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Structuring co-creation for circular ecosystem emergence: The minimum viable circular ecosystem framework

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HIGHLIGHTS

- Develops the MVCE framework, closing a practical gap in orchestration guidance and a theoretical gap in ecosystem emergence.
- Introduces four boundary tools (Vision Board, Value Wheel, Pilot Canvas, Governance Canvas) that each reduce one uncertainty.
- Grounds the framework in design science research: 15 expert interviews and three multi-actor workshops on reusable packaging.
- Advances a process theory: circular ecosystem emergence proceeds through four sequential uncertainty-reduction mechanisms.

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ABSTRACT

Circular economy transitions require coordinated action among multiple interdependent actors across value chains. While research on circular ecosystems has expanded rapidly, two interrelated gaps persist: existing frameworks remain largely conceptual and provide limited process-level guidance for orchestrators, and the field lacks a theoretical account of how circular ecosystem emergence unfolds through co-creation; what orchestration activities are required at each stage and through what mechanisms they shape alignment and value creation outcomes. This study addresses both gaps by developing the Minimum Viable Circular Ecosystem (MVCE) framework through a design science research approach combining a literature synthesis, fifteen semi-structured expert interviews, and three multi-actor workshops conducted in the context of emerging reusable packaging ecosystems. The MVCE framework conceptualises circular ecosystem emergence as an iterative co-creation process unfolding through four interrelated phases: visioning, ecosystem framing, experimentation and learning, and structuring and governance, each operationalised through a dedicated boundary tool supporting collective sensemaking, ecosystem configuration, hypothesis-driven experimentation, and collaborative governance. While prior ecosystem frameworks address individual functions such as actor mapping, readiness assessment, or governance design in isolation, to our knowledge, prior frameworks have not integrated all four functions within a single co-creation process architecture operationalised through complementary boundary tools. The study advances four theoretical contributions: a theoretically grounded process framework for circular ecosystem emergence; the operationalisation of distributed orchestration through boundary objects; an account of value co-creation at the ecosystem emergence level; and a nascent design theory for circular ecosystem orchestration. Together, these contributions advance understanding of how circular ecosystems can be deliberately designed, aligned, and validated through structured co-creation.

1. Introduction

Growing pressures arising from climate change, resource scarcity, and waste accumulation have intensified the search for economic models capable of reconciling economic performance with environmental sustainability (Suchek et al., 2021; European Environment Agency, 2025). In this context, the circular economy (CE) has emerged as a prominent paradigm that seeks to decouple value creation from the consumption of finite resources by promoting closed material loops, reuse, and regeneration (Kirchherr et al., 2018).

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Achieving circularity, however, requires systemic changes in production and consumption systems that extend beyond the boundaries of individual firms. In practice, circular solutions depend on coordinated action among multiple interdependent actors, including suppliers, customers, logistics providers, public authorities, and consumers, particularly in business-to-business contexts characterised by shared infrastructure, long-term relationships, and mutual dependence (Geissdoerfer et al., 2017).

Reflecting this systemic nature, circular economy research has progressively moved beyond an early focus on firm-centric circular business models (Lewandowski, 2016; Bocken et al., 2016) toward perspectives emphasising interorganisational collaboration and ecosystem coordination. These perspectives highlight how multiple actors align incentives and integrate complementary resources to close material loops and generate shared value (Geissdoerfer et al., 2020; Pietrulla, 2022; Kanda, 2023). Building on this shift, scholars increasingly draw on key constructs from ecosystem theory, including the ecosystem value proposition as a system-level offering that requires coordinated contributions from multiple actors and cannot be delivered by a single firm (Adner, 2006, 2017), and complementarity structures that create interdependencies among participants and define conditions for collective value creation (Jacobides et al., 2018), alongside innovation ecosystem research (Thomas and Ritala, 2021) to examine how orchestration, governance, and value co-creation mechanisms enable circular solutions at scale (De Angelis, 2021; Asgari and Asgari, 2021; Aryee et al., 2025). Within this stream, the concept of circular ecosystems has emerged to describe interorganisational configurations in which heterogeneous actors collaborate to create circular value through shared infrastructures, coordinated activities, and collective innovation processes (Aarikka-Stenroos et al., 2021). Parallel developments in ecosystem research have introduced concepts such as the Minimum Viable Ecosystem (MVE), which describes early configurations of actors and roles required to deliver a collective value proposition under conditions of uncertainty (Adner, 2012; Pidun et al., 2020), alongside boundary objects such as ecosystem maps and value blueprints that support cross-actor sensemaking and coordination (Carlile, 2002; Adner, 2012; Talmar et al., 2020).

In this study, circular ecosystem emergence is conceptualised as a co-creation process in which heterogeneous actors, including firms, universities, public organisations, intermediaries, and citizens, combine resources and knowledge to address challenges that exceed the capabilities of individual organisations (De Silva et al., 2021, 2023). From this perspective, circular ecosystem emergence does not result from centralised planning or unilateral strategic action. Instead, it unfolds through iterative and negotiated interactions in which actors align ambitions, experiment with alternative configurations, and progressively shape shared value propositions. Co-creation thus provides a processual lens for understanding how heterogeneous actors collectively construct circular solutions under conditions of uncertainty, and why orchestration in such settings involves facilitating alignment, learning, and coordination rather than exercising hierarchical control. Throughout this paper, *emergence* refers to the process by which a new ecosystem configuration crystallises through interactional dynamics among actors (Jacobides et al., 2018); *alignment* denotes the iterative reconciliation of actor incentives, roles, and expectations around a shared value proposition (Adner, 2017); and *co-creation* describes the joint construction of value through resource integration across organisational boundaries (Vargo and Lusch, 2016).

Despite these advances, circular ecosystems present coordination challenges that existing frameworks only partially address. Their operation requires alignment of physical material flows, regulatory requirements, and cross-industry incentive structures characterised by different cost bases, time horizons, and risk profiles (Konietzko et al., 2020a; Pietrulla, 2022; Aryee et al., 2025). Many existing frameworks remain largely conceptual or address isolated aspects of ecosystem development, offering limited process-oriented guidance for practitioners tasked with structuring collaboration, designing governance arrangements, and validating circular value propositions in applied settings. Beyond this practical limitation, a theoretical gap also persists: while recent studies have begun to examine orchestration dynamics in specific circular contexts (DiVito et al., 2025; Frederiksen et al., 2025), the field still lacks a process-level account of how circular ecosystem emergence unfolds through co-creation; specifically, what orchestration activities are required at each phase of emergence, and through what mechanisms their enactment shapes actor alignment and value creation outcomes (Aryee et al., 2025). These limitations are particularly acute in early stages of ecosystem emergence, where uncertainty is high and orchestrator actions play a decisive role in shaping collaboration trajectories (Thomas and Ritala, 2021). This coordination challenge is qualitatively distinct from digital innovation ecosystem contexts, where platform-based governance and information-as-value flows afford substantially different orchestration dynamics; circular ecosystems must simultaneously govern physical material logistics, contamination risks, and multi-actor infrastructure investments alongside distributed decision-making, making their emergence more demanding to orchestrate.

Addressing these gaps, the present study asks: *How can a structured process framework* support *orchestrators in facilitating the co-creation and emergence of circular economy ecosystems, and what does developing such a framework reveal about the orchestration mechanisms through which circular ecosystems emerge under conditions of uncertainty?* To answer this question, we adopt a design science research (DSR) approach that integrates insights from innovation ecosystem theory and circular economy scholarship with iterative development work conducted in collaboration with ecosystem actors. The study develops the Minimum Viable Circular Ecosystem (MVCE) framework, a process-oriented framework that conceptualises ecosystem emergence as unfolding through four interrelated phases: visioning, ecosystem framing, experimentation and learning, and structuring and governance. Each phase is operationalised through a boundary tool designed to support collective sensemaking, ecosystem configuration, hypothesis-driven experimentation, and collaborative governance.

By integrating ecosystem theory, circular economy research, and design-oriented artefact development, this study advances both a theoretical understanding of how circular ecosystems emerge through co-creation and actionable guidance for practitioners engaged in circular innovation initiatives. The MVCE framework is distinctive in linking visioning, ecosystem configuration, pilot experimentation, and governance design within a single co-creation process architecture operationalised through four complementary boundary tools, an integration that prior ecosystem frameworks and circular economy tools have not achieved. In doing so, it enables orchestrators to navigate the full complexity of early-stage circular ecosystem emergence rather than addressing individual phases or functions in isolation.

The remainder of the article is structured as follows. Section 2 reviews relevant literature on ecosystems and the circular economy and identifies the research gap addressed by this study. Section 3 outlines the research methodology and the design science research process used to develop and evaluate the framework. Section 4 presents the Minimum Viable Circular Ecosystem framework and its associated boundary tools before discussing the theoretical and practical implications of the findings.

2. Theoretical background

2.1. Business ecosystems and emergence

The concept of business ecosystems was first introduced by Moore (1993) to describe competitive environments in which organisations co-evolve through both collaboration and competition. Since then, ecosystem research has developed into a distinct analytical perspective within management and strategy, characterised by heterogeneous actors, non-hierarchical coordination mechanisms, and complex interdependencies between technological, economic, and relational elements (Autio and Thomas, 2020a; Thomas and Ritala, 2021; Shipilov and Gawer, 2020).

A central feature of ecosystems is the ecosystem value proposition, defined as a system-level offering that requires coordinated contributions from multiple actors and cannot be delivered by a single organisation acting independently (Adner, 2006, 2017; Talmar et al., 2020; Lingens et al., 2021). Ecosystems are often initiated or guided by an orchestrator, such as a focal firm, intermediary, or public actor, that mobilises complementary resources and aligns participating actors through strategic direction, shared infrastructures, or governance arrangements (Thomas and Ritala, 2021). During early stages, orchestrators typically articulate an initial vision, define tentative value propositions, and outline desired outcomes through emerging business models or platform concepts.

The emergence phase is particularly critical, as it establishes the foundations for subsequent ecosystem growth and stability. Research identifies actor mobilisation, role definition, governance structuring, and resource alignment as central challenges during this phase (Jacobides et al., 2018). Enabling conditions include the presence of intermediaries facilitating stakeholder alignment and policy interventions that reduce uncertainty and incentivise collaboration (Autio and Thomas, 2020b). However, much of this research has focused on digital or technology-driven ecosystems where platform-based coordination and information-as-value flows afford fundamentally different orchestration dynamics, leaving open questions regarding how these mechanisms translate to circular contexts characterised by physical material flows, infrastructure investments, regulatory complexity, and multi-stakeholder sustainability objectives (Kanda et al., 2021). The constructs reviewed here – ecosystem value proposition, orchestration, and the Minimum Viable Ecosystem (MVE) configuration logic (Adner, 2012; Pidun et al., 2020) – provide the theoretical foundation on which circular ecosystem emergence research builds, operating under the additional constraints of circularity, multi-institutional coordination, and environmental accountability.

