Circular Ecosystem Development: a Process Framework and Practical Application

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Abstract

Collaboration is vital for the transition to a circular economy. However, existing ecosystem design approaches lack essential elements required for circularity. Our four-stage Circular Ecosystem Development Framework addresses these gaps, exemplified by the plastic packaging sector. It fosters sustainable, collaborative, and transformative circular ecosystems across diverse industries, incorporating governance and user-level transformation.

Keywords

Business Ecosystem, Circular Ecosystem, Circular Economy, Ecosystem Design, Circular Business Model

Introduction

Perceived as a "megatrend" in the 2010s, sustainability has increasingly become central to corporate strategies (Lubin & Esty, 2010). Sustainability integrates environmental, social, and economic considerations to ensure present needs are met without compromising future generations (Brundtland, 1987:p.15). Companies today face mounting pressures – from political entities, customers, and financial institutions – to adopt sustainable practices (Aluchna, 2024; Audi & Yu, 2024; Reznikova & Grod, 2024).

A prominent response to these pressures is the concept of the Circular Economy (CE), which proposes shifting from the linear "take-make-waste" model to a "cradle-to-cradle"

approach (Geissdoerfer et al., 2017). Achieving sustainable development through CE necessitates innovative Business Models (BMs) and value creation systems (Kirchherr, Reike & Hekkert, 2017), including new collaborative roles and partnerships (Lüdeke-Freund, Gold & Bocken, 2019; Ghisellini, Cialani & Ulgiati, 2016)

CE requires a systemic approach rather than the analysis of individual actors in isolation (Tate et al., 2019). Business Ecosystems (BEs), networks of interdependent actors collaboratively creating shared value (Jacobides, Cennamo & Gawer, 2018), provide such a systemic perspective. BEs enable cross-industry integration crucial for complex value creation within CE frameworks (Kanda, Geissdoerfer & Hjelm, 2021)).

Integrating CE with the BE concept leads to the notion of a Circular Ecosystem, a BE type explicitly designed to create circular value, aligning economic and environmental sustainability goals (Trevisan et al., 2022). However, while research recognizes the potential of Circular Ecosystems (Pietrulla, 2022), current literature primarily provides qualitative insights, case studies and reviews (Barquete et al., 2022; Kanda, Geissdoerfer & Hjelm, 2021; Moggi & Dameri, 2021; Konietzko, Bocken & Hultink, 2020; Langen, Sornn-Friese & Hallworth, 2020; Parida et al., 2019; Stewart et al., 2018; Fontell & Heikkilä, 2017), complemented by reviews that synthesize key elements and success factors for circular ecosystems (Barquete et al., 2022; Pietrulla, 2022; Trevisan et al., 2022; Asgari & Asgari, 2021; Konietzko, Bocken & Hultink, 2020). There remains a significant gap regarding structured methodologies or process-oriented frameworks explicitly tailored to the systematic design and development of Circular Ecosystems (Trevisan et al., 2022).

To address this gap, our primary aim in this paper is to provide both scholars and practitioners with a conceptual framework for circular ecosystem development. Thus, this paper seeks to answer the central research question: How can a process framework for the development of circular ecosystems be designed?

The paper proceeds as follows: Section 2 introduces and synthesizes key concepts – BE, CE, and Circular Ecosystem. Section 3 describes our research design. Section 4 reviews existing ecosystem design frameworks, evaluating their suitability for Circular Ecosystem applications. Section 5 introduces our proposed Circular Ecosystem Development Framework. Section 6 applies this framework to the context of the Open Circular-Collaboration-Platform for Sustainable Food Packaging from Plastics (COPPA) research project. Section 7 concludes by discussing theoretical and practical implications, limitations, and future research opportunities.

Basic Terms and Theoretical Background

Business Ecosystems

The concept of a BE originated in biology and describes a network of interdependent firms collaborating to co-create value (Jacobides, Cennamo & Gawer, 2018; Adner & Kapoor,

2010). Moore (1993) introduced it to the business world, redefining firms as components of cross-industry ecosystems rather than as isolated members of industries. This perspective emphasizes the dynamic interactions and the evolution of firms within ecosystems, enabling collective innovation and value creation (Moore, 1996).

Moore (1993) proposed four evolutionary stages of BEs: birth, expansion, leadership, and self-renewal. During the birth stage, firms collaborate to address specific customer needs and create a foundation for the BM. The expansion stage involves scaling the Value Proposition (VP) and competing with rival ecosystems. Leadership emerges as one actor dominates and directs the ecosystem. Finally, self-renewal determines whether the ecosystem can continuously adapt and innovate or is replaced by more competitive ecosystems. Each stage requires balancing several cooperative and competitive activities to ensure the BE's long-term survival (Moore, 1993).

The concept of co-evolution is central to ecosystems, as firms mutually influence each other's development and must adapt to changes to survive (Teece, 2016; Bateson, 1979). Failing to evolve risks extinction for individual actors or even the collapse of the entire ecosystem if adoption rates lag (Moore, 1993). Healthy ecosystems depend on strong inter-actor relationships and collective adaptation (Teece, 2016).

BE roles include leaders, niche players, and intermediaries, each with distinct contributions to value creation (Dedehayir, Mäkinen & Roland Ortt, 2018). Leaders (Dedehayir, Mäkinen & Roland Ortt, 2018; Adner, 2017, 2006; Moore, 1996, 1993) or orchestrators (Autio, 2022; Lingens, Huber & Gassmann, 2022) guide the ecosystem by defining its vision, governance, and partnerships (Jacobides, Cennamo & Gawer, 2018). Meanwhile, niche players provide complementary products and services critical to the ecosystem's success (Iansiti & Levien, 2004). Negative roles, such as dominators, extract disproportionate value or destabilize the ecosystem (Iansiti & Levien, 2004; Moore, 1996).

The structural characteristics of BEs differentiate them from traditional supply chains. BEs involve multilateral relationships that foster high interdependence among actors (Hoeborn et al., 2022; Adner, 2017). Despite the leadership role's prominence, individual actors maintain significant autonomy in their contributions, driven by shared rules and incentive structures rather than hierarchical control (Hoeborn et al., 2022; Jacobides, Cennamo & Gawer, 2018).

Circular Economy

The CE addresses the need to balance economic growth with ecological sustainability by optimizing resource efficiency and reducing waste (Heshmati, 2015). Over the decades, CE has synthesized ideas from various disciplines, including cradle-to-cradle design (McDonough & Braungart, 2002), regenerative design (Lyle, 1994), and industrial ecology (Graedel & Allenby, 1995).

Kirchherr, Reike & Hekkert (2017) define CE as an economic system that replaces the "end-of-life" concept with strategies to reduce, reuse, recycle, and recover resources. The CE model envisions closed resource loops, where biological nutrients are returned to the biosphere, and technological materials are reused within production cycles (Ghisellini, Cialani & Ulgiati, 2016). This dual-cycle approach necessitates a rethinking of product design and value creation to ensure compatibility with either biological or technical loops (EMF, 2013).

Three core strategies underpin CE: slowing, closing, and narrowing material flows (Bocken et al., 2016). They transform traditional linear value chains into circular networks, integrating forward and reverse material flows (Zeiss, 2021). CE strategies are operationalized through R-frameworks, which range from basic principles (e.g., reduce, reuse, recycle) to more comprehensive hierarchies such as Potting et al.'s (2017) 10R framework. The implementation of CE occurs at the micro levels (individual firms), the meso levels (industrial parks), and the macro (regional or national) levels (Ghisellini, Cialani & Ulgiati, 2016).

