

Trilha 4 - Tendências Emergentes

CONHECIMENTO COMO CATALISADOR DA CIRCULARIDADE: AVANÇOS TEÓRICOS NA INTERFACE ENTRE GESTÃO DO CONHECIMENTO E ECONOMIA CIRCULAR

KNOWLEDGE AS A CATALYST FOR CIRCULARITY: ADVANCING THEORY AT THE INTERFACE BETWEEN KNOWLEDGE MANAGEMENT AND CIRCULAR ECONOMY

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RESUMO

Este estudo promove avanços teóricos na interface entre a Gestão do Conhecimento (GC) e a Economia Circular (EC) por meio do desenvolvimento de um framework teórico-analítico integrativo fundamentado em uma revisão sistemática da literatura composta por 115 artigos revisados por pares. A revisão analisa e sintetiza, de forma sistemática, a evolução da interface entre GC e EC, identificando lacunas relacionadas à clareza conceitual, à validação empírica e à integração dos fluxos de conhecimento às práticas circulares. O estudo sintetiza 63 práticas de GC em seis macrocategorias e as integra em cinco dimensões complementares — estratégica, organizacional, operacional, tecnológica e sociocultural. Com base nessa síntese, desenvolve-se um framework teórico-analítico integrativo, do qual são derivadas proposições teóricas que explicam como os mecanismos de GC viabilizam práticas circulares, incluindo ecodesign, logística reversa, remanufatura e retenção de valor. Ao conceituar a GC simultaneamente como um habilitador e uma infraestrutura organizacional para a circularidade, o framework explica como processos estruturados de conhecimento sustentam a implementação e a ampliação de iniciativas de EC. O framework proposto integra conhecimentos anteriormente fragmentados entre diferentes disciplinas, oferecendo suporte teórico para pesquisas futuras e orientações práticas para organizações que buscam acelerar suas transições para modelos circulares. Em síntese, o estudo contribui para o avanço da teoria da Gestão do Conhecimento ao explicar como os processos de conhecimento sustentam a criação de valor circular, ao mesmo tempo em que fornece um roteiro estruturado para a implementação e a escalabilidade de iniciativas de Economia Circular em diferentes contextos organizacionais.

PALAVRAS-CHAVE: Economia Circular; Gestão do Conhecimento; Inovação Sustentável; Economia Circular Baseada no Conhecimento.

ABSTRACT

This study advances theory at the interface between Knowledge Management (KM) and Circular Economy (CE) by developing an integrative theoretical–analytical framework grounded in a systematic literature review of 115 peer-reviewed articles. The review systematically analyzes and synthesizes the evolution of the KM–CE interface, identifying gaps related to conceptual clarity, empirical validation, and the integration of knowledge flows into circular practices. The study synthesizes 63 KM practices into six macro-categories and integrates them across five complementary strategic, organizational, operational, technological, and sociocultural dimensions. Building on this synthesis, an integrative theoretical–analytical framework is developed from which theoretical propositions are derived to explain how KM mechanisms enable circular practices, including eco-design, reverse logistics, remanufacturing, and value retention. By conceptualizing KM as both an enabler and an organizational infrastructure for circularity, the framework explains how structured knowledge processes support the implementation and scaling of CE initiatives. The proposed framework integrates fragmented insights across disciplines, offering theoretical guidance for future research and practical support for organizations seeking to accelerate circular transitions. Overall, the study advances KM theory by explaining how knowledge processes underpin circular value creation while providing a structured roadmap for implementing and scaling CE initiatives across organizational contexts.

KEYWORDS: *Circular Economy; Knowledge Management; Sustainable Innovation; Knowledge-Based Circular Economy.*

1. INTRODUCTION

The growing demand for socio-environmental accountability has accelerated the transition from traditional linear production systems toward Circular Economy (CE) models, which seek to preserve the value of products, materials, and resources through strategies such as reduction, reuse, remanufacturing, and recycling (ECCLES; KLIMENKO, 2019; GEISSDOERFER *et al.*, 2017; ELLEN MACARTHUR FOUNDATION, 2015; GHISELLINI; CIALANI; ULGIATI, 2016; KIRCHHERR; REIKE; HEKKERT, 2017). Achieving these objectives extends beyond technological innovation or process redesign, requiring organizations to coordinate information, expertise, and decision-making across interconnected value networks throughout product lifecycles (RIZZI *et al.*, 2017; UL-DARAR *et al.*, 2023). As value creation increasingly depends on collaboration among multiple stakeholders, organizations must be able to create, codify, integrate, share, and apply knowledge across organizational boundaries. Consequently, successful circular transitions depend not only on technological and operational capabilities but also on organizations' ability to effectively mobilize and integrate knowledge across organizations, supply chains, and broader value networks.

This knowledge-intensive nature of CE has positioned Knowledge Management (KM) (NONAKA; TAKEUCHI, 1995) as a strategic capability for enabling circular transitions (CHEMBESSI, 2023; KLAPALOVÁ, 2019; MARRUCCI; DADDI; IRALDO, 2022; KORALAGE *et al.*, 2024). By supporting knowledge creation, integration, sharing, and application, KM enables product redesign, reverse logistics, remanufacturing, and circular business models (BROWN; BOCKEN; BALKENENDE, 2020; HALSTENBERG *et al.*, 2021; LI *et al.*, 2021; BUCEA-MANEA-ȚONIȘ *et al.*, 2022). Accordingly, recent studies increasingly recognize KM as a sociotechnical capability that facilitates collaboration across organizations, supply chains, and circular ecosystems (ALMEIDA *et al.*, 2024; CHEMBESSI, 2023; MARRUCCI; DADDI; IRALDO, 2022).

Despite this growing recognition, the literature has not yet converged on an integrated explanation of how KM collectively enables CE. Existing studies predominantly investigate individual KM mechanisms, such as absorptive capacity, knowledge sharing, organizational learning, digital technologies, and eco-innovation, without explaining how these mechanisms interact across strategic, organizational, and operational levels to enable circular practices (TREVISAN *et al.*, 2023; KORALAGE *et al.*, 2024). Consequently, although valuable insights have been generated, they remain insufficient to explain how knowledge collectively supports circularity across different organizational contexts.