2.2. Circular ecosystem emergence

Circular ecosystems extend traditional innovation ecosystem perspectives by explicitly integrating environmental sustainability into system-level value creation (Konietzko et al., 2020a). Aminoff et al. (2017) describe circular ecosystems as co-evolving configurations in which actors integrate resources and coordinate activities to enable circular material flows. Similarly, Aarikka-Stenroos et al. (2021) define circular ecosystems as communities of hierarchically independent yet interdependent actors that collectively generate sustainable ecosystem outcomes. Research has since expanded across multiple dimensions, including conceptual clarification (Aryee, 2024; Trevisan et al., 2022), typologies (Aarikka-Stenroos et al., 2021), governance dimensions (Aryee et al., 2025), collaboration mechanisms (Ferrari et al., 2023), and, more recently, orchestration processes in specific sector contexts (DiVito et al., 2025; Frederiksen et al., 2025; Castillo-Ospina et al., 2025).

Despite this growing body of work, understanding of how circular ecosystems emerge in practice remains limited. Existing studies indicate that circular ecosystems often develop in sectors where opportunities for reuse, recycling, or resource recovery create incentives for coordinated action among multiple stakeholders (Zerbino et al., 2021). Ecosystem formation typically involves diverse actors, including firms, public authorities, NGOs, and communities who contribute resources, capabilities, and institutional legitimacy (Aryee et al., 2025). At the same time, early stages of circular ecosystem development are characterised by high uncertainty, competing interests, and complex coordination requirements. While recent studies have begun to examine orchestration dynamics in specific sectors such as textiles and construction (DiVito et al., 2025; Harala et al., 2023), they have not yet produced a generalised, multi-phase process framework applicable across circular ecosystem types.

Prior research emphasises that clearly defined roles and responsibilities are critical for ecosystem success (Moggi and Dameri, 2021; Zerbino et al., 2021). Misalignment among actors is particularly problematic during early phases when expectations regarding value creation, cost sharing, and risk distribution remain uncertain. Addressing these challenges requires collaboration mechanisms that enable knowledge sharing, trust building, and joint problem-solving across organisational boundaries (Ferrari et al., 2023; Rocha et al., 2023; Moggi and Dameri, 2021). Within this context, orchestrators play a pivotal role by coordinating activities, mediating conflicts, and facilitating alignment among ecosystem participants (Parida et al., 2019). Orchestration capabilities in circular ecosystems extend beyond traditional coordination tasks to include management of circular consumer offerings, supply chain integration, and complex partnering arrangements (Sandberg, 2023).

Governance constitutes another important dimension of circular ecosystem research. Governance mechanisms, including institutional arrangements, contractual agreements, and shared infrastructures, shape the conditions under which circular ecosystems emerge and evolve. Effective governance often requires adaptive approaches capable of addressing power asymmetries, institutional complexity, and evolving regulatory environments (Girard, 2021; Arfaoui et al., 2022; Anttiroiko, 2023; Aryee et al., 2025). Together, these studies highlight the systemic nature of circular ecosystem emergence and the need for practical process-oriented approaches that support orchestrators in navigating the coordination, governance, and value alignment challenges it entails.

2.3. Tools and frameworks for ecosystem design and management

To address ecosystem coordination challenges, several tools and frameworks have been developed focusing on ecosystem mapping, strategic analysis, and readiness assessment. The Ecosystem Readiness Assessment (Parida et al., 2019) provides a structured approach for scanning technological and regulatory developments that may influence ecosystem formation, though its focus on diagnostic assessment means it offers limited support for collaborative ecosystem design. The Ecosystem Pie Model (Talmar et al., 2020) offers a visual framework for mapping actors, roles, and value flows, enabling organisations to identify interdependencies within emerging ecosystem configurations, but without guidance on how ecosystems develop over time. The Business Ecosystem Management Canvas (Humbeck et al., 2020) supports strategic positioning during ecosystem emergence and diversification, yet remains primarily oriented toward strategic roles rather than experimentation or governance design.

In parallel, several tools have been developed specifically for circular innovation contexts. The Circularity Deck (Konietzko et al., 2020a) stimulates circular innovation ideation at the ecosystem level through a card-based approach, but focuses on opportunity generation rather than ecosystem structuring. The Circular Collaboration Canvas (Brown et al., 2021) supports early-stage partner identification and value mapping, without integrating experimentation or governance phases. The BM3C2 framework (Boldrini and Antheaume, 2021) aligns business models across multiple organisations within circular ecosystems but addresses business model alignment rather than ecosystem orchestration processes. Taken together, these tools address specific functions within circular ecosystem development; none provides an integrated process that guides orchestrators across the full development lifecycle.

Several broader frameworks provide guidance for ecosystem orchestration and transformation. Autio and Thomas (2022) multi-layered orchestration framework conceptualises orchestration across technological, economic, institutional, and behavioural layers, though it remains conceptual and does not operationalise specific coordination activities. Jacobides (2022) proposes an ecosystem development framework emphasising collaborative engagement and strategic coordination, while Kolagar et al. (2022) address ecosystem transformation for digital servitisation. Within circular economy scholarship, Bertassini et al. (2021) propose a circular business ecosystem innovation guide for stakeholder mapping and opportunity identification. De Vasconcelos Gomes et al. (2022) develop a circular ecosystem management framework examining how orchestrators configure and manage the ecosystem value proposition, specifically addressing how value is jointly created, captured, and distributed across ecosystem participants. Thakur and Wilson (2024) offer a conceptual model of circular innovation ecosystems incorporating actors, resource infrastructures, artefacts, and governance arrangements. Most recently, Konietzko et al. (2024) introduce the Minimum Viable Ecosystem for Circularity, providing a step-wise methodology for establishing an initial circular ecosystem configuration. While these approaches provide valuable insights, Table 1 shows that they consistently address specific aspects of ecosystem development rather than offering an integrated process framework supporting orchestrators across the full lifecycle of circular ecosystem emergence.

The present study relates specifically to two prior concepts that warrant explicit positioning before the gap synthesis. The MVE concept (Adner, 2012; Pidun et al., 2020) addresses the minimum configuration of actors and roles required to deliver a collective value proposition, a configuration-level question concerned with identifying who must participate for the ecosystem to function. Konietzko et al.'s (2024) Minimum Viable Ecosystem for Circularity extends this logic to circular contexts through a step-wise methodology for establishing an initial configuration. Both contributions focus on identifying the minimum viable structure rather than on the orchestration process through which circular ecosystems are co-created and developed over time. The MVCE framework proposed in this study differs in three specific respects. First, it conceptualises emergence as an iterative, multi-phase co-creation process rather than a structural configuration challenge. Second, it operationalises orchestration through four complementary boundary tools that enable distributed sensemaking and collective decision-making among heterogeneous actors. Third, it integrates governance design and pilot-based experimentation within the emergence process itself, rather than treating them as separate activities. In doing so, the MVCE addresses a distinct theoretical level, the process through which circular ecosystems are deliberately constructed, that neither the MVE nor existing circular ecosystem frameworks have systematically theorised. Appendix D provides a comparative overview of the MVCE framework against eight representative prior frameworks across seven dimensions of ecosystem development support, demonstrating that while individual frameworks offer strong support for

Table 1
Overview of existing tools and frameworks and functional gaps.

TOOL/FRAMEWORK	PURPOSE	KEY CONTRIBUTION	LIMITATION FOR CIRCULAR ECOSYSTEM EMERGENCE	SOURCE
Ecosystem Readiness Assessment	Assess technological and regulatory readiness for ecosystem development	Helps organisations scan ecosystem opportunities and anticipate ecosystem shifts	Focuses on diagnostic scanning rather than collaborative ecosystem design; provides no support for the iterative co-creation processes through which ecosystems are structured and governed.	Parida et al. (2019)
Ecosystem Pie Model	Map ecosystem actors, activities, and value flows	Visualises actor roles and value complementarities within an ecosystem configuration	Provides a static map of ecosystem structure at a given moment but offers no guidance on how ecosystems develop, reconfigure, and evolve over time through experimentation and governance.	Talmar et al. (2020)
Business Ecosystem Management Canvas	Guide actors during ecosystem emergence and diversification	Supports ecosystem role definition and strategic positioning among participants	Primarily strategic in orientation; provides limited support for hypothesis-driven experimentation, governance design, or iterative ecosystem development as configurations evolve.	Humbeck et al. (2020)
Circularity Deck	Stimulate circular innovation ideas across ecosystem actors	Card-based ideation method for generating circular opportunities at ecosystem level	Focuses on innovation ideation rather than ecosystem structuring, experimentation, or governance; does not provide a process linking ideation to ecosystem configuration and validation.	Konietzko et al., 2020b
Circular Collaboration Canvas	Identify partners and map value exchanges in circular initiatives	Supports early-stage collaboration design and partner identification	Addresses early-stage partner and value mapping but does not integrate with subsequent phases of ecosystem development, including pilot-based experimentation and governance design.	Brown et al. (2021)
BM3C2 Framework	Align business models across multiple organisations	Enables systemic circular business model design across organisational boundaries	Addresses business model alignment rather than ecosystem-level orchestration; does not provide process guidance for how multi-actor ecosystems emerge, experiment, and establish governance over time.	Boldrini and Antheaume (2021)
Circular Business Ecosystem Innovation Guide	Structure stakeholder mapping and circular opportunity identification	Supports ecosystem-level circular innovation design and stakeholder engagement	Provides limited guidance on iterative ecosystem development; does not integrate experimentation and governance design within a coherent emergence process.	Bertassini et al. (2021)
Multi-layered Ecosystem Orchestration Framework	Conceptualise orchestration across technological, economic, institutional and behavioural layers	Provides a systemic view of orchestration activities across ecosystem development stages	Conceptual framework with limited operationalisation; does not provide practical tools or process guidance for enacting orchestration activities in emerging circular ecosystems.	Autio and Thomas, 2022
Circular Ecosystem Management Framework	Orchestrate ecosystem value proposition and configuration	Examines how orchestrators configure and manage circular ecosystem value propositions	Addresses value proposition orchestration but provides limited guidance on the iterative process through which ecosystem configurations are developed, piloted, and institutionalised over time.	De Vasconcelos Gomes et al. (2022)
Circular Innovation Ecosystem Model	Describe circular innovation ecosystems through actors, infrastructures and artefacts	Provides a systemic conceptual model of circular ecosystems and their components	Provides a conceptual map of circular ecosystem elements without operational process guidance; does not support practitioners in navigating the co-creation activities required for ecosystem emergence.	Thakur and Wilson, 2024
Minimum Viable Ecosystem for Circularity	Develop early-stage circular ecosystems	Provides stepwise logic for establishing a minimum viable circular ecosystem configuration	Identifies minimum structural requirements for a circular ecosystem but provides limited guidance on the multi-phase co-creation process through which actors iteratively construct, experiment with, and govern circular ecosystems.	Konietzko et al. (2024)

specific functions, none integrates governance design, pilot-based experimentation, and multi-phase co-creation within a single process architecture operationalised through complementary boundary tools.

