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The influence of circular economy implementation on competitiveness in manufacturing companies

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***Abstract*—As companies in the manufacturing sector are starting to incorporate circular economy targets in their strategies, they need to understand what capabilities and circular engineering solutions they should develop and implement, including their likely impact on the company performance. Based on survey data from manufacturing companies operating in Germany (N=111) collected in December 2021/January 2022, we present how the perceived level of circular economy, via the implementation of circularity into operations, products and services, influences the company's perceived competitiveness on the level of product/service innovativeness. The results indicate that employees in the companies perceive that the level of circular economy implementation (i.e., implementing circularity into operations, products and services) has a significant influence on the perceived product/service innovativeness and perceived competitiveness of companies that have already incorporated circular economy into their strategy. Furthermore, the data indicate that fostering a circular economy-oriented business culture alone is no longer enough for ensuring competitiveness.**

Keywords—circular economy implementation, circular economy-oriented business culture, entrepreneurial orientation, competitiveness

I. Introduction

Recent research findings from European companies indicate that top-level managers consider companies to have major challenges in identifying the key organizational resources they should be focusing on when developing and implementing more circular economy (CE) related capabilities [1]. However, there are still very few studies focusing on the transitioning to the CE in engineering contexts on a practical level to better understand the development of capabilities on the organizational level, also incorporating "soft" human resource management related aspects [2].

Circular business models (CBM) are crucial for companies transitioning to a circular economy [3,4], but companies have been slow in adopting them in practice at the company level [5]. A CBM can be a driver for change, and companies can start on this pathway by fostering circular business model innovation or circular business model experimentation [6]. Companies have also been found to have a gap in the CBM design and actual implementation due to, for example, inconsistent follow-up of idea development, lack of resources in new product and process development, unsuccessful efforts in implementation, and failure in the business experimentation on the markets [4].

So far, in the literature on sustainability transitions within organizations, the focus has been on innovating and implementing CBMs, while there still exists a research gap on the practical level of CBM implementations, including the engineering management perspective in manufacturing contexts, where the application of innovative CBMs need to be implemented in intraorganizational and interorganizational cooperation initiatives [7]. Companies, especially SMEs, are facing the need to renew their internal capabilities which requires the development of new kinds of engineering processes with a focus on CE implementation to actualize the business potential in CBMs [8,9]. The overarching research objective of this study is to explore how a CE-oriented business culture and entrepreneurial orientation influence a) the perceived CE/CBM implementation capabilities of a company, and b) the perceived competitiveness of the company from a product/service innovativeness perspective.

Based on survey data (N=111) collected at the end of 2021 and early 2022 in manufacturing companies operating in Germany that have developed circular economy orientation to some degree in their strategy, either on a small scale or as a core element, we have analyzed the influence of CE implementation and CBM, on the perceived competitiveness of a company. Competitiveness is measured by the respondents' self-assessment on how the company they are working for has been able to 1) increase their capability to introduce innovative products and services, 2) improve the quality of products/services, 3) improve brand value of their products and services, and 4) increase access to new markets [1].

The results indicate that the level of CE/CBM implementation has a significant influence on the competitiveness of companies examined. The results also suggest that solely fostering a CE-oriented business culture does not have a significant influence on ensuring competitiveness. This could indicate that, in the transition towards the CE, manufacturing companies are moving from an initial stage to a new stage of transitioning to the CE, where CBM innovation now also takes place. Research has focused on the changes required on the business model level and human aspects of management, which are very important; however, there is also an urgent need for additional research. With our study, we contribute with a more practical oriented research approach on CE implementation in an industrial engineering setting including, for example, actual plans and specifications for lean and clean production, product design and production operations, extending use cycles and lifespan of materials, that are also reflected in the sourcing guidelines [1,10]. Based on our findings, we propose a framework for a company-level circular economy transition pathway that is especially applicable to engineering-oriented manufacturing companies that at least partially already have a CE strategy.

Our paper is structured as follows. First, we cover the main literature on which we base our conceptual model and hypotheses. After presenting the results from a quantitative data analysis with the partial least squares structural equation modeling approach (PLS-SEM), we discuss relevant implications from our research findings, and suggest future research areas that would benefit the transition to the circular economy on a company level.