Adopting CE requires significant changes to BMs, as traditional linear models often conflict with circular principles. Circular BMs prioritize retaining value through repair, refurbishment, and recycling (Linder & Williander, 2017). Product-service systems, in which providers retain ownership and responsibility for reuse, exemplify this approach (Tukker, 2015).

Circular Ecosystem

The idea of a circular ecosystem integrates CE principles into the idea of a BE, creating systemic circularity in value creation (Konietzko, Bocken & Hultink, 2020). A circular ecosystem facilitates collaboration among actors to co-create circular value while addressing economic and environmental sustainability (Trevisan et al., 2022). Unlike traditional BEs, circular ecosystems emphasize structured value cycles that align with CE strategies (Trevisan et al., 2022). In accordance with the definition of a BE as outlined by Betz & Jung's (2021) well as Trevisan et al.'s (2022), we propose the following definition of circular ecosystems:

> A circular ecosystem is a dynamic structure of different interdependent yet autonomous actors, who coordinate their complementary activities towards a shared purpose to co-create circular value, providing opportunities for economic and environmental sustainability.

The VP for the customer addressed by a circular ecosystem differs from the VP of a conventional BE by its dedicated circularity (Trevisan et al., 2022). Its realization requires the activities of multiple actors in so-called *value cycles*. A circular ecosystem comprises different value cycles and therefore, it requires a more structured approach to collaboration than a linear value network (Trevisan et al., 2022).

Circular ecosystems rely on orchestrator roles, which manage ecosystem governance, support collaboration, and ensure alignment with CE goals (Parida et al., 2019). Orchestrators may be private companies (Parida et al., 2019; Hakanen & Rajala, 2018) or public institutions (Langen, Sornn-Friese & Hallworth, 2020). They monitor and support the implementation of CE characteristics (Parida et al., 2019), provide infrastructure (Langen, Sornn-Friese & Hallworth, 2020), and protect smaller firms within the ecosystem (Hsieh et al., 2017). Additionally, circular ecosystems include roles modeled after biological systems, such as *scavengers* and *decomposers*, to recycle and reintegrate resources into the ecosystem (Tate et al., 2019).

Data integration and resource sharing are critical to circular ecosystem operations (Konietzko, Bocken & Hultink, 2020). Actors must collaborate on data-driven strategies to enhance circularity, necessitating robust management practices and trust-building mechanisms (Trevisan et al., 2022). Digital platforms can facilitate this integration, by supporting shared goals and enabling efficient resource flows (Konietzko, Bocken & Hultink, 2020).

A shared vision and common goals underpin the success of circular ecosystems, aligning actors toward complementary circular strategies (Konietzko, Bocken & Hultink, 2020). These strategies drive economic benefits while also addressing environmental impacts, which can be internalized within operating costs (Stewart et al., 2018). Complementary activities in circular ecosystems are governed by rules and standards established through regulation or negotiation, ensuring alignment with circular objectives (Parida et al., 2019).

Methodology

This study utilizes a Design Science Research (DSR) methodology, which is recognized for its proficiency in creating new artifacts to solve particular issues (Gregor & Hevner, 2013; Peffers et al., 2007). DSR encompasses a range of artifacts, such as products, processes, technologies, tools, methodologies, techniques, procedures, or any other means for accomplishing objectives (Venable, Pries-Heje & Baskerville, 2012). Its intentional focus on the future (Gregor & Hevner, 2013; Venable, Pries-Heje & Baskerville, 2012; Jelinek, Romme & Boland, 2008) renders the research methodology highly suitable for comprehending circular ecosystem design in both theoretical and practical aspects (Jelinek, Romme & Boland, 2008).

To guide our research, we adopt the DSR framework outlined by Hevner et al. (2004), focusing on the three fundamental research cycles (Hevner, 2007) in three iterations. The relevance cycle establishes a connection between the need for a contextual environment and the design science activities. The second rigor cycle links the knowledge base, consisting of scientific foundations, experience, and expertise, informing the research project with the design science activities. Finally, the third cycle, the design cycle, involves

iterative processes focused on building and evaluating design artifacts and processes of the research (Hevner, 2007). Figure 1[1] provides a detailed overview of our DSR-based research.

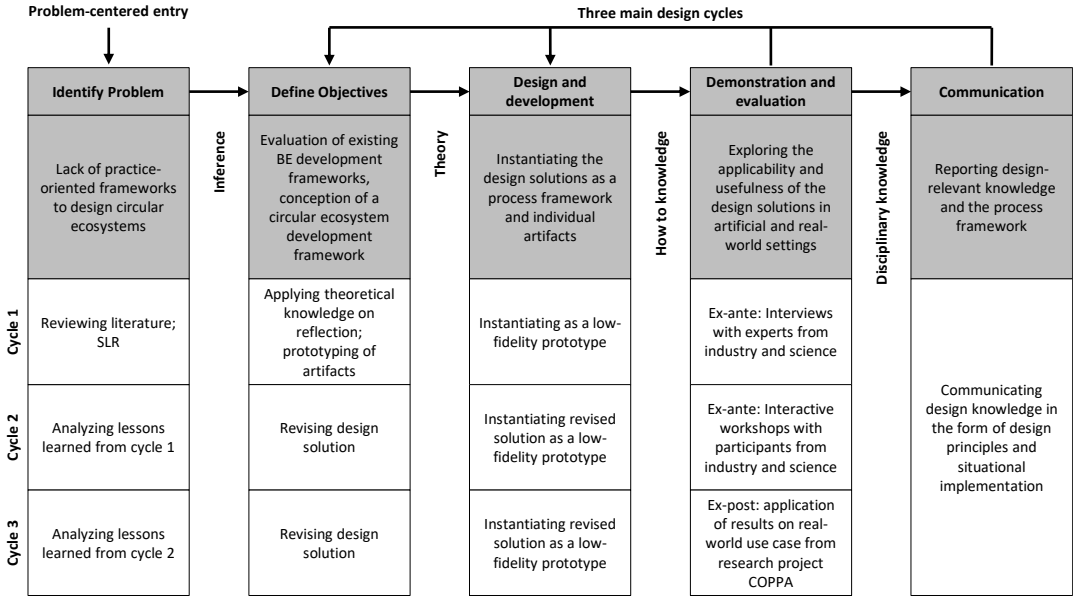

FIGURE 1: DSR RESEARCH APPROACH (ADAPTED FROM PEFFERS ET AL., 2007)

The artifact, the Circular Ecosystem Development Framework, was designed based on existing knowledge and challenges from existing research on the CE and circular ecosystems. Therefore, our study begins with a thorough analysis of the literature on circular ecosystems, as suggested by vom Brocke, Hevner & Maedche (2020). First, we identify particular aspects of circular ecosystems to develop an all-inclusive understanding of the associated requirements for practical circular ecosystem design. Second, we assess the potential setbacks and prerequisites for ecosystem design in practice, striving to determine the vital conditions for flourishing implementation. We integrate insights from ecosystem and business model literature with empirical research focusing on ecosystem development. This approach allows for a synthesis of theoretical foundations and practical observations and experiences (Pidun, Reeves & Schüssler, 2020b; Reeves et al., 2019). By following this methodology, we establish a robust foundation for evaluating existing knowledge and its applicability to circular ecosystem design. In this paper, the introduction presents content from the relevance cycle for the problem description, and the section on criteria development assesses existing approaches to ecosystem design.