2.4. Synthesis and research gap

Taken together, the reviewed literature demonstrates significant progress in understanding circular ecosystems, including their structural characteristics, governance arrangements, and collaborative value creation processes. Research has introduced key conceptual constructs such as ecosystem value propositions (Adner, 2006, 2017), orchestration mechanisms (Jacobides et al., 2018), and circular ecosystem principles (Konietzko et al., 2020b; Bertassini et al., 2021). Numerous tools and frameworks have also been developed to support ecosystem analysis, mapping, and strategic coordination.

Despite these advances, the literature remains fragmented across research streams addressing ecosystem emergence, circular business model innovation, collaboration mechanisms, and governance design, a fragmentation confirmed by systematic reviews of the field (Aryee et al., 2025; Pietrulla, 2022). Many frameworks remain conceptual or address specific aspects of ecosystem development, such as diagnostic assessments, stakeholder mapping, or governance structures, leaving practitioners, particularly ecosystem orchestrators, without integrated and actionable guidance for managing the process of circular ecosystem emergence over time (Konietzko et al., 2024; De Vasconcelos Gomes et al., 2022). Moreover, existing tools are rarely designed to function together as part of a coherent process. Most address specific phases of ecosystem development while providing limited support for iterative coordination, experimentation, and governance design as ecosystems evolve under conditions of uncertainty. These limitations are particularly acute in circular ecosystems, which require coordination of material flows, cross-industry collaboration, regulatory alignment, and negotiated distribution of costs, risks, and benefits among heterogeneous actors (Ferrari et al., 2023; Aryee et al., 2025).

These limitations reveal two interrelated gaps. At the practical level, ecosystem orchestrators lack an integrated framework that links visioning, ecosystem structuring, experimentation, and governance design into a coherent, actionable process for circular ecosystem emergence. At the theoretical level, the field lacks a process account of how such emergence unfolds through co-creation, that is, through what orchestration mechanisms circular value propositions, actor roles, and governance arrangements are progressively constructed under conditions of uncertainty. Aryee et al.'s (2025) systematic review confirms that emergence dynamics and orchestration processes remain among the most underexplored areas in circular ecosystem research. Addressing both gaps requires moving beyond fragmented toolsets toward integrated frameworks that enable orchestrators to deliberately guide ecosystem development over time while generating theoretically transferable insights about the orchestration mechanisms involved. To address this challenge, the present study adopts a Design Science Research (DSR) approach (Hevner et al., 2004) to develop and evaluate a process-oriented framework supporting orchestrators in facilitating circular ecosystem emergence. The following section describes the methodology underpinning this process.

3. Methodology

3.1. Research context and empirical anchoring

Reusable packaging ecosystems provide a relevant empirical context for examining the emergence of circular ecosystems. The study focuses specifically on consumer-facing reusable packaging in food and beverage contexts, such as reusable takeaway containers, cups, and foodservice packaging, rather than the well-established industrial transport packaging systems that have operated in B2B supply chains for decades (Mahmoudi and Parviziomran, 2020). This distinction matters because consumer-facing reusable packaging represents a genuinely emerging ecosystem context: it depends on uncertain consumer return behaviour, lacks standardised infrastructure and regulatory mandates, and requires coordination among actors with no prior collaborative history in reuse systems.

The transition away from single-use packaging has received increasing attention due to the environmental impacts associated with resource depletion, greenhouse gas emissions, and persistent waste accumulation, particularly in plastic packaging systems (Muranko et al., 2021; Coelho et al., 2020). Reusable packaging systems have therefore been promoted as a circular alternative that enables multiple use cycles, reduces demand for virgin materials, and lowers waste generation over time (Bocken et al., 2022). Life cycle assessment studies suggest that, when sufficiently reused and effectively managed, reusable packaging systems can outperform single-use alternatives in terms of overall environmental footprint (Pålsson and Olsson, 2023).

Despite their environmental potential, reusable packaging systems are difficult to implement and therefore require an ecosystem perspective. Their operation depends on coordinated action among diverse and interdependent actors, including material suppliers, manufacturers, logistics providers, retailers, policymakers, and consumers (Tenhunen-Lunkka et al., 2024). Effective implementation relies on shared infrastructure for collection, cleaning, and redistribution, as well as efficient reverse logistics processes. These infrastructures can be costly and operationally complex, particularly when return rates are uncertain or consumer participation remains inconsistent (Coelho et al., 2020). Economic viability further depends on balancing upfront investments in durable packaging and system infrastructure with long-term savings in procurement and waste management (Muranko et al., 2021). Consumer behaviour and institutional conditions add additional layers of complexity. Although awareness of sustainable packaging is increasing, adoption of reuse systems is often constrained by concerns related to convenience, hygiene, and required behavioural changes (Noëth et al., 2024). At the same time, policy frameworks and regulatory incentives play a critical role in shaping system viability by standardising practices and encouraging cross-industry coordination (Long et al., 2022). Taken together, these characteristics make consumer-facing reusable packaging ecosystems an appropriate empirical context for studying circular ecosystem emergence. The need to align material flows, business models, governance arrangements, and stakeholder behaviour illustrates the coordination challenges faced by circular ecosystems more broadly.

3.2. Research logic and design orientation

The study follows a design science research (DSR) approach aimed at developing a theoretically grounded and practically applicable framework supporting circular ecosystem emergence. Design science research focuses on the creation and evaluation of artefacts such as models, methods, or frameworks that address identified problems while generating theoretically relevant knowledge (Hevner et al., 2004; Peffers et al., 2007). In this study, DSR was implemented through an abductive research process that iteratively combined theoretical insights with empirical engagement. Rather than following a strictly linear sequence of research stages, the framework and associated tools were progressively refined through repeated cycles of design, empirical testing, and revision. This approach aligns with the notion of systematic combining proposed by Dubois and Gadde (2002), where theoretical and empirical insights evolve together through iterative confrontation.

Accordingly, the research process involved multiple cycles of artefact development and evaluation. Initial conceptual prototypes were derived from literature on innovation ecosystems, circular economy transitions, and boundary objects. These prototypes were then refined through interviews, workshops, and collaborative design sessions involving ecosystem actors and domain experts. Each iteration informed adjustments to the conceptual framework, the structure of the boundary tools, and their practical usability in facilitating ecosystem orchestration.

Three revision cycles illustrate how empirical feedback informed artefact refinement. First, an early version of the Governance Canvas lacked the structured prompt questions that characterised the other three tools. Participants in WS1 noted that the canvas felt inconsistent in its facilitation logic compared to the rest of the toolkit and contained too many topics to engage with productively at early ecosystem stages, observing that at this stage actors 'may not have enough information' to complete governance discussions meaningfully. This feedback triggered two concrete revisions: guiding prompt questions were added to each section to create a consistent facilitation logic across the toolkit, and several sections were simplified or merged to reduce cognitive load. The feedback also raised a substantive theoretical question about when governance discussions should enter the process, informing the positioning of the Governance Canvas as a Phase 4 tool applied after initial pilot learning rather than during early framing. Second, the initial Value Wheel mapped only direct operational actors in the circular lifecycle without capturing institutional context. Participants in the academic in-house workshop recommended adding an explicit layer of external influencers (policy frameworks, market standards, and public expectations) to the tool instructions, noting that 'perception and expectations matter as much as technical design.' Participants in WS1 independently raised a conceptual ambiguity in the same tool: it was unclear whether the wheel depicted a supply chain, a value chain, or an ecosystem configuration. Together, these observations informed a revision clarifying the ecosystem orientation of the tool and strengthening the space for capturing how institutional and regulatory conditions shape value flows across actors. Third, the Vision Board's initial prompts were experienced as overlapping and insufficiently differentiated: participants in WS1 noted that 'some questions are quite similar' and requested more distinct, actionable prompting per section. The narrative visualisation element was also identified as challenging and generated discomfort rather than strategic clarity, prompting the suggestion to 'skip the visual narrative and keep to text.' These observations led to prompt reformulation to increase discriminating power across sections and simplification of the visualisation component. Participants also noted that the tool 'would have been great earlier in the project,' confirming its intended positioning as the opening activity in the MVCE process and its potential value as a recurring alignment instrument as the ecosystem evolves. In terms of temporal sequencing: the initial conceptual prototype was developed over approximately the first three months of the research process; expert interviews were conducted over a six-month period (months 4–9); the three workshops were conducted sequentially over months 10–13; and artefact consolidation and team-based refinement occurred over months 14–18, yielding a total research cycle of approximately 18 months from prototype development to framework consolidation.

3.3. Overview of the iterative research process

The research process unfolded through three main stages: (1) conceptual prototype development, (2) empirical refinement through interviews, and (3) demonstration and evaluation through multi-actor workshops. Throughout these stages, the evolving framework served both as an analytical lens for interpreting empirical insights and as a design artefact subject to continuous revision. This iterative logic broadly aligns with the design science research model proposed by Peffers et al. (2007), which includes problem identification, design and development, demonstration, evaluation, and communication.

3.4. Conceptual prototype development

The research process began by developing an initial conceptual understanding of circular ecosystem emergence and existing orchestration supports. This stage involved synthesizing literature on ecosystem value propositions and complementarities (Adner, 2006, 2017), innovation ecosystem emergence and orchestration (Jacobides et al., 2018; Thomas and Ritala, 2021), minimum viable ecosystem thinking (Adner, 2012; Pidun et al., 2020), and boundary objects as mechanisms supporting cross-actor coordination (Carlile, 2002). Circular economy research provided additional design requirements specific to circular systems, including the coordination of material flows, multi-dimensional value creation, and institutional complexity (Kirchherr et al., 2018; Konietzko et al., 2020b; Pietrulla, 2022; Aryee et al., 2025). Building on these insights, an initial prototype of the framework was developed consisting of a preliminary process model and early versions of the boundary tools. At this stage, the artefact intentionally remained incomplete. The prototype served as a preliminary representation designed to surface key orchestration challenges and stimulate critical feedback from ecosystem actors during subsequent empirical engagements.

3.5. Empirical refinement through expert interviews

To challenge and refine the initial prototype, the study conducted 15 semi-structured interviews with ecosystem actors and domain experts involved in circular economy initiatives, including reusable packaging systems. The sample was constructed through criterion sampling (Patton, 2015), targeting individuals with direct experience of circular ecosystem development or operational involvement in reusable packaging initiatives. Participants represented five actor categories: packaging solution providers and manufacturers ($n = 4$), retail and food service operators ($n = 3$), innovation intermediaries and circular economy consultants ($n = 4$), policymakers and regulatory actors ($n = 2$), and academic circular economy researchers ($n = 2$). The interviews collectively spanned three distinct reusable packaging ecosystem initiatives, enabling cross-initiative comparison of coordination challenges and orchestration practices. Each interview lasted between 45 and 75 min and was conducted via video conference. An interview guide covering five thematic areas (ecosystem formation experience, coordination and role-definition challenges, governance and value distribution, experimentation and pilot design, and critical reflections on the prototype framework) is provided as Appendix A.