II. Background and Hypotheses Development

A. Circular economy-oriented business culture

In a CE-oriented business culture, both business analytics capability and skills related to driving a circular economy approach are crucial [1]. Especially the companies' organizational culture and orientation need to be at a level where they are willingly making the change required for a transition to the CE [1,7,9]. The actual transition requires dedicated change management activities particularly from the incumbent companies, to drive the adaptation and regeneration of the existing paradigms and business operations redesigning structures and procedures [8,9].

Previous attempts of assessing the relationship between CE-oriented business culture, CE implementation and firm performance have been based on highly complex PLS-SEM models even including third-order constructs [1]. The use of extremely complex, third-order constructs, however, has been criticized in the literature, and recent literature instead strongly advises for PLS-SEM models to be more parsimonious [28]. Therefore, we propose a less complex model which is easier generalizable to other contexts.

With reference to change management (CM) theory, [2] suggest that CM theory could be utilized as the basis when targeting circular economy targets, showing how companies can develop from the current linear economy approach via a transition state to a new state, i.e., the circular economy approach. However, the authors focus on the human resource related soft aspects that are relevant for creating a new CE organizational culture. A CE-oriented business culture requires specific and new mindsets, values, behavioral patterns, capabilities, and competences.

One of the key requirements in creating a CE-oriented business culture is a *systems thinking* approach that allows companies to get an overview of the requirements set for more integrative process development, which also needs to be linked to the engineering management level activities and processes [11]. In the change management process, *continuous and open communication* as well as *co-creation* are required to design and implement effective solutions [12]. In addition, in current quickly evolving business environments, a *data-driven business culture* and the required *data analytics skills* are key to enable and build new CE-based business and to ensure enhanced firm performance [1].

B. Entrepreneurial orientation

Human resource related aspects of business management, including an entrepreneurial orientation (EO), are crucial for organizations in developing and adapting their businesses in their transition towards a CE [2]. Companies are incorporating more CE targets into their corporate strategies, or even including them as a core element, due to the growing policy requirements in the business environment. An EO can drive companies to experiment with new CE business models that can enable a new kind of sustainable competitive advantage in the CE. EO is defined as a company's capability and decision-making ability to strategically drive the company's business initiatives, so that goals are reached by exploring new business opportunities and by launching innovations on the markets with the available resources [13]. EO thereby enables SMEs to perform better and create sustainable growth by driving them toward adapting to new market opportunities and inspiring more technological innovation [14].

In the context of CE implementation, especially *creativity on the operational level* and *constant creation of new products and services* are prerequisites for developing CE-oriented value chains and adopting CE knowledge within a company for developing innovations for markets [15,16]. The development and implementation of novel CE-oriented products and production processes can require *drastically different ways of working* [2,15], on the operational level that can better be tested if the company cultivates an EO. An EO company (typically) also has an innovative R&D department that *introduces regularly totally novel kinds of products or services and innovations* to the market [15,17].

So far, the implementation of circular business models has been slow in incumbent companies. The latter have been resistant to change, i.e., have explored new business model solutions outside their existing paradigms only on a small scale [18]. There is a clear call to experiment with more EO to tackle the innovation challenges associated with new circular business models [16] as well as a call for more research on the management of circular business model design [19].

C. Competitiveness from the product/service innovativeness perspective

Competitiveness can be measured with company level performance on the markets in relation to its former performance and its competitors' performance. In the case of sustainable competitiveness in CE markets, overall competitiveness refers to *excellence in the areas of environmental performance, financial performance, and corporate reputation* [20,1]. With the Circular Economy Action Plan in the EU [21], CBMs are becoming essential for companies and their supply chains to achieve competitiveness in a business environment where waste and natural resource depletion are true risks for a production system of manufacturing that had originally been designed for the linear economy [22]. CBMs are already increasingly being introduced as solutions for companies to stay competitive in the transition to the CE [23,24].

