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Towards collaboration in circular ecosystems: barriers, enablers, and insights from European projects

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ABSTRACT: This study examines barriers for circular ecosystems in literature, and identifies 11 enabling factors for collaboration in circular ecosystems. Based on a web-based analysis of 763 European CE projects, the study analyses how factors are addressed in practice. Collaborative processes, trust building, and technological enablers were most frequent, supporting relational foundations via digital tools. Projects often signal collaboration but rarely detail governance or ecosystem orchestration. Findings highlight design capabilities to foster shared-value creation in circular ecosystems.

KEYWORDS: sustainability, circular economy, circular ecosystem, collaboration, strategic design

1. Introduction

To reduce the negative sustainability consequences associated with products throughout the whole lifecycle and to extend and close resource loops, manufacturers are increasingly required to collaborate beyond the boundaries of their own organizations and value chains. Addressing this challenge is not only a technical or managerial task, but also a design one: it requires reimagining how actors, infrastructures, and systems interact to generate shared value. In this context, the circular economy (CE) is commonly conceptualized as a regenerative system that minimizes resource input and waste by slowing, closing, and narrowing material and energy loops through practices such as reuse, remanufacturing, and recycling (Geissdoerfer et al., 2017). A successful transition to a CE will likely depend on the ability of organizations to shift away from maximizing individual benefits towards shared system-level value creation, where new partnerships, actor roles, and forms of collaboration emerge. Recent research points at the need for circular ecosystems, defined as interdependent and non-hierarchical networks of actors who collaborate to co-create value through CE strategies (Aryee et al., 2025). However, the formation of such circular ecosystems remains challenging. Many companies are not used to engaging in the forms of partnership required for circularity, which involve shared benefits, mutual data openness, and iterative co-creation rather than purely transactional exchanges. As (Aryee et al., 2025) note, "*governance in circular ecosystems is shaped by complex dynamics involving power negotiation, conflict resolution, and contested definitions of value and inclusion",* making collaboration both politically and relationally demanding. Existing research has advanced conceptual foundations for circular ecosystems (Aarikka-Stenroos et al., 2021; Aryee et al., 2025) and provided detailed case studies and prescriptive support (Brown et al., 2021; Konietzko et al., 2020). While these contributions clarify what forms of collaboration are needed and how they can be facilitated, there is still a limited understanding of the enabling factors (e.g., conditions, capabilities, actions) to foster collaboration in circular ecosystems, and the extent to which those factors are present (or absent) in ongoing European CE projects. Moreover, numerous studies have examined CE barriers (e.g., Kirchherr et al., 2018), yet few have focused on barriers related to the formation of circular ecosystems. Accordingly, the purpose of this study is to

address this knowledge gap by asking the following research questions: 1) What are the main barriers for developing circular ecosystems? 2) What are the enabling factors for collaboration in circular ecosystems, and how are those factors addressed in European CE-oriented projects?

2. Methods

To address the research questions, the study used a multi-step approach. First, a literature review identified and categorized barriers for developing circular ecosystems, which were clustered using an interpretative framework developed by the authors. Second, insights from this review, combined with prior research on collaborative circular value chains, were used to derive a list of 11 enabling factors for collaboration in circular ecosystems. These enabling factors were then operationalised into a corresponding list of keywords to support data extraction. Third, a qualitative web-based case analysis was conducted through a custom web scraper, which collected data from publicly accessible European CE project repositories to enable an analysis of how the enabling factors are addressed in practice.

2.1. Literature review

A literature review was conducted to identify the main barriers that hinder the implementation of circular ecosystems. This review builds on Dokter et al. (2025), who identified nine enabling factors for fostering collaborative circular value chains. While their work primarily examined actions and capabilities that support inter-organisational collaboration, the present study adopts a broader perspective. It focuses on barriers that impede the establishment of circular ecosystems, considering multiple levels and diverse aspects. The keywords used for the literature review included "circular ecosystem', "circular value chain", "barrier", "challenge", "collaboration", and "co-creation". The review focused on open-access journal articles from Scopus and Web of Science. To structure the analysis, we developed an interpretive framework inspired by Kirchherr et al. (2018) on barriers to the circular economy, combined with insights from Jones (2014) on systemic design for complex social systems. The framework clusters the barriers into four categories: *regulatory, technological, organisational, and inter-organisational.*