A sample of 15 interviews was determined to be appropriate based on information saturation criteria: thematic redundancy across actor categories was reached by the twelfth interview, with the final three interviews confirming rather than extending the coding structure. This sample size is consistent with norms for expert elicitation studies in design science research and qualitative circular economy research (Guest et al., 2006; Malterud et al., 2016), where purposive samples of domain-knowledgeable participants typically yield higher information power than larger general-population samples.

The interviews explored practical challenges encountered during ecosystem emergence, including actor mobilisation, role definition, governance design, value distribution, and experimentation processes. Rather than treating interview data as an independent dataset for thematic analysis, insights were used abductively to identify mismatches between conceptual assumptions and practitioner experiences.

Interview data were analysed through an abductive procedure combining open coding and deductive mapping. Transcripts were initially coded inductively to identify first-order themes in practitioner language; for example, references to unclear role ownership, difficulty initiating governance discussions without structure, or discomfort with framing pilots as learning experiments rather than demonstrations. These themes were then mapped deductively against the theoretical constructs underpinning the initial prototype (ecosystem value proposition, MVE configuration logic, boundary object functions), enabling systematic identification of mismatches that warranted artefact revision. Design revision memos documented each iteration, specifying the empirical trigger and the corresponding artefact change. A distinction was maintained throughout between elements present in the initial prototype due to theoretical derivation and elements added or revised in response to abductive inference from interview data. To strengthen coding reliability, a subsample of five interview transcripts was independently coded by a second member of the research team using the initial coding framework. Discrepancies between coders were discussed in team sessions until consensus was reached, and the coding framework was updated to resolve ambiguities. All four authors reviewed the final code-to-construct mapping prior to the artefact revision decisions, creating a multi-researcher audit trail consistent with abductive DSR quality standards.

Interview feedback revealed several issues requiring refinement, including ambiguities in actor roles, unclear sequencing between ecosystem development activities, and the need for more explicit guidance supporting governance design and pilot experimentation. These insights informed revisions to both the process structure of the framework and the content of the boundary tools.

3.6. Demonstration and evaluation through multi-actor workshops

The third stage of the research process involved testing and evaluating the evolving toolset through three multi-actor workshops designed as demonstration and evaluation environments. Each workshop followed a structured facilitation format. Participants were guided through the ecosystem development process and introduced to each tool sequentially. Participants worked in small groups and applied the tools to ecosystem design challenges during four consecutive rounds, each focusing on one specific tool. Workshops concluded with a collective discussion in which participants reflected on the usability and relevance of the tools. Following each session, participants completed a post-workshop survey assessing tool clarity, usability, conceptual contribution, and contextual adaptability. Survey questions are provided as Appendix B.

To expose the artefacts to diverse contexts, the workshops were conducted with different participant groups (Table 2).

The first workshop involved industry participants actively developing reusable packaging systems in a Nordic retail and foodservice context. The second workshop included heterogeneous ecosystem actors engaged in circular pilots, including startups, NGOs, and public organisations across multiple sectors. The third workshop was conducted in an academic setting and used a fictional circular ecosystem scenario to evaluate conceptual clarity and transferability of the tools across sector contexts. Evaluation criteria were adapted from Hevner et al. (2004) and focused on four dimensions: utility, usability, conceptual contribution, and contextual adaptability. Evidence was collected through survey responses, completed workshop artefacts, researcher field notes, and feedback discussions. Insights from these workshops informed iterative refinements to the framework and tools, including adjustments to terminology, visual structure, tool sequencing, and facilitation guidance.

The three workshops were deliberately differentiated along two dimensions: domain familiarity and actor heterogeneity. WS1 was selected for depth within the target domain, recruiting participants with direct operational experience in reusable packaging ecosystem development to test practical usability under high contextual relevance. WS2 was selected for cross-sector heterogeneity, spanning startups, corporations, NGOs, and public actors, to evaluate whether the tools remained useful across diverse actor profiles and circular economy contexts beyond packaging. WS3 was selected for theoretical independence, recruiting academic experts unfamiliar with the specific initiative to evaluate conceptual clarity and cross-sector transferability without prior exposure to the tools.

3.7. Artefact consolidation and maturation

Following the empirical evaluation cycles, the framework and tools were further refined through collaborative prototyping sessions involving the research team and circular economy experts. These sessions focused on clarifying conceptual constructs, improving visual layouts, and strengthening the integration between tools through successive design iterations, the artefact evolved into the Minimum Viable Circular Ecosystem (MVCE) framework, consisting of four interconnected boundary tools that support visioning, ecosystem framing, experimentation, and governance design. The tools can be applied either sequentially or modularly depending on the maturity and needs of the ecosystem initiative.

3.8. Rigour and trustworthiness

Several strategies were employed to strengthen methodological rigour. First, data triangulation was used across multiple sources, including literature synthesis, expert interviews, workshops, post-workshop surveys, and researcher field notes to validate insights across different forms of evidence. For example, interview-derived findings indicating that actors required explicit governance directions from early in the ecosystem development process (identified in nine of fifteen interviews) were cross-checked against WS1 and WS2 workshop observations, where participants independently raised governance questions during the framing rounds before any governance tool had been introduced. This convergence across independent data sources strengthened the design decision to position governance as a standalone phase rather than an emergent outcome of earlier phases. Second, the framework was iteratively tested across multiple actor groups and usage contexts, enhancing ecological validity and ensuring that the tools remained applicable in practice. Third, design decisions were consistently grounded in established theoretical literature on ecosystems, circular economy, and boundary objects. This theoretical anchoring ensured that the resulting artefact extends existing research rather than reflecting context-specific observations. Illustrative examples of completed workshop artefacts, including a partially filled Circular Ecosystem Vision Board from WS1 and an annotated Circular Ecosystem Pilot Canvas from WS3 are provided as Supplementary Material to demonstrate the quality and character of outputs generated through tool application. Together, these strategies support the credibility and transferability of the MVCE framework as a design artefact addressing circular ecosystem emergence.

Following DSR evaluation norms (Hevner et al., 2004; Gregor and Hevner, 2013), the present study establishes the MVCE framework's

Table 2
Workshop overview.

Workshop	Location	Participants	Ecosystem context	Sector coverage	Key actor types represented
WS1	Nordic City X	Industry professionals from packaging sector (n:14)	Emerging consumer reusable packaging initiative in Nordic retail and foodservice context	Food and beverage, retail, packaging manufacture, reverse logistics	Packaging solution developers, retailers, logistics and return operators, brand owners
WS2	Central European City	Mixed stakeholders (startups, companies, NGOs, public actors) (n:9)	Active multi-sector circular economy pilot initiatives	Cross-sector circular economy	Startup founders, corporate sustainability managers, NGO representatives, municipal policy actors
WS3	Nordic City Y	Academic experts in circular economy and ecosystems (n:16)	Fictional circular ecosystem scenario (designed to test conceptual transferability across sector contexts)	Cross-sector (fictional/ academic)	Circular economy researchers, ecosystem scholars, design science experts

Note: Post-workshop survey questions are provided as Appendix B.

validity at two of three levels. Design validation, confirming that the artefact is theoretically coherent and grounded in relevant kernel theories, was achieved through the iterative abductive process combining literature synthesis, expert interviews, and collaborative prototyping. Practical usability, confirming that the tools are comprehensible, applicable, and perceived as useful by diverse ecosystem actors, was established through three workshops involving 39 participants across industry, cross-sector, and academic contexts. Empirical effectiveness, demonstrating that applying the MVCE framework produces measurably better circular ecosystem emergence outcomes compared to unstructured approaches, constitutes a known limitation of the present study and represents the primary priority for longitudinal future research (Section 4.8).

4. Results: the minimum viable circular ecosystem framework

This section presents the central outcome of the design science research process: the Minimum Viable Circular Ecosystem (MVCE) framework. The framework provides a process-oriented approach supporting orchestrators in facilitating the emergence of circular ecosystems. Developed through iterative cycles combining ecosystem theory, circular economy research, and empirical engagement with ecosystem actors, the framework translates conceptual insights into an operational orchestration process.

The MVCE framework conceptualises circular ecosystem emergence as unfolding through four interrelated phases: visioning, ecosystem framing, experimentation and learning, and structuring and governance. Each phase addresses a distinct orchestration challenge and is operationalised through a dedicated boundary tool. The framework therefore integrates conceptual insights from ecosystem orchestration research (Adner, 2017; Jacobides et al., 2018; Thomas and Ritala, 2021), circular economy scholarship (Konietzko et al., 2020b; Aarikka-Stenroos et al., 2021), and boundary object theory (Carlile, 2002) into a structured process supporting collaborative ecosystem design.

A key insight underpinning the MVCE framework (Fig. 1) is that circular ecosystem emergence cannot be effectively supported through isolated analytical tools. Orchestrators must simultaneously coordinate multiple activities, including aligning actor ambitions, structuring value creation and capture, designing governance arrangements, and planning experimentation under conditions of uncertainty (Thomas and Ritala, 2021; Aryee et al., 2025). Addressing these challenges requires a process architecture that links localized coordination activities to a coherent ecosystem development trajectory.

Accordingly, the MVCE framework is operationalised through four interconnected boundary tools: the Circular Ecosystem Vision Board, the Circular Ecosystem Value Wheel, the Circular Ecosystem Pilot Canvas, and the Circular Ecosystem Governance Canvas. Individually, each tool supports a specific orchestration activity. Collectively, they form an integrated toolkit enabling orchestrators to translate circular ambitions into coordinated ecosystem configurations.

When applied sequentially, the tools scaffold ecosystem emergence across phases. The Vision Board supports shared sensemaking and alignment around ecosystem ambitions. The Value Wheel structures the ecosystem architecture by clarifying actor roles and value flows. The Pilot Canvas enables hypothesis-driven experimentation and learning through pilot projects. Finally, the Governance Canvas formalizes coordination mechanisms and decision rights as ecosystem interdependencies become clearer. Rather than functioning as standalone artefacts, the tools operate as boundary objects facilitating shared understanding among heterogeneous actors (Carlile, 2002). In doing so, the MVCE framework provides orchestrators with a process-oriented approach to managing the complexity of circular ecosystem emergence.