However, in the manufacturing sector, this has not been as apparent yet and has so far not been researched extensively. In addition, the impact of CE implementations on competitiveness in the minds and perceptions of employees has not been researched yet to the knowledge of the authors. As top-level management talk and strategies are not enough for advancing the CE, more concrete actions are needed on the engineering and practical level – different processes and formalized ways of handling topics such as sourcing secondary, recycled and renewable materials, clean production, optimization and extending product use, and energy efficiency [e.g., 10,1]. In our study, this construct can also be understood to be product or service level innovativeness, as competitiveness is measured by employees' self-assessment of their employers' capability to introduce innovative products and services, improve the quality of products/services and brand value of their products and services, and gain access to new markets [1].

Based on the research background above, the following hypotheses are proposed:

H1: Higher levels of perceived CE-oriented business culture have a positive influence on the perceived competitiveness of the company from a product/service innovativeness perspective.

H2: Higher levels of perceived entrepreneurial orientation have a positive influence on the perceived competitiveness of the company from a product/service innovativeness perspective.

D. *Circular economy/CBM implementation*

In this study, we define CE/CBM implementation as the degree to which a company is capable of enforcing CE strategies in its value chain [1]. Literature has focused on innovation in the context of CBMs, while their actual practical level implications across supply chains from an engineering perspective still require more research [22]. Business model strategies offer high-level abstract solutions for slowing resource CE loops [3]. However, the practical technical solution for extending product value by recycling, reuse, refurbishing and remanufacturing needs to be designed by engineers. The implementation of dynamic and effective sustainable supply chains in the CE context requires companies to integrate more effectively with the conditions, restrictions and requirements stemming from their ecological and social environments [11]. CE initiatives and value propositions are dependent on the industrial sector as well on institutional context shaping the business environment, in which the companies operate, and need to be analyzed within the context of each industrial sector to find the unique characteristics, barriers and enablers to solve the challenges in CE/CBM implementation [22,25,26]. The practical level CBM implementation of CE-compliant product designs and production processes requires complex development and transformation to technical processes as well as ways of working [2]. Currently, manufacturing still generates significant amounts of waste, and unless there is a change in material usage and production systems, this will result in serious natural resource depletion and overexploitation [22].

CBM design is expected to result in successful CE outcomes according to CE principles [19], as CE implementation is expected to improve environmental and financial performance, competitiveness as well as overall corporate reputation of the companies. So far, environmental performance has been improving, but companies are not yet achieving the desired financial performance [20]. The experimentation and development of cost-effective technical solutions can take time, and the return on investments can often lag behind, even though CE/CBM implementation is urgently required for the evolving CE markets. The technical CE implementation requires engineering capabilities to develop technical solutions [1], that have only been planned and envisioned on an abstract level in CBM innovations. On a practical level, more technical and engineering solutions needed for CE implementation include, for example, sourcing of recycled and renewable materials, clean production processes, optimization of product-related energy use, extension of product use through designing for repairability, reusability, re-manufacturability in products [10].

Based on the above literature review, the following hypotheses are proposed:

H3: Higher levels of perceived CE-oriented business culture have a positive influence on the perceived CE/CBM implementation capabilities of a company.

H4: Higher levels of perceived entrepreneurial orientation have a positive influence on the perceived CE/CBM implementation capabilities of a company.

H5: Higher levels of perceived CE/CBM implementation capabilities have a positive influence on the perceived competitiveness of the company from a product/service innovativeness perspective.

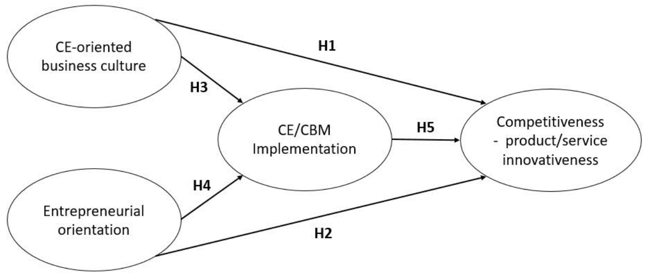


Fig. 1. Conceptual model

III. METHOD

A. *Constructs and operationalization*

In this research, we combine measurement models of four constructs that have been validated and found reliable in previous studies to form a novel conceptual model that we further test in this study. The constructs used in building the conceptual model were based on the literature described under section II.