This limited explanatory capacity stems from theoretical fragmentation, whereby knowledge has accumulated through isolated advances rather than cumulative theoretical development. Consequently, KM is primarily positioned as a supportive operational capability rather than as an analytical lens capable of explaining how circularity emerges and scales. This limitation is reflected in three interrelated gaps: (i) insufficient understanding of how KM processes interact across strategic, organizational, and operational levels (TREVISAN *et al.*, 2023; KORALAGE *et al.*, 2024); (ii) a scarcity of longitudinal empirical evidence linking KM capabilities to circularity performance; and (iii) the absence of integrative theoretical frameworks connecting KM mechanisms with the operational logic of CE (D'AMATO *et al.*, 2022).

Accordingly, advancing this field requires integrating the existing evidence into a coherent theoretical–analytical perspective, leading to the following research question: How has the interface between Knowledge Management and the Circular Economy evolved in the academic literature, and how can the accumulated evidence be systematized into an integrative

theoretical–analytical framework? To address this question, this study conducts a systematic literature review of 115 peer-reviewed articles to synthesize the existing body of knowledge and develop an integrative theoretical–analytical framework explaining how KM supports CE.

This study makes three primary contributions. First, it advances an integrated theoretical perspective of the KM–CE interface by consolidating fragmented evidence into a coherent explanatory framework. Second, it systematizes the principal knowledge mechanisms that enable circularity across strategic, organizational, operational, technological, and sociocultural dimensions. Third, it identifies key theoretical gaps and proposes an integrative research agenda to guide future empirical and theoretical investigations into the relationship between Knowledge Management and the Circular Economy.

2. THEORETICAL BACKGROUND

2.1. Knowledge Management

Knowledge has long been recognized as a strategic resource that underpins organizational learning, innovation, and competitive advantage (NONAKA; TAKEUCHI, 1997; PROBST; RAUB; ROMHARDT, 2002; MARRUCCI; DADDI; IRALDO, 2022; UL-DARAR *et al.*, 2023). Although this perspective was initially developed from an organizational standpoint, recent studies have broadened this understanding by conceptualizing knowledge as a distributed resource that is continuously co-created through collaborative processes and interorganizational networks (D'AMATO *et al.*, 2022; CHEMBESSI, 2023). Among the most influential conceptualizations, Nonaka and Takeuchi (1997) distinguish between tacit and explicit knowledge. Tacit knowledge is personal, experiential, and difficult to codify, whereas explicit knowledge can be articulated, documented, stored, and disseminated through formal repositories, information systems, and other organizational artifacts.

Knowledge Management (KM) emerged in the 1990s as a research field dedicated to understanding how organizations create, integrate, share, store, apply, and protect knowledge to enhance organizational performance and sustain competitive advantage (DAVENPORT; PRUSAK, 1998; NONAKA; TAKEUCHI, 1997). Grounded in the view of knowledge as a strategic organizational resource, KM encompasses the coordinated management of people, processes, technologies, and organizational structures to transform individual knowledge into

organizational capabilities, thereby fostering continuous learning, innovation, and adaptive capacity (TERRA, 2005; PROBST; RAUB; ROMHARDT, 2002).

Originally focused on managing knowledge within organizational boundaries, KM has progressively evolved to incorporate mechanisms for integrating knowledge across organizations, business partners, and other stakeholders, reflecting the growing importance of collaborative ecosystems and interorganizational networks for innovation (DE MARCHI; DI MARIA, 2020; HALSTENBERG *et al.*, 2021). This evolution reflects a broader shift in the KM literature—from an internal perspective centered on organizational knowledge assets toward an ecosystem perspective that emphasizes knowledge integration across distributed actors, collaborative networks, and innovation ecosystems.

Within this perspective, Knowledge Management practices constitute the mechanisms through which knowledge processes are operationalized. Classical studies categorize these practices into dimensions related to people, processes, and technology (BATISTA *et al.*, 2005; GASPAR, 2010). More recent research, however, demonstrates that their role has expanded considerably, supporting interorganizational knowledge integration, collaborative innovation, and the coordination of complex knowledge networks that extend beyond organizational boundaries (HALSTENBERG *et al.*, 2021; MARRUCCI; DADDI; IRALDO, 2022; UL-DARAR *et al.*, 2023).

This conceptual evolution has substantially broadened the scope of Knowledge Management. More recently, KM has been increasingly recognized as a strategic capability for supporting the implementation of the Circular Economy (CE). In this context, knowledge creation, integration, sharing, and application are considered essential for enabling circular strategies such as eco-design, reverse logistics, remanufacturing, industrial symbiosis, and value retention (DE MARCHI; DI MARIA, 2020; HALSTENBERG *et al.*, 2021; D'AMATO *et al.*, 2022; MARRUCCI; DADDI; IRALDO, 2022; UL-DARAR *et al.*, 2023).

Despite this growing recognition, the literature remains fragmented in explaining how different KM processes and practices interact systematically to support the implementation and scaling of circular strategies. This limitation highlights the need for integrative theoretical–analytical frameworks capable of explaining the mechanisms through which Knowledge Management contributes to circular value creation (CHEMBESSI, 2023; UL-DARAR *et al.*, 2023).

2.2. Circular Economy

According to Kirchherr, Reike, and Hekkert (2017), the Circular Economy (CE) is a systemic economic model that replaces the conventional end-of-life paradigm with business models designed to preserve the value of products, components, and materials through strategies such as reduction, reuse, remanufacturing, recycling, and recovery. Implemented across micro, meso, and macro levels, CE seeks to simultaneously promote economic prosperity, environmental quality, and social equity. This systemic perspective implies that circular transitions depend not only on technological and operational innovations but also on the effective coordination and integration of knowledge among multiple stakeholders throughout value networks.