2.2. Web scraping of circular economy-oriented projects

2.2.1. Identification of enabling factors and list of keywords

Based on identified barriers, 11 enabling factors supporting collaboration in circular ecosystems were consolidated, expanding the original nine from Dokter et al. (2025) to include technological infrastructures (e.g., digital product passports, traceability platforms) and policy frameworks (e.g., regulatory incentives, shared standards). Each factor was linked to keywords drawn from the literature and typical project terminology, resulting in 274 keywords across 11 factors (table 2 lists the 11 factors but the list of keywords is omitted due to article length restrictions). To exemplify the approach, the factor *"Trust building'* included keywords such as: *"trust", "trusting", "trustworthy", "building trust", "transparency", "transparent", "reliability", "confidentiality", "secure data sharing", "open communication", "mutual respect", "credibility", "relationship building"*.

2.2.2. Data collection and analysis

A total of 763 cases were sourced from two public CE project repositories, which provide insights into how projects are represented and communicated by organizations. The first, the *knowledge hub powered by Circle Economy* which lists case studies filtered under 'Europe' and key elements 'Incorporate digital technology' and 'Team up to create joint value' (n=135). The second, the *European Circular Economy Stakeholder Platform*, lists 'Good Practices' case studies (n=628). A custom web scraper was developed in Python, with programming support by ChatGPT. The scraper used the requests and BeautifulSoup libraries to extract paragraphs from main content, excluding navigation, headers, filters, and other non-relevant sections, incoherent short sentences (<6 words) were filtered out. The scraping was conducted between 3-11-2025 and 7-11-2025, and factors and keywords were matched in 279 unique projects. The output was stored in structured.xlsx files, including project title, source platform, URL, matched factor, matched keyword, extracted text segments, and retrieval date. When a keyword match was detected, the surrounding text (±25 words) was extracted as a contextual segment. Each keyword was registered once per case to ensure that recurring mentions in a single case did not inflate counts. A qualitative content

analysis of text segments identified recurring actions, strategies, and approaches in relation to the 11 enabling factors. The full dataset, code, and methodology can be shared for reproducibility on request.

3. Results

This section first presents the results of the literature review on the barriers for developing circular ecosystems. It then outlines the results from the web-based analysis of CE projects based on the eleven enabling factors for collaboration in circular ecosystems, showing keyword frequencies across factors and extracted texts illustrating how challenges, approaches, and actions are described in CE initiatives.

3.1. Barriers for circular ecosystems

The barriers are organised into four main clusters: policy and regulatory barriers, technological barriers, inter-organisational barriers, and organisational barriers. This categorisation aims to capture the multi-dimensional nature of the challenges. Table 1 provides a comprehensive understanding of these barriers.

Table 1. Interpretive framework with clustered barriers to circular ecosystem implementation (Cat. = Category, O = Organizational; I = Inter-organizational; P = Policy and regulation; T = Technological); selected references are shown; the full review included additional sources

Cat.	Specific barrier	Selected references
O	Organizational resistance to change and adaptation	Graessler et al., 2024; Lehtimäki et al., 2020
	Lacking dynamic and relational capabilities	Chari et al., 2022; Köhler et al., 2022; Zucchella & Previtali, 2019
	Dominant short-term perspectives and economic benefits	Eikelenboom & de Jong, 2022; Moggi & Dameri, 2021; Parida et al., 2019
	Struggle to identify and mobilise appropriate external stakeholders	Aarikka-Stenroos et al., 2022; Gomes et al., 2024
	Concerns of competitiveness and confidentiality	Jonker & Faber, 2019; Köhler et al., 2022; Mosgaard et al., 2025
	Sustainability leadership	Aarikka-Stenroos et al., 2022; Chari et al., 2022; Pieroni et al., 2019
I	Complexity in coordination among multiple actors	Brown et al., 2020; Ferrari et al., 2023
	Absence of ecosystem orchestrator or coordinator	Danvers et al., 2023; Ferrari et al., 2023; Konietzko et al., 2020; Parida et al., 2019
	Lack of shared vision and difficulty to align interests among multiple actors	Blomsma et al., 2019; Fernandes et al., 2020; Konietzko et al., 2020
	Ambiguous and unclear roles and responsibilities among multiple actors	Leising et al., 2018; Marques-McEwan et al., 2023
	Differences of culture and working norms among organizations	Danvers et al., 2023; Kirchherr et al., 2018
	Power dynamics and asymmetries among organizations	Berardi & Brito, 2021; Marquina et al., 2024
	Lack of trust and transparency among multiple actors	Danvers et al., 2023; Konietzko et al., 2020; Marquina et al., 2024
	Lack of common terminology and knowledge among multiple actors	Blomsma et al., 2019; Parida et al., 2019; Pedersen et al., 2023
	Insufficient communication and collaboration mechanisms among multiple actors	Aryee et al., 2025; Ferrari et al., 2023; Zucchella & Previtali, 2019
	Financial ambiguity and limited resources	Aryee et al., 2025; Konietzko et al., 2020
P	lack of common stands standards and regulations cross value chains and sectors	Ferrari et al., 2023; Konietzko et al., 2020; Sudusinghe & Seuring, 2022
	Lack of policy instruments to mitigate knowledge transfer and intellectual property exchange	Brown et al., 2021; Ormazabal et al., 2018; Ranta et al., 2018
T	Lack of data quality and reliability in supply chains	Erol et al., 2022; Gebhardt et al., 2022; Kouhizadeh et al., 2019
	Lack of technical capabilities for product monitoring and traceability in supply chains	Baumgartner et al., 2024; Erol et al., 2022; Gebhardt et al., 2022; Schöggl et al., 2023