We conducted an online survey that included statements based on the measurement items for each of the constructs. These statements address employees' perceptions on their CE-oriented business culture (CEBC), entrepreneurial orientation (EO), CE implementation (CEI) and competitiveness (COMP) of the company they currently work at/in. The relationships between the constructs are depicted in our conceptual model in Fig. 1. All constructs are operationalized with multiple items (Table I) using reflective measurement models [27]. The items used to measure the constructs in our final PLS-SEM model (Fig. 1) are presented below (Table I) with reference to research that has previously operationalized – and thereby validated – the constructs. They have been adapted to fit the context of this study and were measured on a 7-point-Likert scale from "Do not agree at all" to "Fully agree" and allowing for the option "I don't know" to account for the fact that some respondents might not be able to answer all questions if they do not deal with certain elements in their positions.

B. Sample

Our final data set for this study includes 125 responses. Out of those, 111 respondents work in a manufacturing company that includes CE in its strategy either "A little" (n = 91) or "Somewhat" (n = 20). Thereby, we tested the model with those 111 respondents that indicated some awareness and knowledge about the CE and perceive some level of its implementation in the company they currently work in. The target was to get a generalized view on the current state of CE implementation and product/service innovativeness in companies.

The respondents hold management positions in different business functions within their respective companies (e.g., IT, product design, marketing, strategy, etc.). Among those surveyed, 43% (n = 48) work in SME's with less than 250 employees, 20% (n = 22) work in companies with 250-500 employees and 37% (n = 41) in those that have >500 employees. Respondents are mostly employed either in family-owned businesses (n = 42 or 38%) or in privately-owned businesses (n = 39 or 35%). The remaining respondents work either in publicly listed enterprises (n = 22 or 20%) or in state-owned businesses (n = 8 or 7%). The companies in the sample are also relatively established, with only 10.8% (n = 12) of respondents indicating that their companies are under 10 years old. Instead, most of the companies (n = 56 or 51%) are either between 10 and 49 years old, or even 50+ years old (n = 43 or 39%).

It also appears that many of the companies have not included CE (elements) in their strategy for a very long time yet. Two equally sized groups 28% (n = 31) indicate that their companies have been working with CE in their strategy for 1-3 years and for 3-5 years, respectively. Only 23% (n= 26) have been working with CE in their strategy for 5+ years.

TABLE I. MEASUREMENT ITEMS FOR THE CONSTRUCTS

Construct	***Item***	***References***
CEBC	CEBC_1 Our managers possess systems thinking skills. 1	Kristoffersen et al., 2021
	CEBC_2 We have data science skills in our company.	Kristoffersen et al., 2021
	CEBC_3 We follow a data-driven culture.	Kristoffersen et al., 2021
	CEBC_4 Our innovation culture has circular economy objectives.	Kristoffersen et al., 2021
	CEBC_5 We promote openness and co-creation.	Kristoffersen et al., 2021
EO	EO_1 There is constant generation of new product or service ideas in this firm.	Fan et al., 2021
	EO_2 We constantly search for new ways of doing things.	Fan et al., 2021
	EO_3 There is creativity in our methods of operation.	Fan et al., 2021
	EO_4 This firm is usually a pioneer in the market.	Fan et al., 2021
	EO_5 This firm's R&D supports the frequent introduction of new products or services.	Fan et al., 2021
	EO_6 Our company tries to bring new ideas and innovations to the market.	Fan et al., 2021; Lin, 2007.
CEI	CEI_1 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., 2021
	CEI_2 We run a lean and clean production (e.g., use less energy and materials, treat wastes, rework).	Blomsma et al., 2019; Kristoffersen et al., 2021
	CEI_3 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., 2021
	CEI_4 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., 2021
	CEI_5 We provide activities for extending products and parts to new use-cycles (e.g., reuse, refurbish, remanufacture).	Blomsma et al., 2019; Kristoffersen et al., 2021
	CEI_6 We provide activities for extending the lifespan of materials (e.g., recycle, cascade, energy recovery).	Blomsma et al., 2019; Kristoffersen et al., 2021
COMP	COMP_1 We have increased capability to introduce innovative products/services.	Khan et al., 2020; Kristoffersen et al., 2021
	COMP_2 We have improved quality of products/services.	Khan et al., 2020; Kristoffersen et al., 2021
	COMP_3 We have improved brand value of products/ services.	Khan et al., 2020; Kristoffersen et al., 2021
	COMP_4 We have increased accessibility to new markets.	Khan et al., 2020; Kristoffersen et al., 2021