To build a rigorous knowledge foundation for the development of the framework, a systemic literature review is conducted. This review provides an overview of the current state-of-the-art in ecosystem development and serves as a foundation for the suitability assessment (Rowley & Slack, 2004). To guarantee scientific rigor, we employ the five-step

[1] Note: SLR refers tot he systematic literature review.

literature review process suggested by vom Brocke et al. (2009). Our review only includes academic literature.

The purpose of the design cycle is to iteratively produce and assess alternative designs that meet the established requirements to a satisfactory degree (Simon, 1996). Research activities in this cycle entail a rapid process of creating the artifact, evaluating it, and incorporating feedback to enhance the design (Hevner et al., 2004). To assess the theory-based framework, we conducted several interviews in 2022 and held two workshops in 2024 with experienced representatives from the COPPA research project and the scientific community. The evaluation aimed to rigorously assess the framework's "utility, quality, and efficacy" (Peffers et al., 2007:p.49). We decided on a semi-structured interview format to enable knowledge production through dialogue and enable the interviewer to dynamically focus on specific aspects of the discussion (Brinkmann, 2018). Subsequent workshops were designed for the research purpose and documented following a strict agenda (Ørngreen & Levinsen, 2017). During the interviews, a researcher facilitated the sessions and recorded them for analysis. The researcher also created memos that captured initial interpretations following the discussions. To ensure the validity of the study, data triangulation was utilized, which combined field notes and questionnaires with a five-step scaling system. Workshops were facilitated by one researcher, with the assistance of another who was responsible for taking notes. The preliminary findings were reviewed by multiple researchers, ensuring its credibility and confirmabiblity (Miles & Huberman, 1984).

Concept Delimitations of Existing Approaches for the Development of Circular Ecosystems

Following the establishment of a foundational understanding of BEs, the CE, and circular ecosystems, the existing frameworks for BE development in the linear economy are assessed for their applicability to circular ecosystems. Evaluation criteria derived from literature analyze the approaches' suitability for circular ecosystem development.

Criteria Development

The following subsection outlines the derived ecosystem-related (ER) and application-related (AR) criteria for framework evaluation.

Ecosystem-related criteria

1. **Vision**: A circular ecosystem requires a shared understanding of value and goals (Pietrulla, 2022; Velter et al., 2020). A suitable framework must enable actors to define a common vision, establish goals, and develop the VP for beneficiaries (Konietzko, Bocken & Hultink, 2020).

   ER1: *The framework creates a common understanding of the goals pursued and VP to be created in the ecosystem.*

2. **Configuration**: Poor ecosystem configuration accounts for 18% of failed ecosystems (Pidun, Reeves & Schüssler, 2020b). A framework must define necessary activities, actor roles, and modular architectures while considering digital and physical value streams (Pietrulla, 2022; Trevisan et al., 2022; Konietzko, Bocken & Hultink, 2020; Adner, 2017). Motivational incentives and an orchestrating entity are also essential (Trevisan et al., 2022; Pidun, Reeves & Schüssler, 2020a; Parida et al., 2019; Hsieh et al., 2017).

   ER2: *The framework focuses on the ecosystem's configuration to deliver the targeted VP and launch a Minimal Viable Ecosystem (MVE).*

3. **Integration**: Resource and data sharing among actors is critical (Moggi & Dameri, 2021). A framework must incorporate shared infrastructure, digital data streams, and governance mechanisms to ensure trust (Trevisan et al., 2022; Hakanen & Rajala, 2018).

   ER3: *The framework incorporates relevant (data-)flows and the individual capabilities of the actors involved.*

4. **Management**: Governance issues contribute to 59% of ecosystem failures (Pidun, Reeves & Schüssler, 2020b). A framework must include internal governance structures, value distribution mechanisms, monetization strategies, and external collaboration incentives (Pietrulla, 2022; Konietzko, Bocken & Hultink, 2020; Pidun, Reeves & Schüssler, 2020a).

   ER4: *The framework considers aspects of value capture, incentives, and governance to ensure long-term success.*

5. **Transformation**: Circular ecosystems as networks of organizations may drive organizational change (Lacy, Long & Spindler, 2020). A framework must outline how circular strategies influence firms at the business, operating model, and organizational levels (Trevisan et al., 2022).

   ER5: *The framework provides guidance for the transformation of organizational culture, business, and operating models.*

Application-related criteria

1. **Process**: A structured yet adaptable process ensures usability. To balance complexity and usability, frameworks should have an appropriate number of steps and cause reasonable effort (Bocken et al., 2019). A framework shall incorporate iteration and validation loops, and accommodate both new insights and uncertainty in ecosystem development (Lingens, Miehé & Gassmann, 2021; Giessmann et al., 2013).

   AR1: *The framework focuses on the iterative development process of ecosystems.*

2. **Toolbox**: Another application-related criterion is that a model is applicable by practitioners with various levels of experience. It must guide the user through its methods and provides the necessary support to successfully complete the process by logically structuring the elements (Reuver & Athanasopoulou, 2016; Lofthouse, 2006). Following this, it shall offer methods throughout the development process of an ecosystem. To gain relevant experience through application and to ensure regular use, the scope of each method should be scalable to fit the available resources and capabilities of the corresponding users (Reuver & Athanasopoulou, 2016). To increase user acceptance, methods must be designed in a way that motivates users (Reuver & Athanasopoulou, 2016; Zec et al., 2014).

   AR2: *The framework offers practitioners a toolbox for the development of ecosystems.*

Table 1 provides an overview of the derived criteria.

TABLE 1: CRITERIA FOR FRAMEWORK EVALUATION

	Criterion	Criteria description
Ecosystem-related criteria	ER1: Vision	The framework creates a common understanding of the goals pursued and VP to be created in the ecosystem.
	ER2: Configuration	The framework focuses on the ecosystem's configuration to deliver the targeted VP and launch a minimal viable ecosystem.
	ER3: Integration	The framework incorporates relevant (data) flows and the individual capabilities of the actors involved.
	ER4: Management	The framework considers aspects of value capture, incentives, and governance to ensure long-term success.
	ER5: Transformation	The framework provides guidance for the transformation of organizational culture, business, and operating model.
Application-related criteria	AR1: Process	The framework focuses on the iterative development process of ecosystems.
	AR2: Toolbox	The framework offers practitioners a toolbox for the development of ecosystems.

Evaluation of Existing Approaches

Our initial literature search[2] from Scopus, Web of Science, IEEE Xplore and EBSCOhost yielded a total of 5,646 unique results. Using the open-source tool ASReview for semi-automated screening, we narrowed this to a final sample of 49 publications.

[2] Example of the search string used for Scopus: TITLE-ABS-KEY (("business ecosystem" OR "innovation ecosystem" OR "circular ecosystem" OR "value creation system" OR "value network" OR "value system") AND (development OR analysis OR strategy OR evolution OR orchestration OR innovation OR govern* OR structur* OR transformation OR genesis OR design) AND (model OR framework OR tool OR theory OR process))

This research evaluates a representative sample of eight frameworks for BE development and related concepts from a systematic literature review. The criteria assess their objectives and key characteristics. The frameworks under consideration include:

- Rong et al. (2015) explore how the Internet of Things can replace traditional supply chains, analyzing six BE components: *Context*, *Configuration*, *Capability*, *Cooperation*, *Construction*, and *Change*.
- Tura, Kutvonen & Ritala (2017) present a design science-based framework for platform design, addressing *platform architecture*, *value creation logic*, *governance*, and *platform competition*.
- Parida et al. (2019) present an interactive, two-stage CE transformation process for BEs in resource-intensive industries, focusing on an *ecosystem readiness assessment* and multiple *orchestration mechanisms*.
- Burkhalter (2020) critiques ideocentric business model ontologies and introduces the *Allocentric Business Model Ontology* considering actor interactions, value co-creation and individual value capture.
- Humbeck et al. (2020) develop the *BE Management Canvas* as a management tool for ecosystem orchestration, consisting seven key design fields.
- Talmar et al. (2020) introduce the *Ecosystem Pie Model* for strategic BE design distinguishing between *ecosystem-level* and *actor-level* constructs.
- Jacobides (2022) differentiates between *multi-product* and *multi-actor ecosystems*, proposing a two-plus-five-stage process for BE strategy definition.
- Kolagar, Parida & Sjödin (2022) examine digital servitization in manufacturing, outlining four areas of action during the transformation and a three-step transformation process.