From an organizational perspective, cultures, beliefs, and silo-thinking can hinder possibilities to collaborate. The resistance to change occurs at individual and organizational levels (Graessler, et al., 2024). The dominant short-term perspectives, performance metrics, and traditional cost-benefit analyses can turn circularity into an add-on rather than a strategic priority, causing conflicts between short-term profitability and long-term ecosystem resilience (Moggi and Dameri, 2021; Parida et al., 2019). Another organizational barrier concerns identifying and mobilizing appropriate external actors and many firms lack strategies or experience in doing so (Aarikka-Stenroos et al., 2022). Moreover, complex interdependencies within ecosystems (Gomes et al., 2024), concerns over competitiveness and confidentiality (Mosgaard et al., 2025), and the absence of sustainability leadership (Pieroni et al., 2019; Chari et al., 2022) are discussed as other organizational barriers.

Most barriers are at the inter-organisational level. Inter-organisational collaboration is often challenged by the complexity of coordination among multiple actors (Brown et al., 2020; Ferrari et al., 2023). There is often an absence of a central coordinator or orchestrator that takes responsibility for coordinating and supporting different actors. Without clear governance structures and processes, collaboration remains fragmented and possibilities for shared visions and objectives of the CE are constrained (Blomsma et al., 2019; Danvers et al., 2023; Fernandes et al., 2020; Ferrari et al., 2023; Konietzko et al., 2020; Pedersen et al., 2023). Besides, the lack of common terminology and understanding of circular principles hinders effective communication. Cultural and operational differences across organizations makes collaboration difficult (Kirchherr et al., 2018). Power asymmetries can create tensions, undermine equitable participation, and disrupt trust and willingness to collaborate (Berardi & De Brito, 2021; Marquina et al., 2024). Finally, insufficient financial support and resources also hinder long-term implementation of circular ecosystems (Aryee et al., 2025; Zucchella & Previtali, 2019).

The complex relationship between ecosystem actors and inadequate governmental regulation often acts as a significant barrier to the effective implementation of circular economy in the local ecosystem (Ferrari et al., 2023). The absence of clear standards and shared regulatory frameworks limits alignment among stakeholders. Moreover, existing policy support is frequently fragmented, offering few mechanisms to incentivise cross-sectoral collaboration or to ensure consistent and long-term funding (Konietzko et al., 2020; Sudusinghe & Seuring, 2022). In particular, the absence of effective policy instruments that facilitate knowledge transfer and manage intellectual property exchange constrains collaboration among actors (Brown et al., 2021; Ormazabal et al., 2018; Ranta et al., 2018).

Technological barriers play a crucial role in hindering the implementation of circular ecosystems. Issues related to transparency, traceability, and product tracking across supply chains are particularly significant. The lack of visibility regarding material flows and product life cycles limits the ability of organisations to monitor resource use, evaluate environmental impacts, and recover value from products at the end of their life (Erol et al., 2022). Without reliable systems to support the gathering, aggregation, and exchange of data, stakeholders face difficulties in ensuring accountability and collaboration across the ecosystem (Kouhizadeh et al., 2019; Gebhardt et al., 2022; Schöggl et al., 2023).