The concept of the Circular Economy has evolved considerably over the past decades. Early studies primarily framed circularity as an alternative to the traditional linear production model, emphasizing waste management, recycling, and resource efficiency as strategies to reduce environmental impacts (GHISELLINI; CIALANI; ULGIATI, 2016). Subsequently, the concept expanded to incorporate closed-loop systems that preserve the value of products, components, and materials through practices such as reuse, remanufacturing, and reverse logistics (KIRCHHERR; REIKE; HEKKERT, 2017).

More recently, the Circular Economy has been reconceptualized as a systemic economic model that operates across multiple levels—micro, meso, and macro—integrating business models, production systems, supply chains, and broader socio-economic structures to simultaneously generate environmental, economic, and social value (GEISSDOERFER et al., 2017; KIRCHHERR; REIKE; HEKKERT, 2017).

This conceptual evolution has also shifted the focus from technological and operational solutions toward organizational and knowledge-related capabilities. Recent studies increasingly recognize that implementing circular strategies requires knowledge creation, sharing, integration, and learning across multiple stakeholders, positioning Knowledge Management as a strategic enabler of circular transitions (DE MARCHI; DI MARIA, 2020; D'AMATO et al., 2022; MARRUCCI; DADDI; IRALDO, 2022; UL-DARAR et al., 2023).

3. METHOD

This study adopts a systematic literature review (SLR) to rigorously map, synthesize, and advance the interface between KM and CE. An SLR is uniquely suited for addressing the

conceptual fragmentation and interdisciplinary dispersion inherent to this nexus (Klapalová, 2019), providing a transparent, replicable protocol to evaluate the field's intellectual architecture (Aquilani et al., 2017; Page et al., 2021). Rather than offering a descriptive overview, this review functions as a theory-building mechanism designed to uncover systemic gaps and knowledge mechanisms enabling circular strategies. To ensure methodological rigor, the protocol was adapted from Klapalová (2019), aligned with PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines (Page et al., 2021), and executed across four sequential stages:

1. Problem formulation and research questions: the first stage consisted of defining the research problem and establishing the guiding research questions, as presented in the Introduction. This stage aimed to delimit the scope of the review and define the conceptual boundaries of the KM–CE interface to be analyzed.

2. Literature identification: the literature search was conducted across five multidisciplinary and high-impact databases: Web of Science, Scopus, Scielo, Spell (Scientific Periodicals Electronic Library), and Google Scholar. Searches were carried out in two periods: 19/06/2023–26/06/2023 and 16/05/2025–23/05/2025, to incorporate recent publications and ensure the completeness of the dataset. Google Scholar was used as a complementary source to reduce publication bias and identify additional studies not indexed in the other databases.

3. Screening and selection: the screening stage was conducted using clearly defined inclusion and exclusion criteria. Studies were considered eligible when they explicitly addressed the intersection between CE and KM through combinations of the search terms “Circular economy” AND “Knowledge Management” and “Circular economy” AND “Knowledge” in titles, abstracts, or keywords, without temporal restriction. The initial dataset comprised 205 records, as illustrated in Figure 1. The screening process involved duplicate removal (50 records), accessibility verification (22 records excluded), and thematic relevance assessment (18 records excluded). A two-stage screening procedure was applied, consisting of an initial evaluation of titles, abstracts, and keywords followed by a full-text review to ensure conceptual alignment with the research objective.

4. Corpus analysis: after the screening process, the final dataset consisted of 115 articles, which constituted the analytical corpus of the study. This corpus size is considered adequate for systematic literature reviews that aim to identify theoretical patterns and

conceptual developments within a specific research interface, allowing for comprehensive coverage of the relevant literature while maintaining analytical depth.

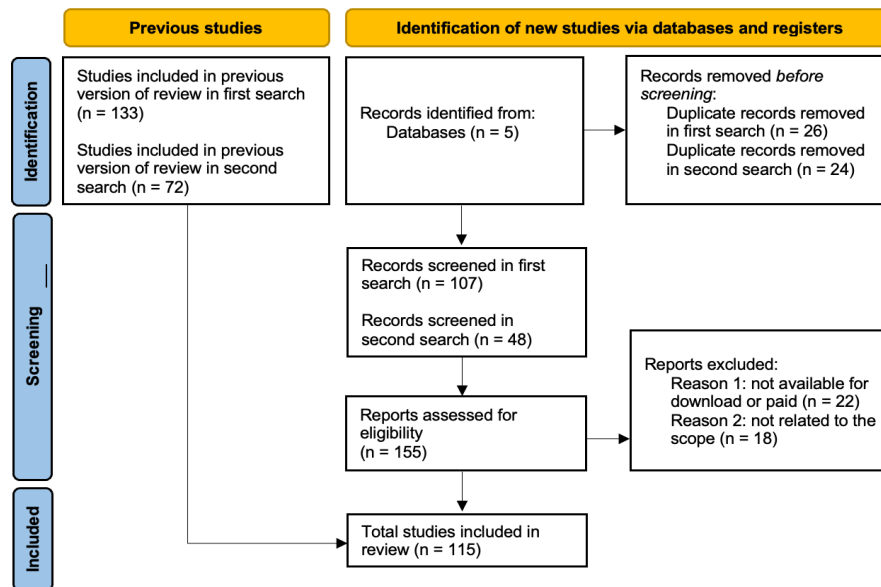


Figure 1 - PRISMA flow diagram of literature search and study selection.
Source: Prepared by the authors

In Phase 4, the qualitative synthesis of the 115 articles was performed through thematic analysis following Braun and Clarke (2006) to identify and interpret patterns for theory-building. The unit of analysis comprised all conceptual and empirical statements regarding the KM–CE interface (e.g., KM mechanisms, practices, technological enablers, and governance arrangements). The analytical process involved open coding of the text corpus, with relevant excerpts systematically extracted to ensure traceability. Through iterative comparison and aggregation, an explicit codebook was developed to ensure interpretive consistency. Codes were then clustered into higher-order themes, resulting in two overarching dimensions, for example: Theoretical Contributions (GT) and Empirical Contributions (GE). To ensure analytical rigor, an audit trail was maintained through 21 specialized analytical matrices and theoretical memos. Category refinement followed an iterative validation process, balancing the coded material against the conceptual foundations of KM and CE (Figure 2), which provided the structural building blocks for the integrative framework.