A qualitative evaluation matrix (Table 2) based on ecosystem and application-related criteria compares these approaches. While each framework provides valuable insights, none fully meets the requirements for a practice-oriented circular ecosystem framework. Gaps in integration (ER3), management (ER4), and transformation (ER5) highlight the need for a more comprehensive approach.

TABLE 2: EVALUATION OF EXISTING FRAMEWORKS

	Ecosystem-related criteria				Application-related criteria		
	ER1: Vision	ER2: Configuration	ER3: Integration	ER4: Management	ER5: Transformation	AR1: Process	AR2: Toolbox
Tura, Kutvonen & Ritala (2017)	◕	◑	◑	◕	○	◑	◕
Parida et al. (2019)	◔	◑	◔	◑	◑	●	◔
Jacobides (2022)	◔	◕	◑	◑	◔	◑	◕
Kolagar, Parida & Sjödin (2022)	◕	◕	◕	◑	◑	◕	◑
Rong et al.	◔	◔	◔	○	○	◔	◑
Talmar et al. (2020)	◑	◑	◑	◔	◔	◑	●
Burkhalter (2020)	◕	◕	◕	◑	◔	◑	◑
Humbeck et al. (2020)	◕	◑	◕	◑	○	◑	●

The Circular Ecosystem Development Framework

Given the need for a novel approach to circular ecosystem development, this section outlines the derivation of an optimal method. The model's requirements are based on the central research question, defined criteria, and identified research gaps.

The ecosystem-related criteria from the previous section guide the framework's development, ensuring comprehensiveness while considering the model's reduction characteristic (Stachowiak, 1973). Its processual components allow elements of existing (linear) BEs to serve as inputs, supporting also ecosystem transformation. To act as a boundary object between academia and practice (Star & Griesemer, 1989) combining scholarly rigor with practical relevance specific tools and canvases complement the components.

The framework consists of six components, which are divided into two levels: the ecosystem-level and the actor-level. The four core components at the **ecosystem-level**, *Vision*, *Configuration*, *Manifestation*, and *Operation*, reflect the core process of ecosystem development. The components follow a processual order. In addition to the main components, the model includes two subcomponents at the individual **actor-level**:

ecosystem development is enabled by specific Actor-level Enablers and results in Actor-level Transformation considering the individual level of circular ecosystem actors is essential, as it reflects their unique enablers and initial conditions for participation in the ecosystem (Kolagar, Parida & Sjödin, 2022). However, it also highlights the transformative potential of such participation to drive organizational-level changes necessary for the transition to a CE (Parida & Wincent, 2019). Figure 2[3] shows a visualization of the framework.

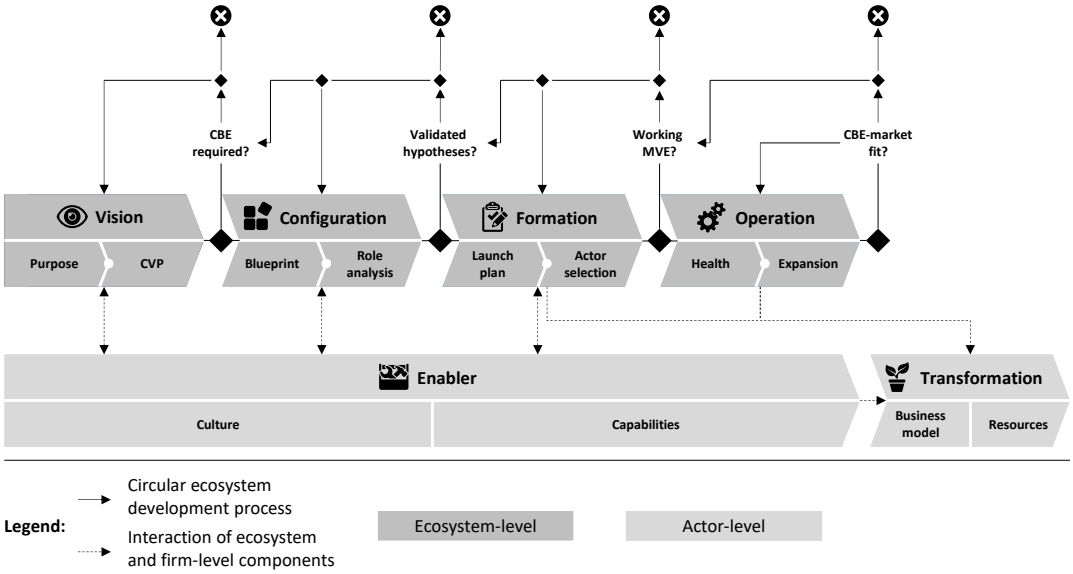

FIGURE 2: OVERVIEW OF THE CIRCULAR ECOSYSTEM DEVELOPMENT FRAMEWORK

Inspired by the stage-gate process for innovation and product development (Cooper, 2002), each main component is followed by a decision gate, serving as a milestone to determine whether to terminate, iterate, or proceed. Transition requirements are defined in advance for each phase, incorporating continuous learning and iteration through a *build-measure-learn approach* (Ries, 2011), thus addressing the critique of the stage-gate approach as too rigid for innovative projects (Cooper, 2014). Table 3 provides a summary of the main components with their descriptions and associated gates.

[3] Note: CVP refers to the circular value proposition of the circular ecosystem, while CBE denotes the circular ecosystem.

TABLE 3: OVERVIEW OF CORE COMPONENTS OF THE CIRCULAR ECOSYSTEM DEVELOPMENT FRAMEWORK

	Vision	Configuration	Formation	Operation
Description	Understand problem space and develop a vision for the circular ecosystem	Develop a blueprint for the circular ecosystem and analyze roles	Plan the initialization of the circular ecosystem and select stakeholders	Ensure the health and expandability of the circular ecosystem
Elements	• Initial situation • Customer segment & jobs-to-be-done • Purpose, vision, mission • (Circular) VP • R-strategies	• Value additions for implementation • Resources required • Roles in the circular ecosystem • BMs and value creation opportunities • Tangible & intangible flows • Risk and requirements analysis of each role	• Realization of the required resources • Onboarding strategy for circular ecosystem actors • Initial governance strategy • Selection of the orchestrator • Actor selection for each role	• Regular evaluation of the circular ecosystem • Ensuring stability • Ensuring prosperity • Identification of expansion opportunities
Outcome	Shared vision for the future	Hypotheses for the implementation of the CVP	Launch of the circular ecosystem	Circular ecosystem health
Gate	Circular ecosystem as a value creation system required	Validated hypotheses to realize the CVP	Working MVE	Circular ecosystem-market fit

Vision

The first component of the Circular Ecosystem Development Framework envisions a desired future, identifies challenges, and defines the CVP for the target customer segment. Guided by structured and unstructured factors, it follows a problem space-solution space approach

(Olsen, 2015). Target customer segments and challenges are identified using an outcome-driven innovation approach to optimize customer needs (Hankammer et al., 2019).