4.1. Phase 1: visioning

4.1.1. Phase objective

The visioning phase focuses on establishing a shared long-term ambition that aligns ecosystem actors around a common purpose. Because circular ecosystems involve heterogeneous stakeholders with different interests and capabilities, early alignment around shared objectives is essential for mobilizing participation and fostering collaboration (Aarikka-Stenroos et al., 2021; Aryee et al., 2025). This phase therefore focuses on articulating a collective vision integrating environmental, social, and economic objectives. Participants explore circular opportunities, analyze trends and benchmarks, and define system boundaries such as geographical scope, industry domain, and time

Phase 1: VISIONING	Phase 2: FRAMING	Phase 3: EXPERIMENTING	Phase 4: STRUCTURING
OBJECTIVES Establish a shared overarching goal, purpose, and approach for the circular ecosystem that aligns diverse stakeholders around a common long-term ambition and impact vision.	**OBJECTIVES** Map the ecosystem's current and potential configuration, clarifying stakeholder roles, value flows, core activities, and exchanged resources to establish a systemic understanding of how the ecosystem will function.	**OBJECTIVES** Design, implement, and evaluate pilot projects or experiments to validate specific hypotheses related to the desirability, feasibility, viability, and sustainability of the circular ecosystem's solutions.	**OBJECTIVES** Design the governance, decision-making, and operational mechanisms that will enable the ecosystem to function transparently, fairly, and effectively for all participants.
KEY ACTIVITIES • Define the ecosystem purpose statement and shared circular economy ambitions. • Identify high-level system boundaries (geography, sector scope, timeline). • Align on target environmental, social, and economic outcomes. • Draft an initial vision narrative/storyboard to make the desired future state tangible.	**KEY ACTIVITIES** • Map current and potential stakeholders and classify their roles • Identify value propositions for each stakeholder group and for the system as a whole. • Analyse value flows (products, materials, information, revenue, impacts). • Document key resources exchanged (materials, data, skills, infrastructure) and associated circular loops. • Identify key drivers, constraints, and interdependencies in the system.	**KEY ACTIVITIES** • Select priority areas or concepts for piloting based on ecosystem goals and stakeholder readiness. • Design pilot scope, success metrics, and data collection. • Test technical solutions, operational processes, and partnership configurations. • Gather qualitative and quantitative feedback from participating stakeholders and users. • Document learnings, refine solution concepts.	**KEY ACTIVITIES** • Define ecosystem governance model . • Assign accountability for decision-making, resource allocation, and performance monitoring. • Develop protocols for data sharing, IP management, and conflict resolution. • Establish agreements on roles, responsibilities, and contributions. • Design operational processes for communications, coordination, and stakeholder engagement.
TOOL: The circular ecosystem vision board	**TOOL: The circular ecosystem value wheel**	**TOOL: The circular ecosystem pilot canvas**	**TOOL: The circular ecosystem governance canvas**

Fig. 1. Minimum Viable Circular Ecosystem: A framework (Authors' own work).

horizon (Konietzko et al., 2024; Tate et al., 2019). Establishing these elements creates a shared narrative that guides subsequent ecosystem development and supports coordinated decision-making.

4.1.2. Circular Ecosystem Vision Board

The Circular Ecosystem Vision Board (Fig. 2) is a strategic foresight tool designed to support collective articulation of a shared vision for the circular ecosystem. The tool structures collaborative discussions around six interconnected elements: ecosystem purpose, ambitions and outcomes, shared culture, values and principles, ecosystem value proposition, synergies from collaboration, and individual stakeholder expectations.

The six-element structure of the Vision Board operationalises boundary object theory (Carlile, 2002) by organising collaborative sensemaking around distinct but interrelated dimensions: the ecosystem purpose and value proposition elements externalise shared ambitions, the shared values element surfaces normative assumptions that actors typically leave implicit, and the stakeholder expectations element makes divergent individual interests visible to the group, creating the conditions for negotiated alignment rather than assumed consensus.

The Vision Board supports collaborative sensemaking by enabling participants to externalise assumptions regarding ecosystem goals and potential value creation opportunities. Visual tools have been shown to facilitate systemic thinking and stakeholder alignment in multi-actor innovation processes (Velter et al., 2022; Bertassini et al., 2021). In circular ecosystems, where actors often operate across organisational and sectoral boundaries, such boundary artefacts help bridge cognitive and institutional differences. The expected outcomes of the Vision Board include a shared ecosystem purpose statement, preliminary ecosystem value propositions, and a clearer articulation of desired circular outcomes. By visualizing future ecosystem configurations, the tool supports alignment among ecosystem participants and fosters a collective identity guiding further collaboration (Pavlopoulou, 2021; Asgari and Asgari, 2023).

Workshop application: Participants used the Vision Board to formulate shared ecosystem purpose statements and surface the tension between ambitious adoption targets and the need for infrastructure flexibility. In the academic workshop, this produced the articulation that the reusable packaging vision should remain open to iteration rather than locked into a rigid pre-design, an output that directly shaped the scope and hypotheses of subsequent phases. Participants in WS1 agreed that the tool would have been most valuable at the earliest stage of their ecosystem initiative and noted its potential as a recurring alignment instrument as ecosystem conditions evolve.

4.2. Phase 2: framing the ecosystem

4.2.1. Phase objective

Following the articulation of a shared vision, the ecosystem framing phase focuses on mapping and analyzing the emerging ecosystem architecture. This involves identifying participating actors, clarifying their roles, and examining how value is created, exchanged, and captured across the ecosystem. Circular ecosystems require coordinated resource flows, including materials, information, financial flows, and environmental impacts, across multiple lifecycle stages (Konietzko et al., 2024). Mapping these interdependencies is therefore essential for identifying complementarities between actors as well as potential coordination challenges (Fehrer and Wieland, 2021).

4.2.2. Circular Ecosystem Value Wheel

The Circular Ecosystem Value Wheel (Fig. 3) is a mapping tool designed to visualize ecosystem architecture and value dynamics. The tool adapts ecosystem mapping principles developed in the Ecosystem Pie Model (Talmar et al., 2020) to circular economy contexts.

The Value Wheel organizes ecosystem activities around lifecycle stages such as raw material sourcing, production, distribution, use, return, and reprocessing. For each participating actor, the tool captures key resources, activities, value creation mechanisms, and value capture

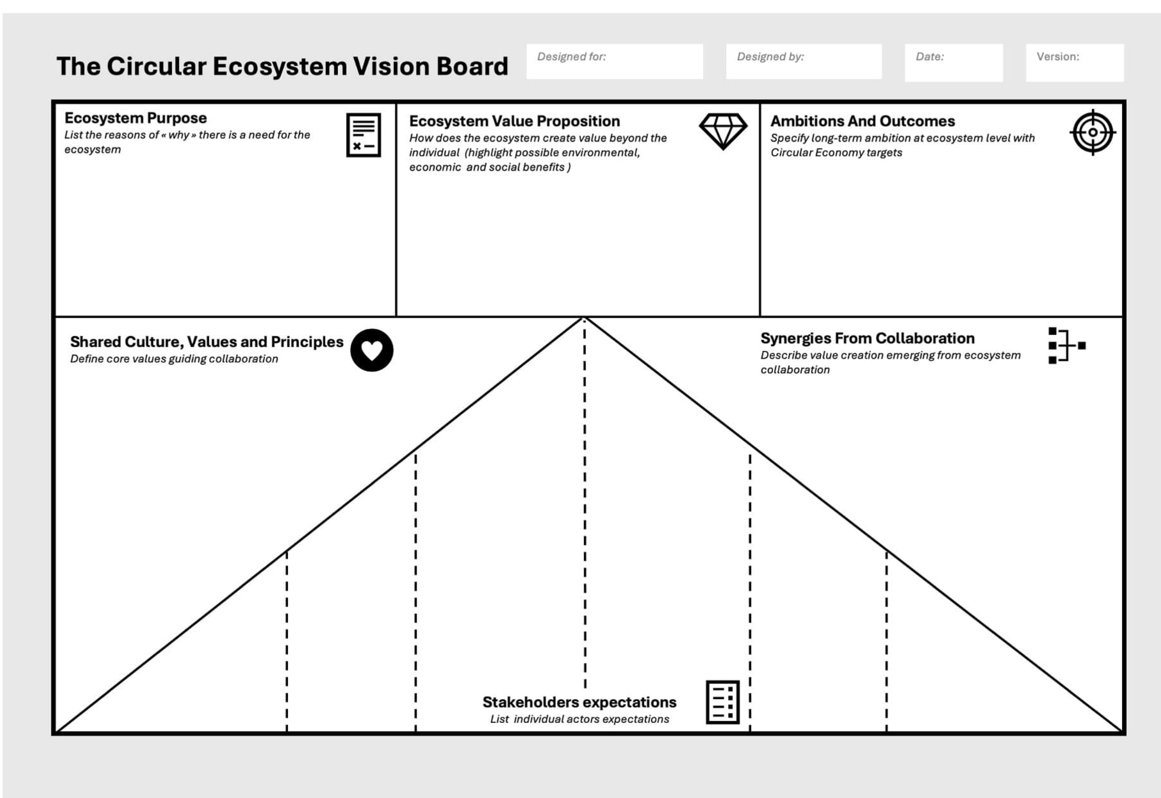

Fig. 2. Circular ecosystem Vision board (Authors' own work).