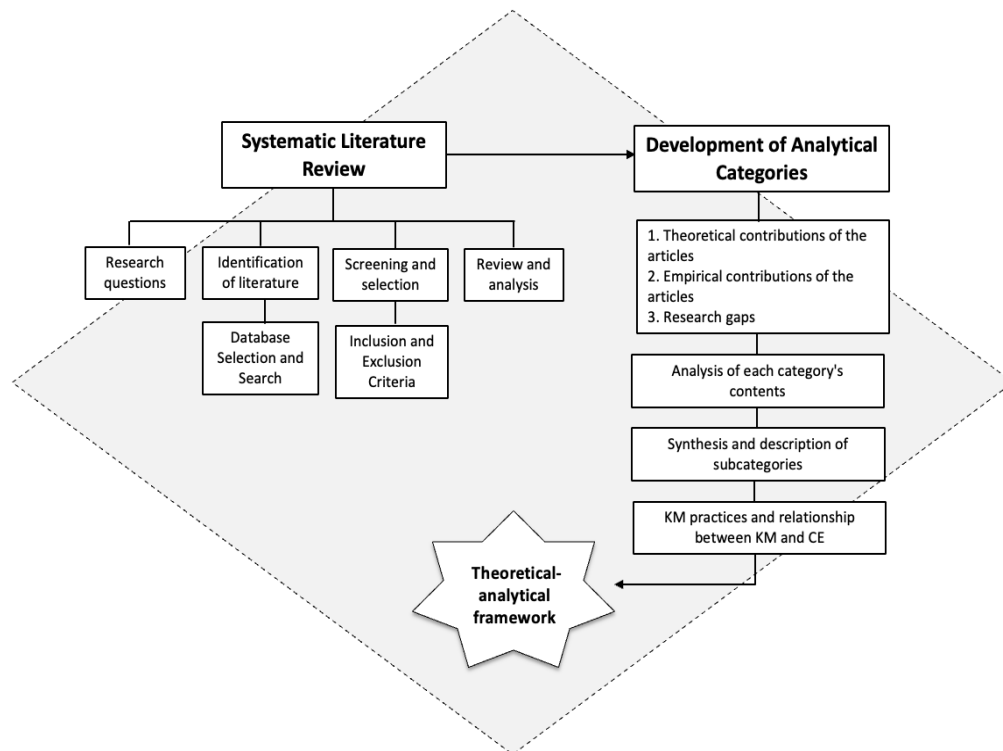


Figure 2 - Research Methodological Design
Source: Prepared by the authors

4. RESULTS AND DISCUSSION

4.1. Analysis and Integration of Theoretical Contributions

The theoretical literature on KM and CE reveals a progressive evolution from descriptive mappings toward conceptual, managerial, and context-specific applications, organized into four thematic groups (GT1–GT4). Rather than representing isolated streams of research, these groups illustrate the gradual maturation of the field, moving from diagnostic studies to conceptual frameworks, implementation strategies, and sectoral applications.

This progression nevertheless reveals an important gap between theoretical development and empirical validation. At its foundation, GT1 establishes the structural boundaries of the field through reviews, bibliometric analyses, and diagnostic studies. However, the literature remains geographically and sectorally concentrated, while fragmented co-authorship networks indicate limited integration of research efforts over time (Cajuela & de Pádua, 2024; Ribeiro, 2022). More importantly, although GT1 successfully maps the evolution of the field, it provides limited explanation of how KM capabilities are translated into CE practices across organizational contexts (Ul-Darar et al., 2023; Zhang et al., 2021). These

limitations motivate the transition toward GT2 and GT3, where research shifts from describing the field to proposing conceptual solutions for its operationalization.

GT2 advances this agenda by proposing data architectures, sector-specific frameworks, KM–eco-innovation integration, and design-for-circularity guidelines (Acerbi et al., 2020; Sassanelli et al., 2020a; Koralage et al., 2024). Nevertheless, many of these proposals remain limited to pilot applications or specific industrial contexts, constraining their external validity (Mullins et al., 2020). Likewise, GT3 extends the discussion from conceptual design to implementation, emphasizing the complementary roles of dedicated KM agents, organizational culture, leadership, training, technological capabilities, governance, and financing mechanisms (Deshpande, 2020; Miyashiro et al., 2023; Kuzma et al., 2021). Collectively, these studies converge on the importance of three interdependent enablers of circular business models, robust knowledge capital, multilevel governance, and hybrid financial mechanisms. However, comparative evidence across sectors, longitudinal analyses, and standardized performance metrics remain limited (Rizzi et al., 2017; Popa & Popa, 2017).

GT4 represents the operational application of these theoretical advances across diverse contexts, including manufacturing, healthcare, education, bioeconomy, chemistry, industrial symbiosis, and territorial initiatives. Across these settings, the reviewed studies consistently indicate that successful circular initiatives depend on the alignment of context-sensitive governance, operational indicators, and digital infrastructures (Almeida et al., 2024; Guarieiro et al., 2022; Jackson et al., 2021). Whether through traceability systems, ERP-based metrics, Circular Chemistry, biorefineries, educational roadmaps, or polycentric governance, the evidence suggests that no single solution is universally applicable; instead, effective implementation depends on adapting KM mechanisms to specific organizational and sectoral conditions. Nevertheless, the literature continues to highlight the need for more systematic validation through longitudinal studies, quasi-experimentais designs, standardized indicators, and open data. Strengthening these dimensions would facilitate stronger integration between the theoretical propositions identified in GT1–GT4 and the empirical agendas synthesized in GE1–GE4, thereby contributing to the cumulative development of the field.

Collectively, these findings demonstrate that advancing theoretical understanding of the KM – CE interface requires integrating conceptual advances, organizational mechanisms, and empirical evidence into a coherent explanatory perspective. This integrative understanding provides the foundation for the theoretical–analytical framework proposed in this study.