C. PLS-SEM methodology

Based on the relationships between the theoretical constructs described above (see Fig. 1), we developed our structural path model. The model is estimated with partial least squares structural equation modeling (PLS-SEM). It is a variance-based model estimation method allowing to analyze the relationships in a path model and to explain a target construct (i.e., "competitiveness", in our model) from a prediction perspective [28]. Being based on developed theory, such an approach provides causal explanations and supports predictive assessments [29]. PLS-SEM is applicable for both reflective and formative measurement model assessment [28,30] as well as complex models [31,32]. Traditionally often applied in marketing [e.g., 33,34], researchers in numerous engineering sciences disciplines have more recently applied and/or suggested the PLS-SEM methodology for empirical analyses of primary as well as secondary data, including information systems research [29,35], software engineering research [36], and construction management research [37]. We used the software SmartPLS 3 [38] to assess our path model.

IV. RESULTS

We tested and estimated the model according to the most recent PLS-SEM guidelines [28]. First, we estimated the reflective measurement models of the constructs for item-level reliability, internal consistency (composite reliability), convergent validity (average variance extracted; AVE) and discriminant validity (heterotrait-monotrait ratio of correlations; HTMT). The results in Table II show that all loadings are above the threshold value of 0.7, supporting indicator reliability [27].

TABLE II. ITEM LOADINGS

Construct	*Item*	*Loading*
CEBC	CEBC_1	0.893***
	CEBC_2	0.818***
	CEBC_3	0.851***
	CEBC_4	0.851***
	CEBC_5	0.856***
EO	EO_1	0.871***
	EO_2	0.818***
	EO_3	0.730***
	EO_4	0.849***
	EO_5	0.868***
	EO_6	0.863***
CEI	CEI_1	0.849***
	CEI_2	0.858***
	CEI_3	0.841***
	CEI_4	0.672***
	CEI_5	0.798***
	CEI_6	0.849***
COMP	COMP_1	0.902***
	COMP_2	0.871***
	COMP_3	0.915***
	COMP_4	0.853***

Note: CEBC = CE-oriented business culture, EO = entrepreneurial orientation, CEI = CE implementation, COMP = competitiveness. *** = p<0.01.

The composite reliability ρ_A allows us to assess the constructs' internal consistency reliability. The ρ_A criterion of all constructs are between the required thresholds of 0.7 and 0.95 [31]. Moreover, the AVE of all constructs is above the threshold of 0.5, which supports convergent validity (Table III).

TABLE III. RELIABILITY AND VALIDITY OF CONSTRUCTS

Construct	ρ_A	*AVE*
CEBC	0.910	0.730
EO	0.920	0.697
CEI	0.905	0.662
COMP	0.910	0.784

Note: Two-tailed test. AVE = average variance extracted.

The heterotrait-monotrait (HTMT) ratio of correlations allows us to assess the discriminant validity of reflectively measured constructs [39]. All HTMT values are significantly below the 0.9 threshold [30], which supports discriminant validity (Table IV).