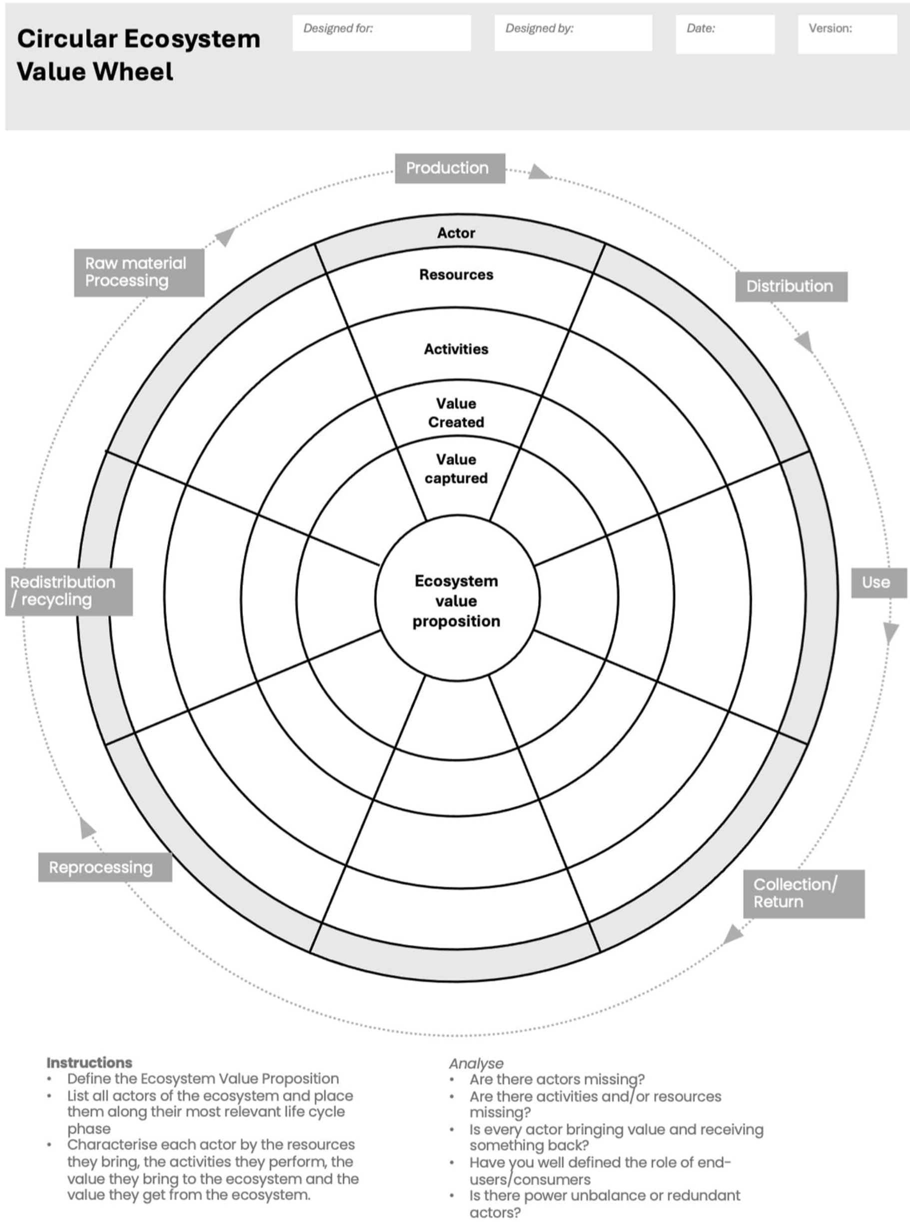

Fig. 3. The Circular ecosystem value wheel (adapted from Talmar et al., 2020).

expectations. The concentric ring structure of the Value Wheel is designed to make two analytically distinct contributions visible simultaneously: the outer rings capture what actors bring to the ecosystem (resources, activities) while the inner rings capture what they receive from it (value created, value captured). This distinction, grounded in value co-creation theory (Vargo and Lusch, 2016), surfaces asymmetries in the distribution of contributions and benefits that are often a source of coordination failure in early-stage circular ecosystems. Visualizing these elements helps ecosystem actors identify complementarities, dependencies, and potential bottlenecks within the emerging ecosystem configuration (Adams et al., 2017; Bocken et al., 2021). The tool also facilitates discussions regarding alternative ecosystem configurations and possible coordination strategies. Outputs of the Value Wheel typically include a system-level map of the ecosystem, identification of critical actor roles, and improved understanding of value flows across the circular lifecycle.

Workshop application: Participants in WS1 found that the Value Wheel clarified the role of operators, identified as the most complex and least well-defined actor in their reusable packaging initiative, surfacing a coordination gap that would have remained invisible without structured mapping. In the academic workshop, participants mapped the core reuse cycle (use → return → wash → redistribute) and identified the absence of external institutional actors (policy bodies, market standards organisations, and public expectations) as a structural gap in their ecosystem configuration, recommending these be added as an explicit layer to ensure the wheel captures the full institutional environment shaping value flows.

4.3. Phase 3: experimentation and learning

4.3.1. Phase objective

Circular ecosystems often emerge under conditions of uncertainty regarding technological feasibility, economic viability, and user acceptance. Experimentation therefore plays a critical role in validating ecosystem configurations before large-scale implementation (Geissdoerfer et al., 2020; Bocken et al., 2021). Pilot initiatives provide opportunities to test technical solutions, partnership configurations, and operational processes in real-world contexts. In sustainability transition research, such experiments function as protected spaces where actors can explore alternative socio-technical configurations and learn from implementation experiences (Schot and Geels, 2013; Loorbach et al., 2020). Recent work on social-ecological resilience further highlights the value of continuous data feedback loops in adapting ecosystem configurations to complex social and environmental behaviours (Wu et al., 2026), consistent with the hypothesis-driven experimental logic of Phase 3, where pilot-generated evidence is used to refine value propositions, actor roles, and operational parameters before full-scale ecosystem commitment.

4.3.2. Circular Ecosystem Pilot Canvas

The Circular Ecosystem Pilot Canvas (Fig. 4) supports the design and evaluation of ecosystem pilot initiatives. The tool structures pilot development around several components including problem definition, stakeholder roles, proposed solution, pilot scope, validation metrics, and expected learning outcomes.

The four validation quadrants of the Pilot Canvas (desirability, feasibility, viability, and sustainability) operationalise a multi-dimensional hypothesis structure consistent with research on experimentation in sustainability transitions (Bocken et al., 2022; Kemp et al., 1998). By requiring actors to formulate a testable assumption for each dimension rather than a single overall pilot objective, the canvas prevents the conflation of technical success with ecosystem viability and forces explicit attention to user adoption, economic sustainability, and environmental impact as independent validation criteria.

Importantly, the canvas frames pilot initiatives as learning experiments rather than demonstrations of predetermined solutions. Each element of the pilot is formulated as a hypothesis to be tested through implementation. This approach aligns with research on experimentation in sustainability transitions emphasising iterative learning and adaptive innovation processes (Kemp et al., 1998; Sengers et al., 2016). Through structured experimentation, the Pilot Canvas enables ecosystem actors to evaluate technological feasibility, actor coordination mechanisms, and user adoption conditions while generating insights for ecosystem scaling decisions.

Workshop application: Participants in WS1 identified metrics and KPIs they had not previously considered in depth, noting that the canvas directed attention to measurement in a way their existing pilot planning had not. In the academic workshop, participants defined specific performance indicators, such as return rates, convenience scores, hygiene outcomes, and cost per use, and raised the standardisation of container formats as a prerequisite for pilot scalability, demonstrating how the canvas generates not only measurement criteria but also design requirements for the ecosystem configuration itself.

4.4. Phase 4: structuring and governing

4.4.1. Phase objective

As ecosystem configurations mature through experimentation, attention shifts toward establishing governance arrangements that support long-term coordination and collaboration. Circular ecosystems require governance mechanisms defining participation rules, decision-making processes, and resource allocation across actors (Jacobides et al., 2018; Aryee et al., 2025). Effective governance must balance coordination and flexibility, enabling ecosystems to adapt to evolving market conditions, technological developments, and regulatory changes (Chaffin et al., 2014; Pahl-Wostl, 2019).

4.4.2. Circular Ecosystem Governance Canvas

The Circular Ecosystem Governance Canvas (Fig. 5) supports the collective design of governance arrangements for circular ecosystems. The tool structures governance discussions across four domains: ecosystem orientation, entry and participation rules, orchestration mechanisms, and ecosystem evolution.

The four-domain architecture of the Governance Canvas (ecosystem orientation, entry and participation, orchestration mechanisms, and ecosystem evolution) reflects an adaptive governance logic (Chaffin

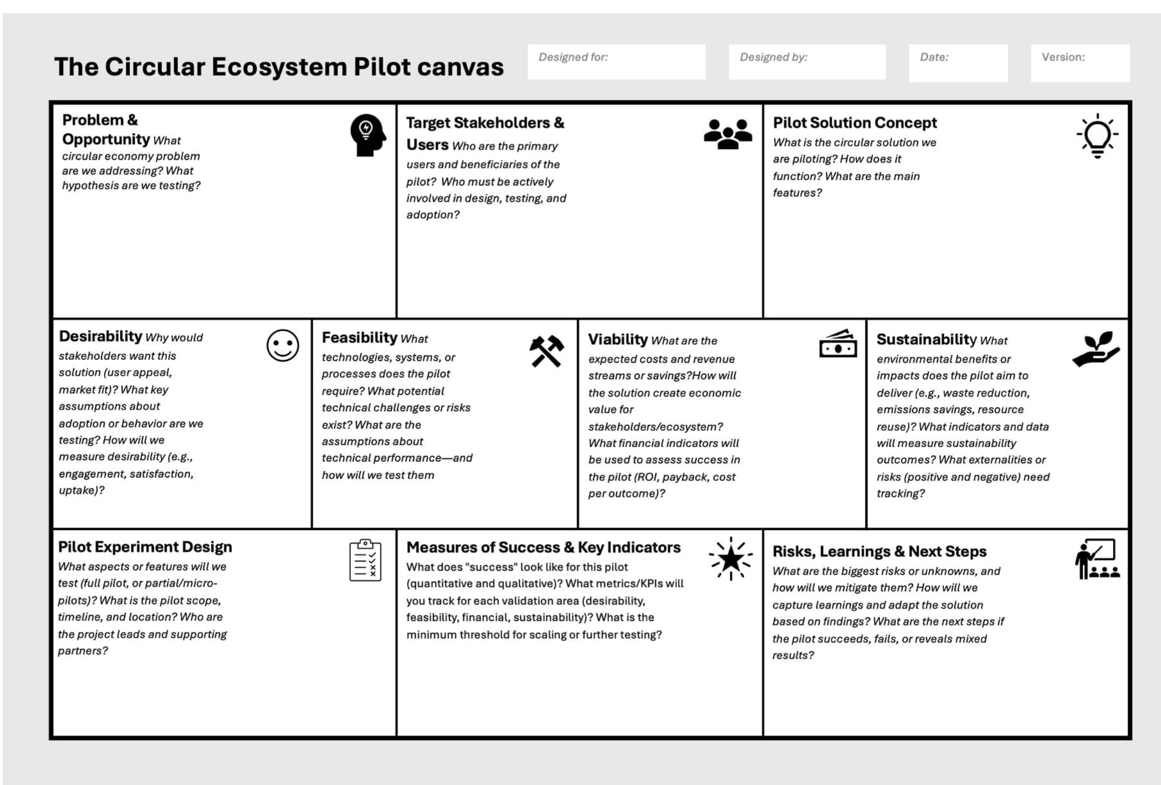

Fig. 4. The Circular Ecosystem Pilot Canvas (Authors' own work).