Stakeholder alignment is critical, as establishing a shared definition of sustainability and ecosystem goals is a significant challenge (White, 2013). Sinek's (2009) Golden Circle framework highlights the ecosystem's "why", its purpose, as derived from addressing the shared sustainability understanding and customer jobs (Pidun, Reeves & Schüssler, 2019; Sinek, 2009).

The solution space begins with defining the VP, initially addressing customer needs without integrating CE principles. Through iterative refinement with the application of CE's r-strategies, so-called *circularity debt* is minimized, and a comprehensive CVP emerges, integrating system-level goals (Konietzko, Bocken & Hultink, 2020). The selected r-strategies guide the "how", the circular ecosystem's value creation and differentiation, while the CVP informs the "what," or mission and final product (Sinek, 2009).

The Circular Ecosystem Vision Canvas visualized in Figure 3 supports this process, combining the Value Proposition Canvas (Osterwalder et al., 2014) with the technical cycle of the CE Butterfly Diagram (EMF, 2019) to emphasize circularity. Practical application incorporates all r-strategies, fostering an accessible, iterative development approach.

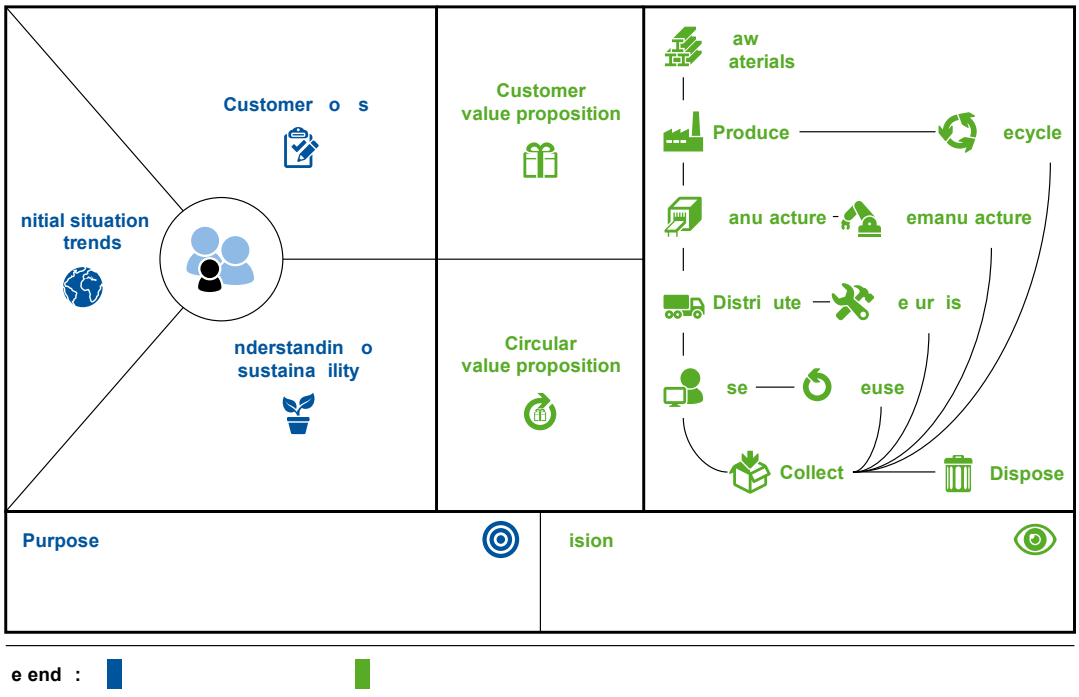

FIGURE 3: CIRCULAR ECOSYSTEM VISION CANVAS

A critical assessment determines if a circular ecosystem is suitable for realizing the CVP. Four guiding questions support this assessment (Jacobides, 2022; Pidun, Reeves & Schüssler, 2019; Jacobides, Cennamo & Gawer, 2018):

1. Does the realization of the CVP require multiple actors?
2. Does it require a high degree of coordination between the actors involved in the realization of the CVP?
3. Does collaboration with other actors in the realization of the CVP provide the opportunity to define the profile of the industry?
4. Does the solution to realize the targeted CVP require a high degree of modularity?

If unsuitable, the vision may proceed through sustainable business models or be discontinued (Antikainen & Valkokari, 2016; Mentink, 2014).

Configuration

The second component of the Circular Ecosystem Development Framework focuses on realizing the ecosystem through value additions, resources, roles, and exchange relationships. It develops and validates hypotheses for forming the ecosystem, starting from the CVP defined earlier. Value additions – representing the productive components of roles – are identified for pre-, during-, and post-use phases, ensuring circularity (Talmar et al., 2020). Resources underlying these activities include physical, human, and intangible assets, including capabilities, which may be owned, shared, or jointly utilized (Langen, Sornn-Friese & Hallworth, 2020; Lubik & Garnsey, 2016).

Roles are analyzed to determine their capacity to deliver value additions, emphasizing financial or non-monetary value capture as motivation for participation (Lepak, Smith & Taylor, 2007). Economic feasibility remains critical, requiring tailored business models to support value realization (Govindan & Hasanagic, 2018; Kirchherr et al., 2018). Exchange relationships between roles are mapped, integrating material, monetary, and intangible value streams to analyze interdependencies and associated risks (Ouden, 2012). Risk factors include participation incentives, role dependencies, and value creation complexity (Adner, 2006; Iansiti & Levien, 2004).

The Circular Ecosystem Configuration Canvas supports this stage, offering a role-level analysis while illustrating systemic interdependencies (Talmar et al., 2020). Validation is conducted through methods like stakeholder interviews, focus groups, or digital simulations (Konietzko, Bocken & Hultink, 2020). If assumptions are validated, ecosystem formation begins; otherwise, the process iterates or concludes.

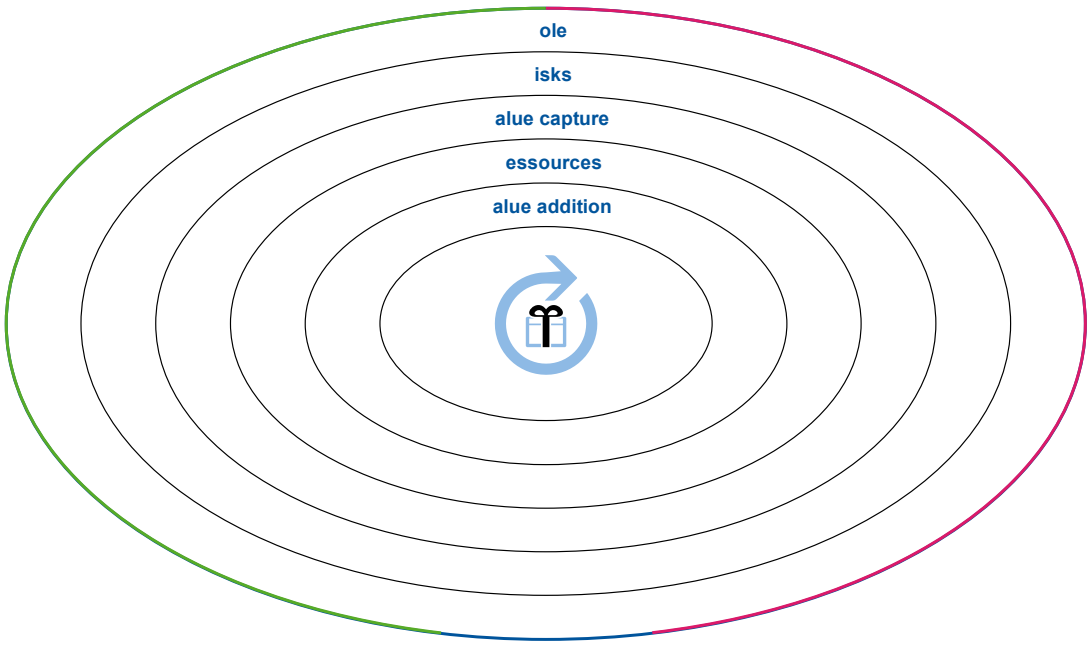

FIGURE 4: CIRCULAR ECOSYSTEM CONFIGURATION CANVAS (BASED ON TALMAR ET AL., 2020)

Formation

The third component, Formation, focuses on translating validated hypotheses into a functional circular ecosystem through a structured formation plan and actor selection. Four key action areas are addressed: *resources*, *onboarding strategy*, *governance structure*, and the *orchestrator role*.