4.2. Analysis and Integration of Empirical Contributions

The empirical literature (GE1–GE4) extends beyond describing distinct operational scales of CE implementation. Collectively, the reviewed studies reveal a coherent socio-technical pattern in which advances in CE are increasingly associated with the development of KM capabilities. Viewed through a KM perspective, the empirical evidence can be interpreted as spanning two complementary dimensions: techno-analytical mechanisms supporting knowledge codification (GE1–GE2) and socio-cognitive and institutional processes facilitating knowledge integration and diffusion (GE3–GE4).

At the operational level, GE1 and GE2 highlight the complementary roles of digital technologies, KM processes, and performance measurement. Rather than functioning as independent drivers of circularity, digital artefacts, including prime-number cryptography for IoT infrastructures, blockchain, and process–system metamodels, appear to contribute more effectively when embedded within intra- and interorganizational KM routines that support the transformation of digital information into organizational learning and circular decision-making (Bucea-Manea-Țoniș et al., 2022; Chen et al., 2024; Magnanini & Tolio, 2024). Similarly, the reviewed studies indicate that blockchain, case-based reasoning, and edge-computing solutions contribute to remanufacturing and operational learning by supporting knowledge exchange across production and logistics processes (Alonso Muñoz et al., 2021; Li et al., 2021; Salinas Osuna et al., 2021). Collectively, these findings suggest that measurable environmental and competitive gains are more likely to emerge when digital infrastructures, KM routines, and integrated eco-economic metrics operate in a complementary manner.

The evidence also indicates that the transition from performance measurement to decision support remains an important challenge. Frameworks such as Green Lean Six Sigma, Life Cycle Assessment (LCA), Material Flow Analysis (MFA), and techno-economic optimization successfully capture trade-offs between economic and environmental objectives (Farrukh et al., 2023; Guilhem & Klein, 2024; Raabe et al., 2017; Pacheco-López et al., 2023). However, many of these approaches have primarily been evaluated within pilot initiatives or sector-specific applications, limiting the generalizability of their findings (De Marchi & Di Maria, 2020; Hagström et al., 2020; Halstenberg et al., 2021; Ni et al., 2019). Collectively, these findings suggest that broader implementation depends not only on expanding data availability but also on strengthening organizations' capacity to integrate, interpret, and apply knowledge

through standardized indicators, interoperable data infrastructures, and comparable evaluation frameworks.

Moving beyond technological capabilities, GE3 and GE4 indicate that successful CE implementation increasingly depends on socio-cognitive and institutional conditions. Across the reviewed studies, green identities, entrepreneurial orientation, organizational learning, relational trust, and knowledge sharing consistently emerge as important enablers of circular practices (Agyabeng-Mensah et al., 2021). Likewise, digital twins appear to support CE not only as technological tools but also as mechanisms facilitating knowledge visualization, communication, and collaboration across organizational boundaries (Ritola et al., 2022). These findings further suggest that circular literacy is fostered through knowledge co-production involving universities, governments, firms, cooperatives, and civil society (Bakırlioğlu & McMahon, 2021; Baptista et al., 2021; Dokter et al., 2021, 2023; Leuzzo & Nava, 2020; Pereira et al., 2024; Schlüter et al., 2022; Stelmaszczyk et al., 2021; Valenga et al., 2023). Nevertheless, the literature still provides limited empirical evidence linking these socio-cognitive capabilities to measurable circular performance, highlighting the need for comparable indicators and longitudinal assessment.

At a broader institutional level, GE4 indicates that scaling CE initiatives appears to be facilitated by governance arrangements capable of aligning public policies, financial mechanisms, territorial coordination, and local capabilities. Polycentric governance supported by geospatial information, together with public investment in green R&D, appears to strengthen regional innovation ecosystems and support CE diffusion, particularly when accompanied by shared metrics and reduced territorial asymmetries (Gibellato et al., 2023; Jackson et al., 2021; Mulrow et al., 2017; Šimelytė & Tvaronavičienė, 2022). Rather than identifying a universal implementation pathway, the reviewed evidence indicates that effective CE strategies depend on adapting KM mechanisms to different organizational and territorial contexts.

Viewed collectively, GE1–GE4 confirm that many implementation challenges reported in the CE literature can be interpreted through a KM lens. Difficulties associated with eco-design, reverse logistics, remanufacturing, and cross-sector collaboration frequently coincide with limitations in knowledge acquisition, integration, sharing, codification, and application across organizational boundaries. Accordingly, the reviewed evidence indicates that technological innovation and regulatory support, while important, are unlikely to be sufficient in isolation. Instead, successful CE implementation appears to depend on the development of

multilevel KM capabilities capable of connecting digital infrastructures, organizational routines, and institutional arrangements into integrated knowledge systems that support continuous learning and circular value creation.

4.3. Analysis and Integration of Future Research Recommendations

Considering the conceptual, methodological, and empirical gaps identified through the systematic review, it becomes essential to outline a research agenda that can guide the advancement of the field. The recommendations presented herein were derived from a cross-analysis of the 115 articles examined, triangulating explicit “future research” statements by the authors with implicit gaps revealed by the findings in Sections 3 and 4. This taxonomy is intended to serve as a strategic roadmap for researchers, funding agencies, and industrial stakeholders seeking to address critical gaps and accelerate the transition towards genuinely circular ecosystems:

1. Knowledge, capabilities, and behavior: move beyond descriptive studies toward quasi-experimental and multilevel designs; test mediating mechanisms (e.g., circular literacy) and moderating conditions (e.g., organizational culture) along the GC → practices → performance chain; conduct cross-sector studies to strengthen external validity (Atiku, 2020; Trevisan et al., 2023; Ul-Darar, 2023; Miyashiro et al., 2023; Weissbrodt et al., 2020).