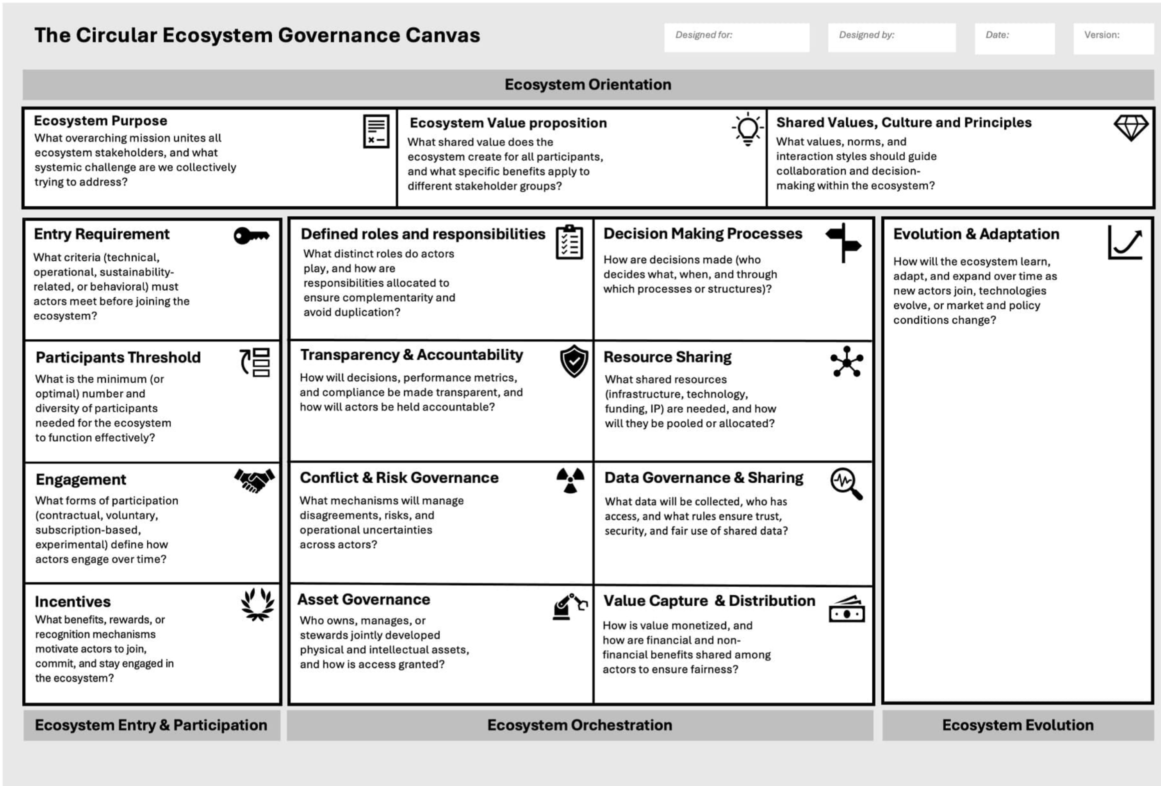

Fig. 5. The Circular Ecosystem Governance Canvas (Authors' own work).

et al., 2014; Pahl-Wostl, 2019) by distinguishing between what is stable (shared values, entry criteria) and what must remain flexible (decision processes, resource allocation, evolution pathways). This distinction is particularly important in circular ecosystems, where governance arrangements must accommodate changing actor compositions, regulatory environments, and technology developments over time.

The ecosystem orientation domain focuses on aligning shared purpose and collaboration principles. Entry and participation rules define criteria for ecosystem membership and engagement. The orchestration domain structures decision-making processes, data sharing arrangements, conflict resolution mechanisms, and value distribution. Finally, the ecosystem evolution domain addresses how governance arrangements are reviewed and adapted over time. By making governance assumptions explicit, the Governance Canvas supports negotiation among ecosystem actors and helps prevent coordination failures that may arise from unclear roles or expectations (Ansell and Gash, 2008; Emerson and Nabatchi, 2015).

Workshop application: Participants in WS1 described the Governance Canvas as a concrete and systematic tool that generated inclusive discussion, noting that 'there is something for everyone.' While participants recommended applying the canvas after initial pilot work rather than at the earliest ecosystem stages, the discussions it triggered on decision rights, data-sharing protocols, and conflict resolution mechanisms, demonstrated its value in surfacing governance assumptions that would otherwise remain implicit and unexamined until they became sources of conflict.

4.5. *Using the MVCE framework as an integrated process*

The four phases and associated tools together constitute the Minimum Viable Circular Ecosystem framework as an integrated process supporting circular ecosystem emergence. Rather than prescribing a rigid development sequence, the framework provides orchestrators with a flexible process architecture combining task-specific guidance with a system-level perspective on ecosystem development. Tools may be applied sequentially during early ecosystem formation or modularly to address specific coordination challenges in more mature ecosystems. Importantly, the framework positions orchestrators as facilitators of collective coordination and learning rather than centralized decision-makers. The boundary tools externalise assumptions, support shared sensemaking, and enable distributed collaboration among ecosystem actors (Carlile, 2002; Thomas and Ritala, 2021). By linking visioning, ecosystem configuration, experimentation, and governance within a coherent process architecture, the MVCE framework offers a structured approach supporting the emergence and evolution of circular ecosystems.

While several frameworks have been proposed to support ecosystem design and circular innovation, the MVCE framework differs in three important respects. First, whereas many ecosystem tools focus primarily on ecosystem mapping or strategic diagnostics (e.g., Talmar et al., 2020; Humbeck et al., 2020), the MVCE framework explicitly structures ecosystem emergence as a process linking visioning, ecosystem configuration, experimentation, and governance design. Second, while conceptual ecosystem orchestration frameworks highlight the importance of coordination mechanisms (Autio and Thomas, 2022; Jacobides et al., 2018), they typically provide limited operational guidance for practitioners. The MVCE framework addresses this limitation by operationalizing orchestration through a set of interconnected boundary tools that support collective sensemaking and decision-making among heterogeneous actors. Third, compared with recent circular ecosystem frameworks (Konietzko et al., 2024; Bertassini et al., 2021; De Silva et al., 2023), the MVCE framework integrates experimentation and governance design within the ecosystem development process, thereby linking early-stage ecosystem design with iterative learning and institutionalization. In doing so, the framework provides a process-oriented approach supporting orchestrators in managing the complexity and uncertainty inherent in circular ecosystem emergence.

The process logic underpinning the MVCE framework rests on a specific causal mechanism: each phase reduces a distinct form of uncertainty that would otherwise impede progress in subsequent phases: a staged approach to managing complex systemic uncertainty that finds a structural parallel in ecological management frameworks addressing uncertainty across spatial and temporal scales (Li et al., 2026). Phase 1 (Visioning) addresses interpretive uncertainty. By externalising and negotiating assumptions about ecosystem purpose and value creation before any structural commitments are made, it lowers the cost of subsequent coordination and reduces the risk of misaligned investments (observed in WS1, where Vision Board use prevented premature infrastructure scope decisions that participants later identified as a recurring source of wasted investment in their prior initiative). Phase 2 (Framing) addresses configurational uncertainty. By mapping actor roles, value flows, and system interdependencies, it surfaces coordination gaps and structural absences before they crystallise into conflicts or operational failures (evidenced in WS1 and WS2, where the Value Wheel consistently surfaced missing actor roles that participants had not identified through prior planning). Phase 3 (Experimenting) addresses assumption uncertainty. By testing desirability, feasibility, viability, and sustainability in a bounded pilot, it generates evidence that reduces the investment risk of full-scale ecosystem commitment and allows actor roles and value propositions to be refined under real conditions (observed in WS1, where the Pilot Canvas directed attention to KPIs and measurement approaches that participants had not previously considered). Phase 4 (Structuring) addresses institutional uncertainty. By designing governance arrangements after pilot evidence is available, it produces structures grounded in validated interdependencies rather than speculative projections (consistent with WS1 feedback that governance discussions were more productive and actionable after pilot learning than when attempted without prior experimentation). The sequential enactment of these four uncertainty-reduction functions is what distinguishes the MVCE as a process framework from prior diagnostic or mapping tools, which address only one or two of these functions in isolation.

4.6. Theoretical implications

This study was motivated by two interrelated gaps identified in the introduction: the absence of a process-level theoretical account of how circular ecosystems emerge through co-creation, and the lack of an integrated orchestration framework supporting practitioners across the full lifecycle of circular ecosystem emergence. In addressing both gaps through a design science research approach, the study advances four interrelated theoretical contributions. The central theoretical insight is that circular ecosystem emergence can be understood as a staged reduction of interpretive, configurational, assumption-related, and institutional uncertainty through artefact-mediated co-creation. This insight contributes to research on circular ecosystems, ecosystem orchestration, value co-creation, and design-oriented theorising. Specifically, the process theory contribution extends circular ecosystem research beyond descriptive typologies by theorising the mechanisms through which emergence unfolds; the orchestration contribution operationalises, rather than merely conceptualises, distributed facilitation through four boundary tools; the co-creation contribution advances the level of analysis from dyadic interaction to multi-phase ecosystem emergence; and the design theory contribution makes explicit the kernel theories, design principles, and problem class that prior operational frameworks leave tacit.

First, the study advances circular ecosystem research by theorising emergence as a structured yet iterative co-creation process rather than a structural configuration or a pattern observed ex post. While recent studies have begun to examine emergence dynamics in specific sector contexts (DiVito et al., 2025; Harala et al., 2023), the field has largely produced accounts that identify characteristics or enabling conditions after ecosystem formation (Aarikka-Stenroos et al., 2021; De Angelis, 2021). The MVCE framework contributes a forward-looking process account, specifying the four orchestration activities through which circular ecosystems are deliberately constructed and the uncertainty-reduction mechanisms through which their sequencing is expected to support progressive alignment and ecosystem development, as elaborated in Section 4.5. It is important to note that this process account was generated through theoretical inference and the abductive synthesis of practitioner experience, not through longitudinal empirical observation. The framework theorises emergence as a temporal process; empirical validation of its temporal dynamics is explicitly acknowledged as a limitation of the present study and a priority for future research (Section 4.8). In advancing this process perspective, the study responds to calls for more dynamic and process-oriented theorising of circular ecosystems and sustainability transitions (Geissdoerfer et al., 2020; Autio and Thomas, 2020a; Aryee et al., 2025).

Second, the study contributes to ecosystem orchestration theory by demonstrating how distributed, facilitative orchestration – a concept recognised in prior literature (Thomas and Ritala, 2021; DiVito et al., 2025) but largely addressed at a conceptual level (Dedehayir et al., 2018; Jacobides et al., 2018) - can be operationalised in practice through a coordinated toolkit of boundary objects. Prior research has established that orchestration in non-hierarchical ecosystems involves facilitating alignment and enabling collective action rather than exercising centralised control (Thomas and Ritala, 2021). The MVCE framework's specific contribution is to demonstrate how this facilitative logic is enacted in practice: each of the four boundary tools externalises a different class of assumptions, supports a different form of collective sensemaking, and enables coordinated decision-making without requiring formal authority. In doing so, the framework shows not only that orchestration can be distributed, which prior work has established, but precisely through what artefact-mediated mechanisms distributed orchestration functions in circular ecosystem contexts where power, resources, and legitimacy are dispersed across heterogeneous actor networks. It should be noted, however, that this distributed orchestration logic assumes a context in which no single actor holds sufficient authority to impose governance unilaterally, and in which the orchestrator's convening role is accepted by other actors as legitimate. In ecosystem contexts characterised by significant power asymmetry, where a dominant focal firm, platform controller, or regulatory body holds disproportionate influence, the distributed logic may require adaptation toward hybrid orchestration models that combine facilitative co-creation with structured authority, as explored further in the limitations section (Section 4.8).