3.2. Results from web-based case analysis

3.2.1. Overview of extracted cases

A total of 763 cases were analysed, with a factor identified in 279 unique projects (37%). Of these, 187 came from the EU's circular economy stakeholder platform and 92 from the Circle Economy knowledge hub. Cases spanned diverse sectors (e.g., construction, fashion, city planning, manufacturing, food systems) and CE strategies (remanufacturing, sharing systems, industrial symbiosis, product-service systems, take-back programs). There were 389 factor occurrences and 487 distinct keyword occurrences. Each case included an average of 1.39 factors (SD = 0.81) and 1.75 keywords (SD = 1.50).

3.2.2. Frequency of collaboration-enabling factors and keywords

Table 2 summarizes the frequency of collaboration-enabling factors across cases. Collaborative processes occurred most often, followed by Trust building and Technological enablers. The presence of both Collaborative processes and Trust building highlights a focus on reliability and transparency, often elaborated through workshops and other multi-stakeholder engagements. While many project descriptions emphasize collaboration, few detail formal governance structures (e.g., agreements, contracts), explaining the low frequency of collaborative governance. Trust building and technological enablers frequently co-occurred, indicating digital infrastructures support transparency and reliability.

Ecosystem perspective and Ecosystem orchestration appeared in under 8% and 2% of cases, showing circularity is mainly framed at the project or organizational level.

Table 2. Frequencies of 11 enabling factors matched across the studied cases (n=279)

Factor matched	Count	Top keywords
Collaborative processes	148	collaboration, cooperation, facilitate, workshop, engagement
Trust building	45	transparency, transparent, trust, reliability, credibility
Technological enablers	41	traceability, blockchain, tracking, digital platform, secure
Sustainability leadership	36	transformation, leadership, net zero, sustainability goals, net-zero
Monitoring & evaluation	31	assessment, monitoring, evaluation, metrics, benchmarking
Shared vision	27	vision, storytelling
Ecosystem perspective	21	ecosystem, circular ecosystem, circular value chain, multi-actor, systems perspective
Policy enablers	21	compliance, extended producer responsibility, standardization, circular economy action plan, knowledge transfer
Collaborative governance	10	accountability, decision-making, knowledge exchange, shared responsibility, collaborative governance
Value mapping	5	material flow, co-benefits, identify opportunities, mapping stakeholders
Ecosystem orchestration	4	steering, facilitator

The 487 keyword occurrences were analysed and Figure 1 presents the top 20 keywords. Because the scraping method prevented keyword repetition within a factor occurrence, the keyword frequencies represent single occurrences within distinct projects rather than counting keyword repetition. While references to collaboration and cooperation are expected in CE projects, collaboration appears to require more than relational coordination alone. The prominence of transparency and traceability indicates a focus on shared information infrastructures as foundations for trust and collective action.

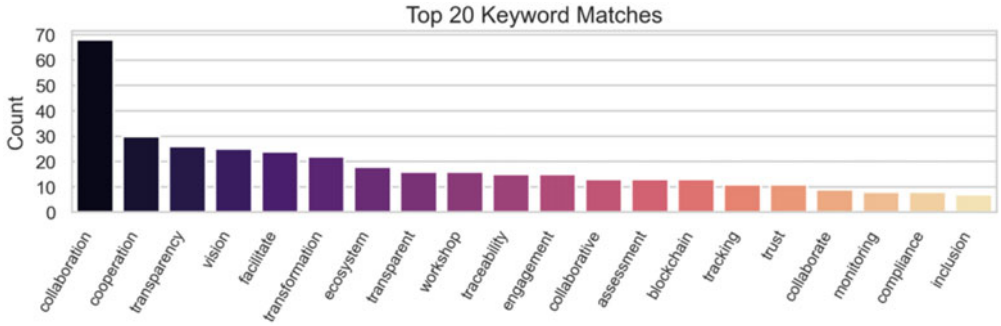

Figure 1. Overview of the frequency of the top 20 keyword occurrences across the studied cases

3.2.3. Extracted text segments and illustrative examples

From the 279 analysed cases, a total of 720 text segments were identified that referenced one or more of the nine enabling factors. Each segment captured a project context in which a relevant keyword appeared, revealing a range of actions, approaches, and strategies associated with collaboration in CE projects. Summaries and quotes of recurrent themes associated with each factor are outlined in Table 3.

