kaipainen and Aarikka-Stenroos, 2022). Moreover, companies transitioning to the CE need to transform their ways of working and acquire capabilities to support their innovations through both general innovation capability (Fan et al., 2021; Lin, 2007; Walz et al., 2017) as well as CE innovation capability (Blomsma et al., 2019; Jakhar et al., 2019; Kristoffersen et al., 2021a). It is especially critical for companies to implement practical CE technologies and engineering solutions to create new products based on CE guidelines and compliant materials by developing new internal, external, and supply chain level CE processes (Blomsma et al., 2019; Kristoffersen et al., 2021a).

Finally, companies that have a CE-oriented strategy need to take the next step in the CE transition pathway to reach business maturity and gain competitive advantage from their circular product and service innovations. Therefore, we argue that companies operating in both the manufacturing and construction industries require systemic transition management orientation not only on a company level, but also on sector, industry, and societal levels due to the need for close collaboration efforts, especially when planning and developing their dynamic CE innovation capabilities.

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CRediT authorship contribution statement

Ulla A. Saari: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Project administration. **Svenja Damberg:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing. **Matthias Schneider:** Formal analysis, Investigation, Data curation, Writing – review & editing. **Leena Aarikka-Stenroos:** Writing – review & editing. **Cornelius Herstatt:** Conceptualization, Writing – review & editing. **Minna Lanz:** Funding acquisition, Writing – review & editing. **Christian M. Ringle:** Methodology, Validation, Formal analysis, Writing – review & editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: This study uses the statistical software SmartPLS (https://www.smartpls.com). Ringle acknowledges a financial interest in SmartPLS.

Data availability

Data will be made available on request.

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