Third, the study contributes to value co-creation–informed ecosystem research by providing a process architecture that extends co-creation theory from the interaction level to the ecosystem emergence level. Prior research has grounded value co-creation in resource integration across actors (Vargo and Lusch, 2016; Aarikka-Stenroos and Ritala, 2017), and more recent work has examined co-creation in the context of interorganisational sensemaking and actor engagement in circular transitions (Kuhlmann et al., 2023; Verleye et al., 2023). However, these contributions largely address co-creation within already-constituted ecosystem relationships. The MVCE framework advances understanding of how co-creation constitutes the process through which ecosystem configurations themselves emerge: Phase 1 co-creates shared ambitions, Phase 2 co-creates the ecosystem architecture, Phase 3 co-creates validated value propositions and actor roles through real-world experimentation, and Phase 4 co-creates governance arrangements grounded in empirical learning. Each phase represents a distinct mode of co-creation operating at a progressively higher level of institutional commitment, from exploratory sensemaking to formalised governance, connecting the concept of co-creation to the full trajectory of ecosystem emergence in a way prior work has not systematically theorised. Recent work has begun to develop structural accounts of value co-creation mechanisms in digital transformation contexts, including hypernetwork perspectives examining how multiple actors jointly create value through complex interdependencies (Gao et al., 2026); the MVCE framework advances an equivalent process logic for physical circular ecosystem contexts, where material flow constraints and multi-institutional coordination requirements shape co-creation differently from digital platform settings.

Finally, the study makes an explicit design theory contribution in the sense defined by Gregor and Hevner (2013): the MVCE framework constitutes a nascent design theory for circular ecosystem emergence, specifying the kernel theories on which it draws (ecosystem theory, boundary object theory, adaptive governance theory, and experimentation theory in sustainability transitions), the design principles it embodies (integrate visioning, framing, experimenting, and governing within a single process architecture; operationalise orchestration through a toolkit of complementary boundary tools; position orchestrators as facilitators of collective sensemaking rather than centralised controllers; sequence phases to reduce distinct forms of uncertainty), and the class of design problems it addresses (the deliberate co-creation and emergence of multi-actor circular ecosystems under conditions of high uncertainty). While several recent frameworks have provided operational guidance for circular ecosystem development (Konietzko et al., 2024; De Vasconcelos Gomes et al., 2022), they do not constitute design theories in this sense;they provide procedural steps without making the underlying design principles and kernel theories explicit and transferable. In articulating these elements, the MVCE framework advances design theory for ecosystem emergence and provides the theoretical grounding through which the framework's principles can be adapted and extended to new contexts.

4.7. Practical implications

The findings of this study also provide several implications for managers, ecosystem orchestrators, and public actors engaged in circular economy initiatives. First, circular ecosystem development should be approached as a staged and iterative process rather than a one-time design exercise. The MVCE framework provides practitioners with a structured way to sequence ecosystem development activities, enabling them to distinguish phases where vision alignment, ecosystem structuring, experimentation, or governance design are most critical. This staged approach helps avoid premature investments or rigid governance structures before key assumptions regarding value creation, actor roles, and system feasibility have been validated.

Second, practitioners can benefit from boundary tools that facilitate collective sensemaking and coordination among heterogeneous stakeholders. Circular ecosystems typically involve actors from different industries and institutional contexts with diverse capabilities and incentives. The tools developed in this study provide shared reference points that help make assumptions, interdependencies, and expectations explicit, thereby reducing coordination failures and supporting collaborative decision-making.

Third, the results highlight the importance of experimentation and adaptive governance in circular ecosystems. Pilot initiatives should be understood as learning mechanisms that test not only technological feasibility but also actor coordination, user behaviour, and economic viability. Governance arrangements should therefore be designed as adaptive structures capable of evolving as new knowledge emerges and ecosystem conditions change. The MVCE framework supports this adaptive logic by linking experimentation and governance design within a coherent ecosystem development process. When actor incentives are structurally misaligned, for instance, where the capital costs of reuse infrastructure fall on one actor while operational savings and brand benefits accrue to others, the Pilot Canvas's viability quadrant should explicitly model proposed value redistribution scenarios as testable hypotheses, and the Governance Canvas should be used to negotiate redistribution mechanisms before ecosystem scaling. The framework does not resolve incentive conflicts automatically; rather, it provides the structured space in which such conflicts can be surfaced, modelled, and negotiated among actors before they harden into barriers to ecosystem participation.

Practitioners seeking to implement the MVCE framework should begin by convening core ecosystem actors and using the Circular Ecosystem Vision Board to establish a shared purpose statement and preliminary value proposition before any structural commitments are made. Once a shared ambition is established, the Circular Ecosystem Value Wheel should be used to map the emerging ecosystem architecture, identifying actor roles, value flows, coordination dependencies, and gaps that would prevent the ecosystem from functioning. A bounded pilot initiative should then be designed and evaluated using the Circular Ecosystem Pilot Canvas, treating each element as a testable hypothesis rather than a predetermined solution. Finally, the Circular Ecosystem Governance Canvas should be used to formalise coordination mechanisms, participation rules, and value distribution arrangements, informed by pilot evidence, so that governance structures are grounded in validated interdependencies rather than speculative projections.

4.8. Limitations and directions for future research

Despite its contributions, this study has several limitations that open opportunities for further research. First, like any artefact developed through design science research, the MVCE framework simplifies complex real-world dynamics in order to provide actionable guidance. Although developed through multiple empirical engagements, including literature synthesis, interviews, workshops, and collaborative design sessions, it remains grounded in the context of circular ecosystems and particularly consumer-facing reusable packaging systems. Future research could examine the applicability of the framework in other circular contexts, such as construction, textiles, or industrial symbiosis, to better understand which elements are transferable and which require contextual adaptation.

Second, the evaluation conducted in this study primarily focused on the perceived usefulness and usability of the framework during early stages of ecosystem development. While appropriate for artefact evaluation within design science research (Hevner et al., 2004), this approach does not capture long-term ecosystem outcomes such as ecosystem stability, scalability, or sustainability performance. Furthermore, the process theory advanced by the MVCE framework was developed through theoretical inference and abductive synthesis rather than through longitudinal empirical tracking of ecosystem emergence. Longitudinal research examining ecosystem trajectories following framework implementation could therefore both validate the temporal dynamics the framework theorises and contribute to the further development of design theory in circular ecosystem research (Gregor and Hevner, 2013).

Third, ecosystem development processes are embedded in complex social and political dynamics that extend beyond structured analytical tools (Jarzabkowski and Kaplan, 2015). Although the MVCE framework facilitates coordination and collective sensemaking, it cannot fully account for power asymmetries, strategic conflicts, or institutional constraints that may shape ecosystem trajectories. Future research could explore how process-oriented ecosystem tools interact with strategic agency, power relations, and institutional dynamics, as well as how facilitation practices influence their effectiveness in different contexts.

Fourth, the MVCE framework's applicability is bounded by specific contextual conditions. The framework is designed for emerging ecosystems in which governance structures do not yet exist and orchestration responsibilities are distributed. It is less applicable in mature ecosystems with established governance, where incremental adaptation rather than foundational co-creation is required, and in digital platform ecosystems, where orchestration dynamics and value co-creation mechanisms differ substantially from the physical material flow contexts the MVCE was designed for. In terms of sector transferability, the framework is expected to apply most readily to emerging circular ecosystems in textiles, construction, urban food systems, and furniture, sectors where reuse, product-as-a-service, or material recovery models are gaining traction and no dominant orchestrator has yet established governance unilaterally. The framework is least applicable in single-firm closed-loop systems, highly commodified value chains, and contexts dominated by a focal firm with sufficient market power to impose governance terms on other actors. The mechanism in the latter case is straightforward: dominant focal firms face lower transaction costs under centralised governance than under the distributed co-creation logic the MVCE requires. From a rational choice perspective, engaging in multi-actor visioning, structured experimentation, and collective governance design offers limited advantage when a single actor already holds the authority and resources to shape the ecosystem unilaterally. The MVCE framework's value proposition is therefore highest in contexts where power is genuinely distributed and no single actor can substitute co-creation with directive orchestration.

Fifth, applying the tools across three workshop contexts revealed specific facilitation challenges that future practitioners and researchers should anticipate. In WS1, participants found the Governance Canvas difficult to complete within the available session time, noting that the breadth of governance topics exceeded what could be meaningfully addressed before pilot work had been conducted, reinforcing the timing recommendation discussed in Section 4.4.2 and suggesting that facilitated pre-negotiation of priority governance domains may be necessary before group canvas sessions. In the academic workshop, the absence of direct business or regulatory constraints meant participants engaged with visioning and framing in more abstract terms than industry practitioners typically would, pointing to the importance of calibrating tool facilitation and prompt specificity to the institutional context and expertise profile of participants. More broadly, future research should prioritise: (1) longitudinal studies tracking ecosystem trajectories over time to validate the temporal dynamics the MVCE framework theorises; (2) quantitative evaluation approaches measuring ecosystem performance outcomes before and after framework implementation to complement the qualitative DSR methodology; (3) sector extension studies in textiles, construction, and urban food systems to establish transferability; and (4) emerging digital infrastructure, including AI-assisted actor matching, digital product passports, and platform-based orchestration tools, as a natural extension of the boundary tool logic into automated and data-rich ecosystem contexts. The macro-level spatio-temporal dynamics of green transitions, including regional policy variation and geographical concentration of circular industries (Wang et al., 2025), also represent an important contextual layer for future research connecting ecosystem-level process theory to broader sustainability transition dynamics.

As circular economy ambitions scale to the ecosystem level, driven by evolving extended producer responsibility regulation, digital product passport infrastructure, and growing interorganisational interdependence across value chains, the need for frameworks that support deliberate and collaborative ecosystem construction will only intensify. The MVCE framework provides a starting point for this work while pointing toward a broader research agenda: longitudinal validation of the process dynamics it theorises, adaptation and testing across circular economy sectors beyond reusable packaging, and deeper integration of institutional complexity and power dynamics into ecosystem orchestration theory and practice.

CRediT authorship contribution statement

Erwan Mouazan: Writing – original draft, Visualization, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Petra Berg:** Writing – review & editing, Project administration, Formal analysis, Data curation. **Hannu Makkonen:** Writing – review & editing, Validation, Supervision, Funding acquisition. **Kim Ribacka:** Writing – review & editing, Investigation, Formal analysis.

Declaration of competing interests

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.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2026.149329.

Data availability

The data that has been used is confidential.

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