2. Digital technologies, Industry 4.0, and processes: advance interoperability, ontologies, and APIs; strengthen data governance; and conduct LCAs of digitalisation to avoid “digital islands” and rebound effects (Bucea-Manea-Țoniș, et al., 2022; Chen et al., 2024; Sassanelli et al., 2020a; Magnanini & Tolio, 2024; Halstenberg et al., 2021; Hagström et al., 2020; Ingemarsdotter et al., 2020; Kazmi et al., 2023).

3. Circular supply chains and business models: Key Performance Indicators (KPIs) for Closed-Loop Supply Chains (CLSC), Reverse Logistics, and Product-Service Systems (PSS), test design-for-X, makerspaces, and co-creation across sectors and firm sizes; quantify unit economics for remanufacturing and industrial symbiosis; provide regulatory-financial roadmaps for Small and Medium-sized Enterprise (SME); and map cultural and market barriers in global supply chains (De Marchi & Di Maria, 2020; Popa & Popa, 2017; Agyabeng-Mensah et al., 2021; Papamichael et al., 2022; Roldan et al., 2024; Wuni, 2022; Valdez & Canobbio, 2025).

4. Metrics, evaluation, and decision support: standardise 360° indicators; integrate LCA/LCC into real-time decision tools; build open dashboards and benchmarking systems; run longitudinal studies with causal identification; and tighten the metric → decision linkage (Raabe et al., 2017; Pacheco-López et al., 2020/2023; Olivier et al., 2015; Zheng et al., 2024; De Marchi & Di Maria, 2020; Vann Yaroson et al., 2024; Leitão et al., 2024; Premyanov et al., 2022; Weissbrodt et al., 2020; Ni et al., 2019; Rizzi et al., 2017).

5. Policies, governance, and scalability: evaluate multilevel CE policies adapted to regional contexts; model collaborative governance and green financing; map regulatory and cultural barriers and the roles of industrial-symbiosis facilitators; align institutional indicators with the SDGs and with verifiable metrics (Jackson et al., 2021; Mulrow et al., 2017; Šimelytė & Tvaronavičienė, 2022; Campbell-Johnston et al., 2019; Schlüter et al., 2022; Leuzzo & Nava, 2020; Gazzola & Vitoriano, 2023; Raabe et al., 2017; Hodson de Jaramillo, 2018; Cortés et al., 2021; Duarte et al., 2024; Cajuela & de Pádua, 2024; Kazmi et al., 2023).

Taken together, the five groups delineate a line of action: multiscale causal identification of the KM → processes → metrics → value chain, standardization and interoperation of data and ontologies to avoid techno social lock-ins, cost–benefit and risk-adjusted appraisal of circular business models, and policies and finance anchored in verifiable indicators, which are preconditions for converting digital architectures and organizational capabilities into measurable and scalable circularity gains. Future research should also explicitly investigate how mechanisms, such as absorptive capacity, knowledge repositories, interorganizational knowledge sharing, and digital knowledge infrastructures, shape the effectiveness of circular practices such as durability, reuse, remanufacturing, and reverse logistics.

4.4. Conceptual framework of the relationship between KM and the CE

The synthesis of the 115 studies included in this review indicates that KM constitutes a foundational organizational capability supporting the transition, implementation, and long-term sustainment of the CE. Across the reviewed evidence, circular outcomes consistently rely on well-structured KM practices supported by robust architectures for knowledge creation, sharing, and institutionalization (Rizzi et al., 2017).

This interpretation is supported by studies highlighting complementary KM mechanisms. For example, previous research identifies KM processes as foundational pillars of

circular value chains (Rizzi et al., 2017), highlights absorptive capacity as an important enabler of environmental performance (Marrucci et al., 2022), conceptualizes multi-stage KM cycles as supporting infrastructures for CE implementation (Koralage et al., 2024), and emphasizes knowledge activation and application as key mechanisms for fostering circular innovation (Leitão et al., 2024; Ul-Darar et al., 2023; Gazzola & Vitoriano, 2023).

Collectively, these findings suggest that the role of KM can be operationalized through a set of recurring organizational practices. From the reviewed studies, 63 reported practices were identified and organized into six interdependent macro-axes:

1. Knowledge Acquisition & Creation (Ingemarsdotter et al., 2020; Koralage et al., 2024; Rizzi et al., 2017; Brown, 2020; Berbenni-Rehm, 2023; Miyashiro et al., 2023): Methods to capture existing knowledge (explicit and tacit) and collaboratively generate new knowledge relevant to circularity. This includes data collection (field research, data mining, IoT sensors, user feedback) and open innovation/multi-stakeholder co-creation initiatives.

2. Knowledge Structuring & Storage (Bucea-Manea-Țoniș et al., 2022; Koralage et al., 2024; Li et al., 2021; Abdelmeguid et al., 2021): Formal organization of knowledge to ensure easy access and digital interoperability. It involves developing ontologies, taxonomies, and data standards (e.g., digital twins, knowledge graphs) and implementing secure repositories (BIM, data lakes, blockchain) to preserve and protect lessons learned and circular data.

3. Sharing & Transfer (Premyanov et al., 2022; Bucea-Manea-Țoniș et al., 2022; Koralage et al., 2024; Berbenni-Rehm 2023; Alonso Muñoz et al., 2021; Abdelmeguid et al., 2022): Collaborative processes and platforms for disseminating and exchanging knowledge within and across organizations. This includes communities of practice, innovation hubs, makerspaces, and living labs, which facilitate the transfer of knowledge and experience (intra- and interorganizational) to advance circularity.

4. Application & Continuous Learning (Agyabeng-Mensah et al., 2021; Ritola et al., 2020; Sassanelli 2020b; Olivier et al., 2015; Lin et al., 2019; Iyer-Raniga & Huovila, 2020): Practical use of captured knowledge to improve circular processes and products (e.g., design-for-X, predictive maintenance, reverse logistics), coupled with feedback mechanisms that close the organizational learning cycle. These learning loops enhance absorptive capacity and support continuous improvement in circular-economy initiatives.

5. Competence Development (Atiku, 2020; Weissbrodt, 2020; Loste et al., 2020): Capacity-building for people to operate in the CE through education and training. This includes

formal education (academic curricula, MOOCs, serious games), corporate training programs, and initiatives to cultivate sustainability-oriented competencies and innovative mindsets (including ethics and green entrepreneurship).