Table 3. Summary of text segments extracted across factors alongside selected examples

ID	Summary	Example from analysed projects
Collaborative processes	Recurring approaches include the triple helix model, community co-creation, and participatory innovation platforms, spanning sectors such as construction, textiles, water, waste management, and urban planning. Initiatives include joint research, co-development, pilot projects, workshops, and open digital platforms to enhance transparency and learning. Key challenges involve fragmented governance, scaling collaboration, diverse stakeholder priorities, and balancing sustainability goals, while successful efforts expressively rely on trust-building, systems thinking, and iterative bottom-up and top-down coordination.	"To promote innovation and collaboration between different companies in the harbour area (something that was not commonly done prior to this project), concrete visions, plans, agendas, and project ideas for collaborative innovations were drawn up through workshops and bilateral interactions led by a core working group of industry operators, public bodies, knowledge institutions, and real estate institutions."
Building trust	This theme overlapped with technological enablers, as text segments repeated transparency and traceability as a foundation for trust. Actions related to tracking products across entire lifecycles, providing clear information to consumers and stakeholders, supporting transparency in circularity efforts, and ensuring fair and responsible practices.	"Various matchmaking approaches were therefore tested and refined, supporting the building of trust between various businesses and helping partnerships to form."
Technological enablers	Segments focus on technologies to improve transparency, traceability, and accountability in supply chains. Technologies mentioned are blockchain, digital twins, digital product passports, NFC tags, IoT tracking. Challenges relate to supply chain complexity, lacking transparency and traceability, difficulty in sourcing consistent quality materials, and technologies and standards for interoperability between actors. While transparency can stimulate collaboration, lacking transparency can be linked to mistrust and exaggerated sustainability efforts.	"Another relevant result of the solution is that traceability allows everyone involved in the supply chain to have greater visibility and active participation in the construction of the product, which is necessary for the context of the circular economy. In other words, everyone benefits from an approach with greater transparency and traceability."
Sustainability leadership	The segments indicate efforts to integrate sustainability strategies and goals, circularity, and net-zero objectives into planning, industry, procurement, and design. Actions involve developing sustainability roadmaps, fostering engaged organizational cultures, deploying innovative technologies, scaling recycling initiatives, and promoting stakeholder engagement.	"The city of Ludwigsburg in Germany has a sustainable development strategy that includes the use of procurement to achieve its sustainability goals, instructing all public procurement departments to follow "Cradle to Cradle" principles in their procurement and awarding criteria."
Monitoring & evaluation	Segments focused on tracking environmental, social, and economic impacts across value chains and CE initiatives. Recurring approaches include LCA, real-time monitoring with sensors and digital tools, and blockchain for traceability. Projects reference indicators, metrics, databases, and platforms to measure resource recovery, recycling, emissions, and social impacts, often linking this factor to policy and technological enablers.	"The project created new circular models and practices and devised indicators for assessing ongoing performance and impact assessment from a social, environmental and economic standpoint in six pilot cities: Amsterdam, Berlin, Cluj-Napoca, Milan, Paris and Vejle."

(*Continued*)

Table 3. Continued

ID	Summary	Example from analysed projects
Shared vision	Vision building anchors CE and sustainability in a clear long-term direction. While many examples are organizational, some describe region- or sector-wide ambitions, embedding circularity in policy and business practice. Visions focus on resource flows, repairability, recyclability, and fostering communities of stakeholders.	"The INSIGHT Consortium vision projects into a future where the industrial symbiosis is recognized as a key resource strategy and disseminated throughout Europe, to achieve a circular and regenerative economy."
Ecosystem perspective	The word ecosystem appeared in various constellations, from biological ecosystems to ecosystem innovation. Ecosystems were mentioned in contexts such as fashion, regional initiatives, and manufacturing. Ecosystem often appears in conjunction with industrial symbiosis, and refers both to stakeholder constellations and digital infrastructure like open ecosystem platforms for value chain actors.	"When local entrepreneurs sought a premise for innovative companies experimenting with sustainability, they found inspiration in the former Tropicana water resort in Rotterdam's riverside boulevard and began work on a circular ecosystem."
Policy enablers	The segments indicate that policy enablers focus on regulatory frameworks, standardization, and compliance mechanisms to advance circular ecosystems. The Extended Producer Responsibility (EPR) is mentioned as a driver for collaborative efforts and broader international initiatives. Initiatives mention AI and digital tools to monitor compliance, detect anomalies, and ensure adherence to legislation.	"Ecopneus is a non-profit consortium company created by the major tyre manufacturers in Italy in order to track, collect and process end-of-life tyres (ELT) so that they can meet their Extended Producer Responsibility obligations."
Collaborative governance	The texts highlight the lack of standardized governance structures and its importance to foster collaboration. Enforcement mechanisms are mentioned to increase accountability. Many cases propose frameworks (such as Moa, and R-ladder) as enablers for collaboration by confirming stakeholder support, supporting decision making, and prioritizing high impact actions.	"As part of the Circ-NSR project, this initiative focuses on developing effective governance structures for circular public procurement, fostering collaboration among regional public authorities."
Value mapping	Segments highlight co-benefits of circular approaches, including resource efficiency, cost savings, knowledge sharing, and achieving sustainability goals. Some note the importance of stakeholder mapping to develop circular supply chains and identify missing links, as well as mapping lifecycle impacts to collectively reveal circularity opportunities.	"Accelerating Circularity is building knowledge and mapping stakeholders to create a new circular supply chain and implement textile-to-textile recycling at a commercial scale, outlining missing links."
Ecosystem orchestration	While the term orchestration or orchestrator was not mentioned specifically in any of the extracted text segments, segments mentioned themes related to steering groups between organizations focusing on CE initiatives and the role of the industrial symbiosis facilitator who promotes synergies and shared benefits between companies.	"The industrial symbiosis facilitator would be responsible for different tasks: conducting analysis in their area of influence, defining and promoting synergies between companies from different sectors, capitalising on the benefits of implementing circular economy principles."