Resources involve ensuring the necessary inputs for the launch and operation of the ecosystem. This includes distinguishing between existing resources from current contributors and the resource gap to be filled. Critical and complementary missing resources may require integrating suppliers as complementors or establishing dyadic relationships, depending on their relevance to value creation.

Onboarding strategy addresses capability development of involved actors, handling of digital data, technological infrastructure and product standardization, as well as funding. Key considerations include knowledge sharing, digital literacy, data exchange standards, and the need for a digital platform or modular CVP architecture to ensure actor autonomy (Kolagar, Parida & Sjödin, 2022; Konietzko, Bocken & Hultink, 2020). Upfront costs vary by role, necessitating funding strategies, such as subsidies combined with profit-sharing mechanisms (Parida et al., 2019).

Governance structure and control is crucial for the success of an ecosystem. It includes the overall governance structure, which formalizes collaboration. It also encompasses the rules of collaboration, which are responsible for regulating the behavior of individual actors within the ecosystem. Furthermore, it comprises metrics for goal-oriented management of

the circular ecosystem, ensuring that all actors align their actions towards a common goal. Finally, it involves value capture for all actors, guaranteeing the satisfaction of all parties involved. Governance must align actors' actions toward shared goals while ensuring fair value distribution.

The orchestrator is responsible for overseeing the ecosystem, balancing strategic tasks (e.g., CVP refinement) with operational coordination (Kolagar, Parida & Sjödin, 2022; Lingens, Huber & Gassmann, 2022; Brusoni & Prencipe, 2013). If a single orchestrator lacks requisite skills, co-orchestrators or a multi-orchestrator model may be implemented to ensure effective management (Lingens, Huber & Gassmann, 2022).

The Formation Canvas (Figure 5) supports ecosystem initialization, providing a structured approach to the planning of resources, actor, and governance. Following formation, a pilot launch of a MVE in a test market determines readiness for full-scale operations. If validation fails, the process iterates or terminates, potentially revisiting earlier components such as *Vision* or *Configuration*.

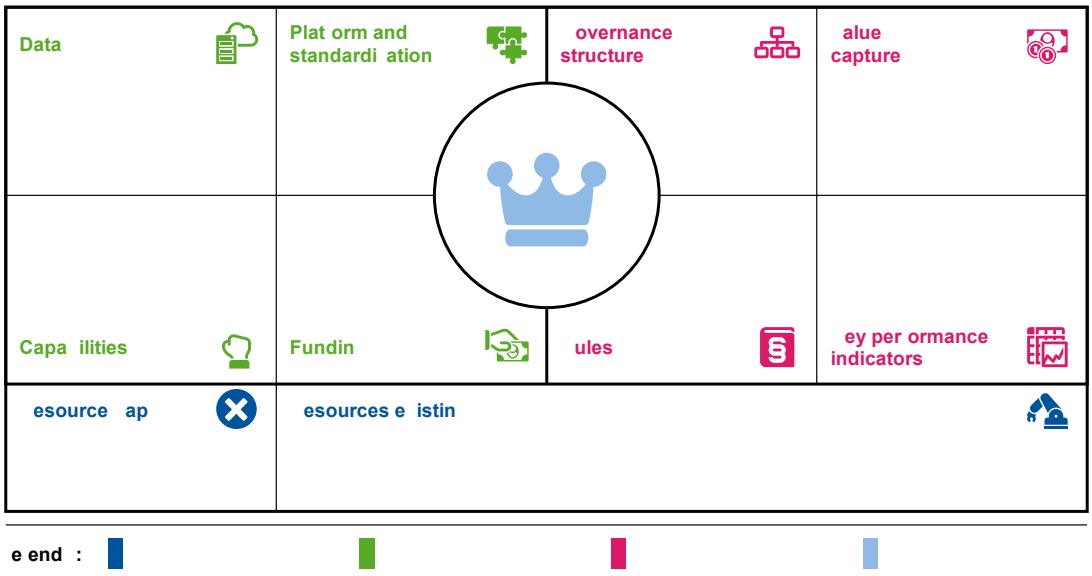

FIGURE 5: CIRCULAR ECOSYSTEM FORMATION CANVAS

Following formation, a pilot launch of a MVE in a test market may determine readiness for full-scale operations. If validation fails, the process iterates or terminates, potentially revisiting earlier components such as Vision or Configuration.

Operation

Following successful testing of the MVE, the Operation component transitions the circular ecosystem from development to maturity and expansion. This stage ensures long-term ecosystem health, defined by robustness, productivity, and niche creation (Iansiti & Levien,

2002). Activities focus on *stability*, *prosperity*, and *expansion*, with ecosystem health as the central objective.

Stability ensures the ecosystem's foundations, which consist of addressing governance, conflict resolution, task distribution, and actor coordination. Governance mechanisms, including decision-making, role definition, and rules of collaboration, must be reviewed and adapted as needed (Humbeck et al., 2020). Interfaces between actors must be maintained to prevent conflicts and ensure CVP realization, fostering integration and knowledge exchange (Parida et al., 2019).

Prosperity optimizes value creation by addressing gaps in capabilities, evaluating Key Performance Indicators (KPIs), and aligning actor-level and ecosystem-level strategies. Capability-building ensures actors can fulfill roles, while KPIs measure progress toward shared goals. Alignment reviews the appropriateness of the double-sided VP and strategies to sustain cooperation and motivation (Humbeck et al., 2020).

Expansion focuses on growth through openness and shaping industry standards. The ecosystem can expand by onboarding new partners or adapting the CVP to additional use cases, leveraging network effects (Tura, Kutvonen & Ritala, 2017). Shaping strategies, such as influencing legislation or market norms, can further amplify impact.

The Circular Ecosystem Operation Canvas (Figure 6) supports collaborative evaluation and planning for ecosystem health, incorporating stability, prosperity, and growth. Periodic assessments enable iteration or termination if the ecosystem’s health is insufficient. Sustainability-specific KPIs complement traditional metrics to align with ecosystem goals (Hristov & Chirico, 2019; Hartigh et al., 2013). This component ensures continued evolution or guides decisions to iterate or conclude the circular ecosystem endeavor.