6. KM Governance & Evaluation (Campbell-Johnston 2019; Trevisan et al, 2023; Leitão et al., 2024): Strategic alignment of KM with organizational objectives and CE public policies, ensuring institutional support (circular business models, open protocols). It also involves defining metrics (KPIs, dashboards) and using diagnostic/maturity tools to assess KM performance in the circular transition and identify improvement gaps.

This taxonomy indicates that operationalizing KM in the CE requires the simultaneous integration of human capabilities, organizational structures, and digital technologies to foster sustainable cycles of learning, innovation, and circularity. Furthermore, as Ni et al. (2019) emphasize, the effectiveness of these KM practices is contingent upon internal factors (installed technology, information systems, managerial support, workforce skills, logistics infrastructure) and external factors (government regulation, market demand, customer requirements, competitive pressure, environmental policies, among others).

Beyond these individual practices, the reviewed evidence also indicates that KM contributes to CE across five complementary dimensions, linking strategic intent with operational implementation:

1. Strategic: Align governance, KM practice choices, policies, and stakeholder networks, translating knowledge into strategic decisions (Halstenberg et al., 2021; Deshpande, 2020; Roldan et al., 2024).

2. Organizational: Develop dynamic capabilities, a structure for KM practices, and adaptive KM models that institutionalize circularity as an organizational culture and routine (Gazzola & Vitoriano, 2023).

3. Operational: Applying knowledge to circular maintenance, reverse logistics, and life cycle assessment (Duarte et al., 2024; Sassanelli et al., 2020b; Hagström et al., 2020).

4. Technological: Leveraging enabling technologies (IoT, blockchain, big data, AI) for KM practices and for knowledge circulation, traceability, and data-driven decision-making (Berbenni-Rehm, 2023; Koralage et al., 2024; Acerbi et al., 2020; Trevisan et al., 2023; Mora Pin et al., 2024).

5. Cultural/Social: Transforming mindsets, fostering collective learning, and embedding a culture of knowledge sharing to enable circular ecosystems (Romero Gomez et al., 2025).

Taken together, the identified KM practices and complementary organizational dimensions provide the foundation for the integrative theoretical–analytical framework proposed in Figure 3. Rather than depicting isolated KM activities, the framework synthesizes the reviewed evidence into a coherent explanatory structure that illustrates how KM supports CE implementation across multiple organizational levels. Figure 3 integrates these elements into a coherent theoretical–analytical framework. At the core of the proposed framework lies the KM Practices Cycle, which encompasses the interconnected processes of mapping, acquisition, creation, storage, sharing and transfer, co-creation, and knowledge application (Romero Gomez et al., 2025; Chembessi, 2023). Consistent with the reviewed evidence, these processes collectively transform tacit and explicit knowledge into actionable resources supporting CE implementation (Baptista et al., 2021; Chembessi, 2023; Halstenberg et al., 2021; Koralage et al., 2024; Romero Gomez et al., 2025).

Viewed through the proposed framework, several empirical challenges associated with CE implementation can be reinterpreted through a KM lens. Many operational barriers identified in the literature, such as weak reverse logistics systems, limited diffusion of eco-design practices, and difficulties in product life-cycle management, reflect underlying deficiencies in knowledge processes. These include limited absorptive capacity, fragmented knowledge repositories, weak knowledge-sharing routines across supply chains, and insufficient mechanisms for capturing and reusing lifecycle knowledge.