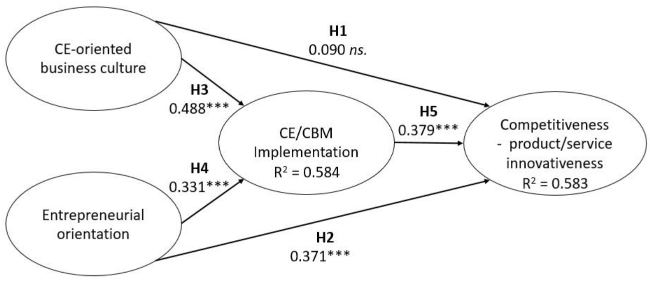
TABLE IV. THE RESULTS FOR THE HTMT CRITERION

Correlation	*HTMT ratio*	*95% PBCI*
COMP -> CEI	0.770	[0.618; 0.879]
EO -> CEI	0.752	[0.609; 0.856]
EO -> COMP	0.763	[0.642; 0.853]
CEBC -> CEI	0.809	[0.690; 0.893]
CEBC -> COMP	0.701	[0.508; 0.832]
CEBC -> EO	0.802	[0.670; 0.895]

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

The variance inflation factor (VIF) provides an assessment of collinearity in the structural model. The VIF values range from 2.157 to 2.730 and, thus, are below the more conservative threshold of 3.3. Hence, collinearity does not substantially affect the estimated coefficients of the structural model. For significance testing, we used a two-sided test and the 95% percentile bootstrap confidence intervals with 10,000 subsamples.

All path coefficients are statistically significant, except for the relationship between CEBC and COMP (Fig. 2). Overall model explains 58.3 percent of the competitiveness construct's variance, which is the key target construct in the model.



Note: *** = $p < 0.01$, ns = not significant.

Fig. 2. PLS-SEM results.

The indirect effect from CEBC via CEI to COMP has a significant value of 0.185. Hence, we establish a full mediation [40]. The indirect effect of EO via CEI to COMP has a significant value of 0.125. Thereby, we establish a complementary partial mediation [28]. With regards to the total effect (i.e., the direct plus the indirect effect), EO (0.496) has a much stronger influence on COMP than on CEBC (0.275).

V. DISCUSSION AND CONCLUSIONS

Our results suggest that there is an influence from perceived CE/CBM implementation [1,10] to perceived competitiveness on the level of product/service innovativeness [1,20] among companies that have incorporated CE into their strategy to at least some degree (either on a small scale or as a core element). Moreover, the results show that just fostering a CE-oriented business culture [1] is no longer perceived to be enough for ensuring product/service level innovativeness and thus impacting competitiveness [1,20].

Based on the results for the path coefficients that are statistically significant, four out of five hypotheses were supported by the findings (i.e., H2, H3, H4 and H5). In line with the literature on entrepreneurial orientation (Fan et al., 2021; Lin, 2007), our results confirm that higher levels of perceived entrepreneurial orientation have a positive influence on the perceived competitiveness of the company from a product/service innovativeness perspective (H2). One of the reasons for this is that an entrepreneurial orientation motivates employees to actively explore new business opportunities and innovate [13]. Similarly, higher levels of perceived entrepreneurial orientation have a positive influence on the perceived CE/CBM implementation capabilities of a company (H4). Also, higher levels of perceived CE-oriented business culture have a positive influence on the perceived CE/CBM implementation capabilities (H3). These results show how the orientation of a business culture within a company is one of the cornerstones for developing CE engineering capabilities on a wider scale across the whole company [1]. Furthermore, the results of our study indicate that higher levels of perceived CE/CBM implementation capabilities have a positive influence on the perceived competitiveness of the company from a product/service innovativeness perspective (H5). This shows the mediating effect of CE/CBM implementation capabilities on perceived competitiveness. Only a CE-oriented business culture that also leads to CE/CBM implementations further positively influences perceived service/product competitiveness. These results support the research of Kristoffersen et al, (2021) who have previously argued for a positive influence of CE implementation on firm performance.

However, hypothesis H1 was not supported, indicating that higher levels of perceived CE-oriented business culture do not seem to directly influence the perceived competitiveness of the company from a product/service innovativeness perspective, at least in the case of manufacturing companies included in this data set collected from Germany. This finding shows that on top of a pure cultural orientation and higher-level strategic intent, also an entrepreneurial orientation is needed to develop the competences needed. This is supported by the resulting indirect effect from CEBC via CEI to COMP that is statistically significant value.

As the model explains 58.3 percent of the variance in the target construct, i.e., the perceived competitiveness from a product/service innovativeness competitiveness perspective, the model can be considered to be applicable and also relevant for manufacturing companies.