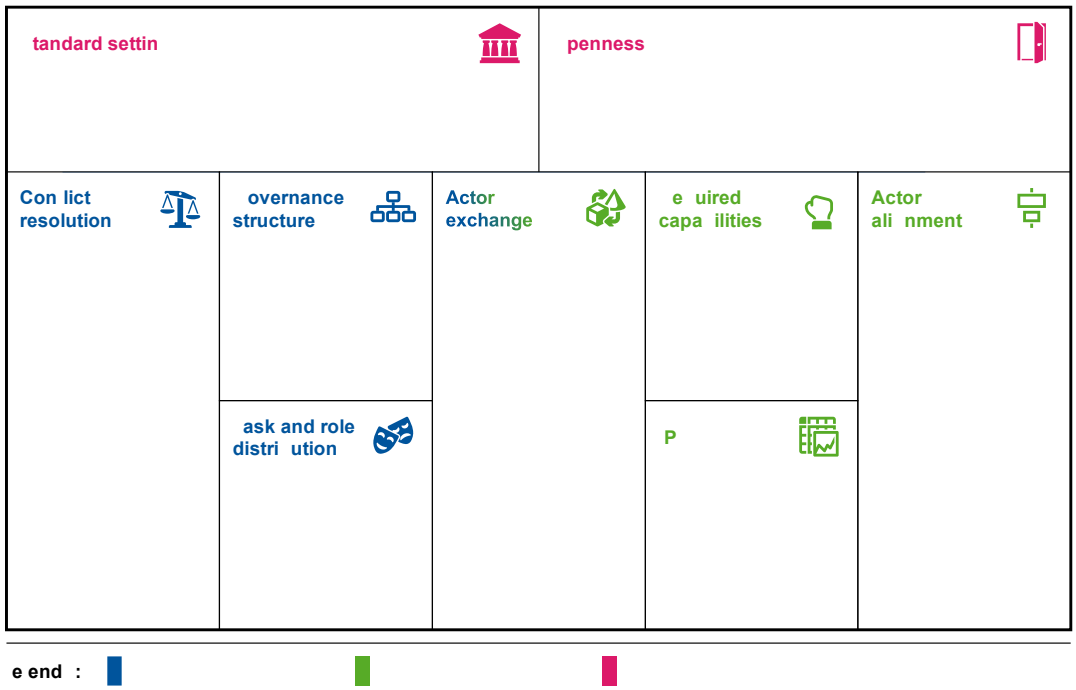

FIGURE 6: CIRCULAR ECOSYSTEM OPERATION CANVAS

Actor-level Components

Although the circular ecosystem is developed collectively under the orchestrator's leadership, individual actor-level factors significantly influence its success and design. This dynamic necessitates a focus on *Actor-level Enablers* and the *Actor-level Transformation* resulting from ecosystem participation.

Actor-level Enablers

The success of a circular ecosystem depends on actors' cultural characteristics and capabilities. Cultural enablers, such as transparency, openness, accountability, and trust, foster data sharing and collaboration. For instance, openness encourages knowledge exchange, while accountability ensures responsibility even in loosely regulated settings (Kolagar, Parida & Sjödin, 2022).

Key capabilities include relationships, digital, product development, and business model competencies. Relationship capabilities enable coordination and conflict management, particularly for orchestrators balancing internal and external priorities. Digital capabilities, including data processing and platform skills, are critical in the data-oriented circular ecosystem (Trevisan et al., 2022). Product development capabilities depend on roles and may involve engineering, material science, or design expertise (Los Rios & Charnley, 2017). Business model capabilities are essential for adapting and innovating VPs (Kolagar, Parida & Sjödin, 2022).

Actors can identify and close gaps in these enablers through gap analyses, roadmaps, and focused development efforts (Schuh et al., 2020).

Actor-level Transformation

Based on Trevisan et al.'s observation that actors in a circular ecosystem can take action to adopt circular strategies, even beyond the materialization of the CVP (Trevisan et al., 2022), the *Actor-level Transformation* component emerged. Participation in circular ecosystems shapes organizations by fostering new enablers and driving transformations in value creation, capabilities, and operations (Parida & Wincent, 2019; Bocken et al., 2014). Actor-level transformations often align with sustainability goals, requiring structured management tools like the Business Transformation Canvas (Gudergan, Feige & Krechting, 2017). Ultimately, circular ecosystems enable mutual growth, helping actors achieve sustainability while driving organizational transformation.

Application of the Circular Ecosystem Development Framework

One sector facing considerable pressure for sustainable transformation is the plastic packaging industry (Feber et al., 2022). Driven by customer demands and stringent political regulations, such as the European Union's (EU's) revised Packaging and Packaging Waste legislation (European Commission (EC), 2022; Cherel-Bonnemaison et al., 2022; Feber et al., 2022), the industry must significantly reduce waste and emissions. Despite Germany's high recycling rate of 65.9% for plastic packaging waste (Cayé et al., 2024), only 10% of the recycled material is reused in packaging of equivalent quality (Sestak, 2021). A fundamental shift towards proactive waste prevention in product design and development is required to reduce environmental impacts effectively (Lemille, 2019).

Context of the Field of Application

In Germany, Packaging consumption reached 8,867.1 kilotons in 2020, with plastic being the fastest-growing material, increasing by 111.4% since 1991 (GVM, 2022). Plastic packaging, especially in food, is favored for its moldability, light weight, and cost efficiency (Cooper, 2013). The packaging industry explores sustainable innovations like reusable packaging, deposit refund systems, and refillable options (WEF, EMF & McKinsey, 2016). Digital technologies and intelligent packaging design enhance sustainability efforts by improving life cycle assessments and supporting traceability (Sharma & Ghoshal, 2018). Achieving a CE in the food packaging industry requires systematic changes, including improvements in recycling technologies, new materials, and regulatory frameworks (Berg et al., 2020; WEF, EMF & McKinsey, 2016).

Digital platforms are a good example of new technologies that can have a significant impact on the food packaging industry. The research project COPPA, funded by the German Federal Ministry of Agriculture, aims to develop an open Circular Collaboration Platform (CCP)

designed to facilitate more precise and efficient information exchange among various stakeholders in the food packaging industry. The CCP enables participants to effortlessly track plastic packaging by automatically verifying information on quality, content, and recyclate availability, thereby supporting the closure of loops and advancing circularity. The transition from a predominantly linear economy to a digitally-enabled CE can lead to significant changes in value creation flows in the market and the requirements for market participants. Therefore, the project is developing and testing a circular ecosystem to realize and promote the CCP with existing and new stakeholders. The objective of COPPA is to develop a prototype demonstrator within the required CE and a Technology Readiness Level of around 5. Therefore, the application of the Circular Ecosystem Development Framework focuses on the initial two components of the development process: vision and configuration, with the results presented in the following section.

Vision of COPPA

The plastic packaging industry faces significant challenges in the transitioning to a CE, primarily due to a lack of transparency regarding material origin, quality, and availability. Market participants often struggle with trust issues and limited knowledge about technical and commercial opportunities, which hinders their ability to integrate recycled materials effectively. Additionally, strong regulatory restrictions, the absence of viable business and ownership models, and high costs for recycled materials further complicate the shift.