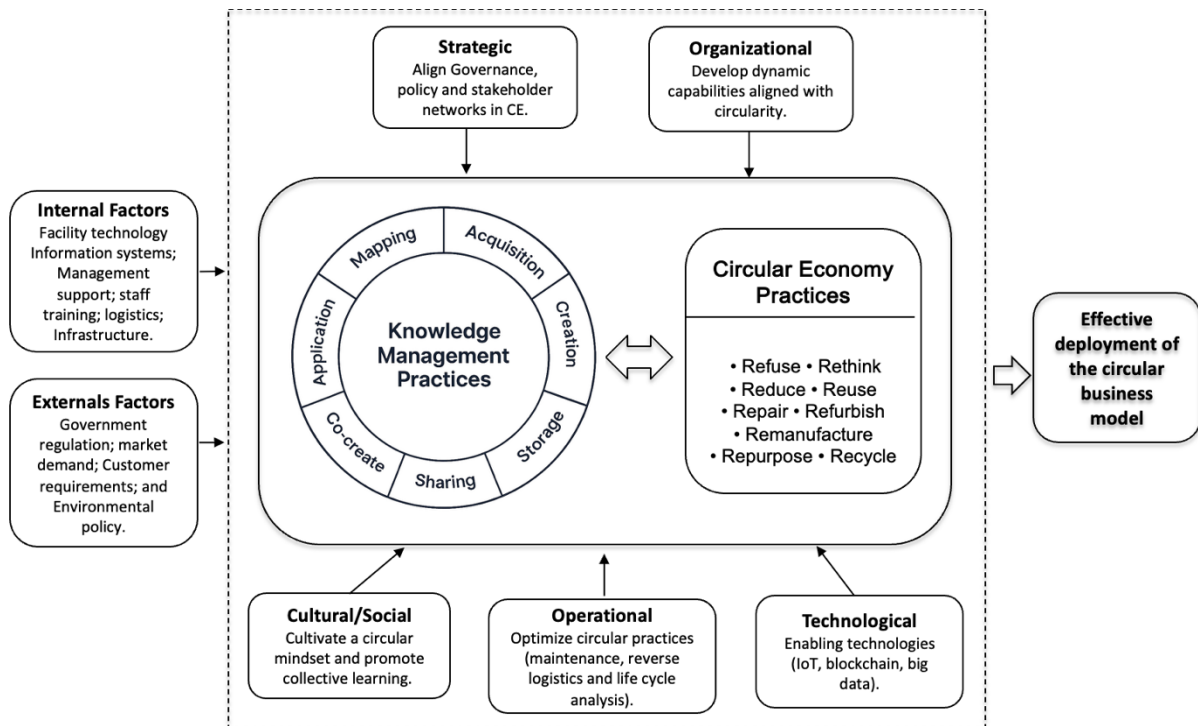


Figure 3 - Framework of the Role of KM in the CE

Source: Prepared by the authors

The key KM processes are as follows: mapping and acquisition, critical knowledge flows, actors, and sources on materials and products, enabling technologies, production processes, regulatory frameworks, financial models, supply chains, and sector-specific policies/standards are identified (Koralage et al., 2024; Deshpande, 2020); in creation and storage, knowledge generated through R&D, applied research, and organizational learning is systematically recorded in accessible repositories such as Building Information Modelling (BIM) systems, databases, and digital platforms, ensuring the longevity and scalability of circular practices (Berbenni-Rehm, 2023; in sharing, dissemination via training programs, stakeholder networks, open platforms, and interorganizational processes breaks silos and accelerates the diffusion and adaptation of CE innovations (Marrucci et al., 2022; Ritola et al., 2020); finally, in co-creation and application, solutions are collaboratively developed and implemented in the redesign of processes, products, and circular business models (Romero Gomez et al., 2025).

The cycle's effectiveness is modulated by internal (e.g., IT infrastructure, logistics, leadership) and external (e.g., public policies, regulatory pressures, market incentives) factors that jointly condition KM outcomes and CE adoption (Ni et al., 2019; Koralage et al., 2024). The bidirectional relationship between the KM cycle and CE practices underscores that

effective KM is pivotal for operationalizing the *9Rs*: Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle (Koralage et al., 2024), while the execution of these practices generates new data and lessons that, in turn, feed back into the KM system.

Empirical evidence further reinforces this interdependence: successful remanufacturing strategies require updated and collaborative knowledge bases, and the effectiveness of reverse logistics models depends on the dissemination of shared metrics and common ontologies (Ni et al., 2019). Taken together, these findings suggest that the integration between KM and CE is shaped by the interaction between internal organizational capabilities and external institutional conditions. The proposed framework therefore illustrates how multilevel KM processes support the implementation, adaptation, and continuous evolution of CE strategies across organizational contexts.

5. CONCLUSIONS AND IMPLICATION

The systematic analysis of the interface between KM and the CE reveals a clear trajectory of scientific maturation. Theoretical studies (GT1–GT4) evolve from diagnostic mappings of the state of the art toward developing conceptual frameworks, translating them into business models and governance structures, and ultimately applying them across industry-specific contexts. Empirical studies (GE1–GE4), in turn, validate the technologies, metrics, and organizational practices derived from these frameworks while progressively expanding the analytical scope to encompass social capacity-building and territorial governance dimensions.

Beyond mapping this intellectual evolution, the findings of this study advance theory-building in the field of KM by clarifying the mechanisms through which knowledge processes enable the operationalization of circular strategies. The review demonstrates that circular outcomes do not depend solely on technological solutions, regulatory incentives, or sustainability-oriented business models. Instead, they are strongly conditioned by structured knowledge processes that allow organizations to capture, integrate, share, and apply knowledge across product lifecycles and interconnected value networks.

From this perspective, the study contributes to the KM literature by identifying a core set of knowledge mechanisms that underpin circular practices. These include knowledge codification mechanisms supporting eco-design, absorptive capacity processes enabling circular innovation, interorganizational knowledge-sharing practices facilitating reverse logistics coordination, lifecycle knowledge integration strengthening remanufacturing

strategies, and knowledge infrastructures sustaining value retention across multiple product cycles. By synthesizing these mechanisms within an integrative analytical framework, this study advances the understanding of how KM operates as a foundational capability supporting the transition toward circular production systems.

Another primary theoretical contribution lies in repositioning the CE as an empirical and institutional context within which KM mechanisms operate. While much of the CE literature emphasizes technological innovation, regulatory instruments, or business-model transformation, this study highlights that the effectiveness and scalability of circular strategies are fundamentally dependent on the quality of the knowledge processes and infrastructures supporting them. In doing so, the study bridges sustainability-transition research with knowledge-based perspectives of the firm, demonstrating how KM functions as a critical micro-foundation of circular transformation.

From a practical perspective, the findings offer actionable guidance for managers and policymakers seeking to accelerate circular transitions. The identification of 63 KM practices organized into six macro-axes provides a structured roadmap for organizations aiming to embed circularity within their strategic, organizational, operational, technological, and sociocultural processes. These practices underscore the importance of integrating human capabilities, organizational structures, and digital infrastructures to enable sustainable cycles of learning, innovation, and resource circulation.

Despite these contributions, some limitations must be acknowledged. The study deliberately focused on peer-reviewed articles indexed in major academic databases, which may have excluded relevant insights present in grey literature, technical reports, and policy documents. In addition, although systematic reviews are effective for mapping research landscapes and identifying conceptual patterns, they provide limited evidence regarding causal relationships between KM practices and circular performance indicators.

Future research should therefore prioritize the empirical validation of these KM mechanisms through longitudinal and multilevel research designs. Studies should investigate how specific KM interventions, such as knowledge-sharing platforms, digital knowledge infrastructures, training programs, and collaborative innovation networks, affect the adoption and performance of circular practices like remanufacturing, reuse, and reverse logistics. Moreover, further work is needed to explore the cultural, institutional, and governance barriers that influence knowledge circulation within global supply chains and circular ecosystems.

Finally, integrating emerging digital technologies, including artificial intelligence, blockchain, and Internet of Things (IoT) infrastructures, into KM systems represents a promising pathway for developing continuous-learning ecosystems capable of sustaining circular innovation. Rather than treating KM as a complementary managerial function, this study reconceptualizes it as the organizational capability through which circularity is enacted, coordinated, and continuously developed across multiple organizational levels. By strengthening the analytical connection between knowledge processes and circular practices, future studies will contribute to building more robust theoretical and empirical foundations for the knowledge-based transition toward circular economies.

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