4. Discussion and final remarks

The initial aim of the study was to identify the main barriers for developing circular ecosystems, highlighting inter-organizational collaboration as a primary barrier. Following, the study identified 11 enabling factors for collaboration in circular ecosystems, which helped to examine how these factors are addressed in European CE-oriented projects. In sustainable design and circular innovation, designers are increasingly required to coordinate multi-actor collaboration and foster relational conditions under which circular solutions can be realised. Understanding factors supporting collaboration in circular ecosystems offers insights for design researchers and practitioners working at the ecosystem level.

Based on four clusters of barriers for circular ecosystems and 11 enabling factors for collaboration, the study systematically analysed 763 project descriptions from 2 publicly available European project repositories through web scraping. Results show that collaborative processes, trust building, and technological enablers are among the most frequent factors, reinforcing relational foundations for circular ecosystems through novel digital technologies. In practice, this is evidenced by the growth of product traceability platforms which can positively impact inter-organizational collaboration and enable confidential and trustworthy environments (Baumgartner et al., 2024; Schöggl et al., 2023). Analysed cases frequently signalled collaborative intentions but provided limited detail on how collaboration is achieved, and through what governance structures. This is partly a limitation of the method, as project descriptions mainly focused on outcomes over processes. Moreover, projects were often temporary and focused on initiating collaboration rather than managing it over time and sustaining it at larger scales. The term ecosystem often referred to resource flows rather than stakeholder constellations and there were few references to circular ecosystems or ecosystem orchestration, possibly indicating that these terms are still primarily concepts in academic debate (Aarikka-Stenroos et al., 2021; Aryee et al., 2025).

To date, the potential role of design capabilities and designers in fostering and orchestrating circular ecosystems remains underexplored. Konietzko et al. (2020, 2024) highlighted the necessity of initial alignment through shared visions in circular ecosystems supported by workshops, experimentation, visualization, and prototyping. Aryee et al. (2025) emphasised the use of participatory approaches, such as co-design methods and strategies, to promote diverse representation and enhance engagement and shared ownership of circular initiatives. The 3I's framework (Trevisan et al., 2023) underscores that orchestration relies on innovating in circular product design, integrating diverse actors, and investing in shared infrastructures. The first two challenges resonate directly with strategic design capabilities in managing complexity and enabling co-creation, reinforcing the need for further research on design capabilities as foundational mechanisms for circular ecosystem orchestration. We argue that the notion of circular ecosystems opens up new spaces for design and designers to contribute, for instance through strategic design capabilities such as holistic thinking, empathy, a willingness to experiment, and managing complexity (Boyer et al., 2013; Calabretta et al., 2016). These are necessary features to address the inter-organizational barriers and contribute to the formation, governance, and collaborative dimension of circular ecosystems. This study makes a methodological contribution by demonstrating how keyword-based automated web scraping and text analysis can be used to map theoretically grounded factors across a large set of cases from publicly accessible CE repositories. A main limitation is that public project descriptions reflect how organizations present their work, not necessarily how CE projects occurred. Nevertheless, the large dataset reveals insights less apparent in small-sample qualitative studies. Future studies will focus on in-depth qualitative studies of circular ecosystems to examine the presence of identified factors and the dynamics underpinning successful collaboration, as well as the role of design capabilities.

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