The COPPA research project aims to address these challenges by developing a transparent, efficient, and collaborative ecosystem for circular plastic packaging through the development of a circular collaboration platform. The platform offers its participants the following VP:

- Creation of an aggregated database to facilitate more accurate and efficient information exchange, enabling seamless tracking of plastics from food packaging
- Documentation of raw materials, additives, recycled content, recycled quality, origin, and ownership, all accessible via a Digital Product Passport (DPP)
- Notarization of data through a smart contract model to verify its authenticity
- Democratization of platform participation by adhering to data standards
- Provision of a CO2 calculator to assess the carbon footprint of products and offer decision support for reducing packaging material and increasing recycled content

Configuration of the COPPA Circular Ecosystem

The Configuration consists of developing a circular ecosystem blueprint and individual role analyses to develop hypotheses as a foundation for initializing the circular ecosystem. Based on the developed VP, the circular ecosystem blueprint is created as a plan for the ecosystem. The first step is to define the individual **value additions** required to realize the VP. The necessary **resources** are then allocated to individual value additions. The individual

activities and resources are then assigned to the respective **roles** in the ecosystem. In practice, an actor may take on multiple roles; for example, a grocery shop chain may take on the roles of *retailer* and *collector*, or a (petro-)chemical company may take on the roles of p*olymer producer* and *compounder*. From a **value capture** perspective, two sets of roles can be identified: first, the suppliers of the physical product components, and second, the providers of the services required to realize the circular VP, such as the platform operator and digital product passport aggregator. The central role of the Platform Operator for the circular ecosystem becomes clear when the **exchange relationships** are visualized. The material flows along the supply chain remains untouched, while the platform acts as the central hub for data aggregation and exchange between players. Prior to the launch of the circular ecosystem, the actors are assessed in terms of their **risk** regarding VP fulfillment. The full Configuration blueprint can be derived from the Configuration Canvas of the COPPA ecosystem provided in Appendix 1.

Conclusion and Contributions

The objective of our research is to address the gap in application-oriented frameworks for circular ecosystem development. To this end, a Circular Ecosystem Development Framework has been developed to fulfill this need. The framework is based on a systematic literature review, which evaluates existing models and offers a modular, flexible approach that accounts for both ecosystem-level developments and enablers at the individual actor level. The framework was applied and validated to a case study in the plastic packaging industry, based on the research project COPPA to demonstrate the suitability of the model.

This paper provides contributions to circular ecosystem research by offering a systematic literature review of existing development models and identifying their limitations in supporting circular ecosystems. It introduces seven criteria for evaluating frameworks based on ecosystem design moments, circular ecosystem characteristics, and application perspectives. The evaluation reveals that while some frameworks meet certain requirements, no one fully supports circular ecosystem development. The central contribution of this paper is the development of the Circular Ecosystem Development Framework, which addresses the limitations of existing methods by focusing on both ecosystem-level development and individual actor enablers. The framework is flexible and modular, allowing for adaptation to various starting points in ecosystem management and development. It includes four main components, supported by specific methodologies for practitioners, and allows for iterative development.

However, the applicability of the framework was tested in a specific context, limiting its generalizability. Future research should focus on applying the framework in diverse industries and with a broader group of participants to assess its broader relevance. The paper also underscores the necessity to explore enablers for participation in circular ecosystems and the impact of ecosystem activity on individual roles. Further studies could

examine actor roles within circular ecosystems, particularly the orchestrator role, and explore how different CE strategies require distinct circular ecosystem configurations.

Lastly, future research could integrate digital tools, such as artificial intelligence, into circular ecosystem development. These tools could support hybrid innovation teams, enhancing creativity and traceability in the process, and help expand the solution space for Circular ecosystem challenges.

Credit authorship contribution statement

L. Klapper: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing – Original Draft, Writing – Review & Editing. **D. Spindler:** Validation, Writing – Original Draft, Project administration. **G. Hoeborn:** Conceptualization, Methodology, Validation, Investigation, Writing – Review & Editing, Supervision, Project administration, Funding acquisition. **W. Boos:** Resources, Writing – Review & Editing, Supervision.

Declaration of Interest statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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During the preparation of this work the authors used DeepL and ChatGPT 4o to improve readability and language of the manuscript. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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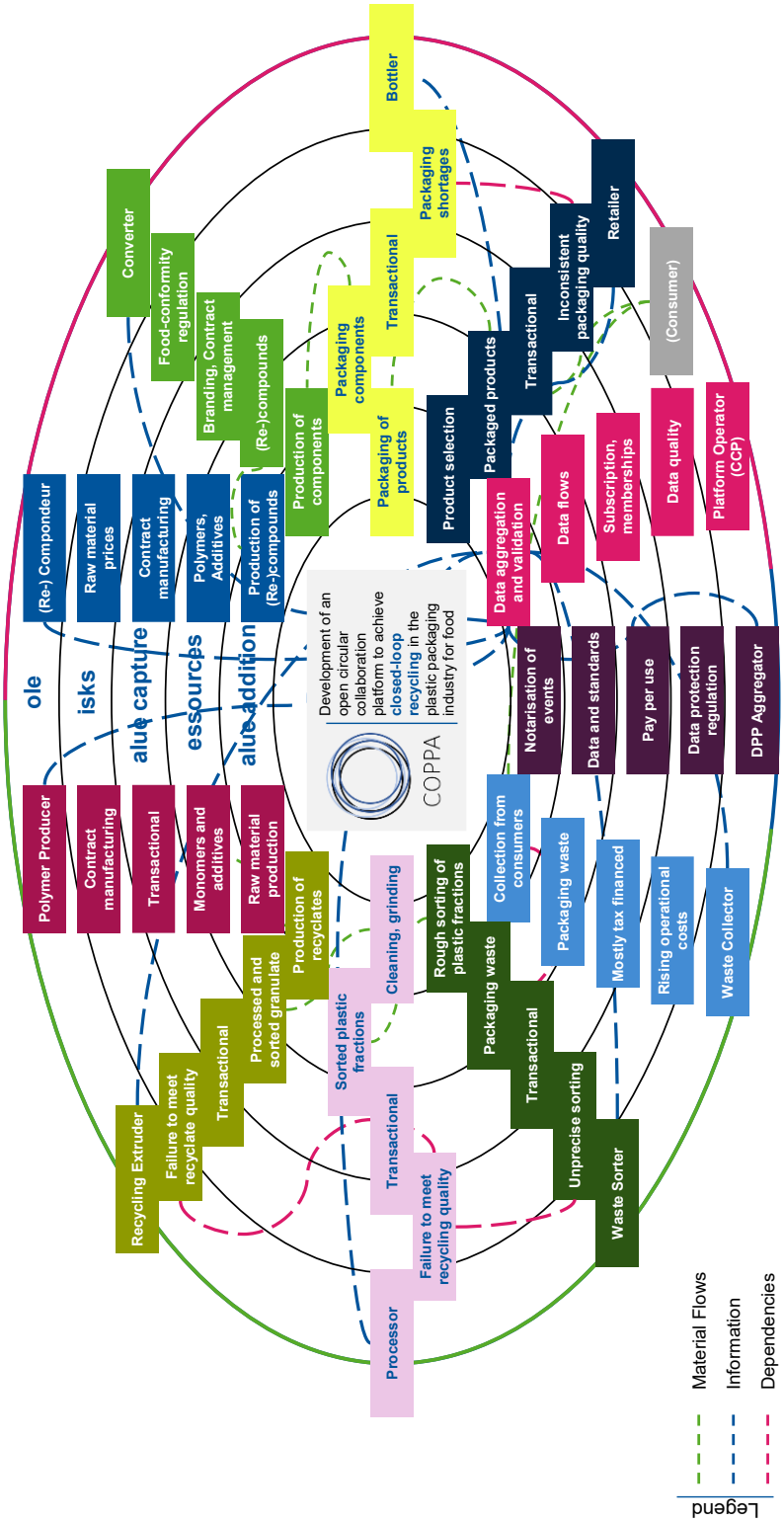
Appendix



APPENDIX 1: CONFIGURATION CANVAS OF THE COPPA ECOSYSTEM