In the transition towards the CE, manufacturing companies seem to be moving to a new stage from the initial phase where CBM innovation takes place. However, we consider this to be only one step in the overall CE transition pathway of a company, as seeking competitiveness from the level of product/service level innovativeness requires a long process of strategic change covering both technological and business strategies, often requiring investments in technology development as well changes in business models [9]. Additionally, there are other stages that the company needs to go through, such as becoming more entrepreneurial in its orientation [15] and finding actual practical engineering solutions to create new products from CE compliant materials with new internal, external and supply chain level CE processes [1,10]. After the CBM innovation stage reaches the CE/CBM implementation stage, to ensure innovativeness that is perceived to lead to competitiveness and considered as product/service level innovativeness. The market entry to CE markets and maturation of CE markets follows a transition pathway via intra- and inter-organizational learning, experimentation, and innovation processes.

More recently, the cradle-to-cradle (C2C) design approach has brought a new way of thinking, a change of mind set into prevailing industrial system design [41]. A C2C system consists of regenerative closed-loop cycles that are safe to humans and the environment and aligned with circular economy targets. The C2C product design has already evolved into a voluntary product certification standard for a circular economy [42,43]. However, C2C product and process implementation need to be designed with green engineering principles that require special technical and material level engineering expertise for reinventing existing technical and engineering solutions. The overall strategic level CE targets, business model development and innovation stages are initiation stages in the fuzzy front end innovation phase [44], that need to be followed by more hard work, experimentation, technical development and piloting on the product and process development levels before successful market launches on a wider scale [45].

When an organization is past the first stage (Fig. 3) in the transitioning towards a CE oriented culture, it is no longer enough to focus just on the soft aspects of CE transition integration. More attention needs to be put to the actual implementation of the CE on the engineering and technical level to implement the strategy on the product, service, and process levels.

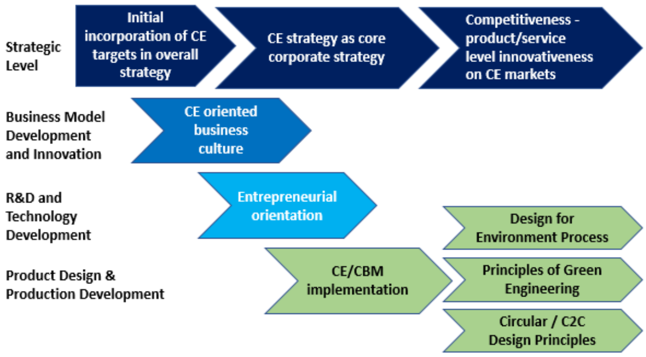


Fig. 3. Circular economy transition pathway on a company level

The linkage between the actual CBM ideation and innovation to the practical level CE implementation is a crucial step in companies that may require special efforts and additional investments. However, at this point, companies may even be hesitant to make these initial investments, as there is uncertainty on the markets and possibilities to stay competitive with a CE strategy.

To advance and accelerate the CE transition, the combination of circular engineering skills and digital tools is therefore required to develop specific business analytic capabilities within companies. This is needed to plan wide-ranging organizational level changes and transformation initiatives. This twin transition, coupling of circular engineering and digitalization is driven also on the European level [21].

One strength and at the same time limitation of our study, is the perceptional perspective of individual company employees in different roles, that we use to measure "competitiveness" regarding product/service level innovativeness and increased accessed to new markets. Future research should explore the way that perceptions of employees in different roles and in different sized companies vary in more detail. In addition, future research should further analyze how the variation on R's (reduction vs. reuse vs. recycling-based business) or closing vs. extending vs. narrowing of business models is influenced by the diversity of circular businesses depending on the size, age, and CE strategic approach. Future research could thereby focus more closely on studying manufacturing companies that work on developing new green engineering solutions. They will require a more systemic transition management orientation on a company level as the next step, when planning change management and CE implementation within their companies. Those companies that have already been incorporating a CE-oriented strategy to some extent or as an integral part of their corporate strategy, need to take the next step in the circular economy transition pathway. To reach a level of circular business maturity, the CE implementation needs to take place on the product design and production levels.

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