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A systematic review of evolution, thematic domains, and future directions in reverse logistics

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Abstract

This study presents a literature review that tracks the historical development of reverse logistics research, identifying key theoretical advances, ongoing challenges, and critical gaps in both academic inquiry and practical applications. Using a structured content analysis approach, the review systematically gathers, assesses, and synthesizes relevant scholarly work to map the field's intellectual evolution over time. The results identify four major stages: 1. An initial focus on operational efficiency and return flows. 2. The rise of environmental and regulatory pressures as main drivers. 3. The strategic integration of RL into boader supply chain management frameworks. 4. A current shift toward circular economy principles and digital transformation. Based on this historical overview, the study organizes the literature into six main thematic areas: 1. Strategic and Organizational Design. 2. Network Design and Optimization. 3. Consumer Behavior and Disposition Decisions. 4. Sustainability, Circular Economy, and Environmental Performance. 5. Digitalization and Emerging Technologies. 6. Performance Measurement, Risk, and Decision Support Models. Each area is analyzed in terms of its theoretical development, predominant methods, and research gaps. By critically examining the scope and depth of contributions across these areas, the review highlights the growing interdisciplinary nature of reverse logistics and underscores the need for empirical validation, integrated models, and context-specific approaches. This work provides a comprehensive reference for researchers and practitioners aiming to develop and improve reverse logistics systems that are not only operationally effective but also environmentally sustainable, digitally advanced, and strategically aligned with evolving supply chain paradigms.
Keywords: Reverse logistics, literature review, sustainability, closed-loop supply chains, circular economy.

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Introduction

In recent decades, Reverse Logistics (RL) has become a vital part of supply chain management, driven by increasing environmental concerns, shifting consumer expectations, regulatory pressures, and the growing need for sustainable business practices (Tibben, 2002; Nikolaou *et al.,* 2013; Bernon *et al.,* 2018). Unlike traditional forward logistics, which focuses on the efficient movement of goods from producers to consumers, RL involves the flow of returned products, reusable materials, end-of-life goods, and waste back through the supply chain for reuse, remanufacturing, recycling, or responsible disposal (Dekker *et al.,* 1998; Dowlatshahi, 2000; Rogers & Tibben, 2001). As governments and companies work toward circular economy goals, effective RL systems have become essential for closing supply chain loops and minimizing environmental impact (Guide & Van, 2009; Bernon *et al.,* 2018; Guarnieri *et al.,* 2020).

Despite growing significance, the field of RL has remained fragmented over the past thirty years, characterized by diverse research areas and multidisciplinary practical challenges. While notable progress has been made in modeling, planning, and managing reverse flows (Fleischmann *et al.,* 1997, 2000; Pokharel & Mutha, 2009; Jayant *et al.,* 2012), key operational and strategic gaps continue to exist. Rubio *et al.* (2008) and Rouhani *et al.* (2025) emphasize the importance of developing strategic and organizational theories in RL, moving beyond merely operational or tactical perspectives.

These unresolved challenges motivate a comprehensive review and synthesis of RL literature, aiming to unify existing knowledge and connect it to the field's historical development. This approach not only identifies gaps but also provides a foundation for future research. Through a structured analysis, this paper aims to synthesize current studies and offer practical insights for practitioners managing increasingly complex, sustainability-focused supply chains.

Existing review studies often focus on specific aspects of RL, such as quantitative models (Fleischmann *et al.,* 1997), network design (Chanintrakul *et al.,* 2009), industry-specific applications (e.g., construction (Vargas *et al.,* 2021) or pharmaceuticals (de Campos *et al.,* 2017), product categories like waste of electrical and electronic equipment (Ni *et al.,* 2023), end-of-life vehicles (He *et al.,* 2020), geographical contexts (Bouzon *et al.,* 2014), or frameworks for designing RL programs (Mallick *et al.,* 2024).

In contrast, this paper takes a comprehensive approach, examining the field's development, evolutionary path, and changing priorities. By assessing the influence of key contributions and current hurdles, we aim to develop a forward-looking research agenda that guides practical decisions and speeds up the shift to circular supply chains.

The rest of this paper is structured as follows: Section 2 describes the content analysis methodology for this systematic review. Section 3 provides a bibliometric analysis of the selected literature. Section 4 traces the historical development of RL, emphasizing key milestones and paradigm shifts. Section 5 categorizes major research areas, synthesizing theoretical and empirical progress. Section 6 suggests future research directions to tackle important challenges. Finally, Section 7 summarizes the key findings and their implications.

Methodology

This study uses a structured content analysis method (Brewerton & Millward, 2001; Seuring & Müller, 2008; Sandin & Peters, 2018), carried out in two sequential stages:

1. Finding and gathering relevant literature from academic databases based on predefined criteria to ensure scholarly rigor, and
2. Systematically categorizing and assessing the selected literature using an analytical framework designed to extract, analyze, and synthesize key findings (see Figure 1).

Bibliometric analysis

This bibliometric analysis aims to identify specific metrics related to RL. The selected references range from early conceptual discussions on RL (Zikmund & Stanton, 1971; Peronnet, 1979; Barnes, 1982) to recent applications that incorporate digital transformation and circular economy principles (Bhowmik *et al.,* 2024; Yun & Han, 2025). Literature encompasses theoretical foundations, empirical case studies, reviews, modeling approaches, and sustainability-focused frameworks (see Table 1), covering a diverse range of contexts. Developed economies (USA, EU, Japan) lead early conceptualization, while recent years show increased contributions from emerging economies (Brazil, India, China) in sector-specific studies.

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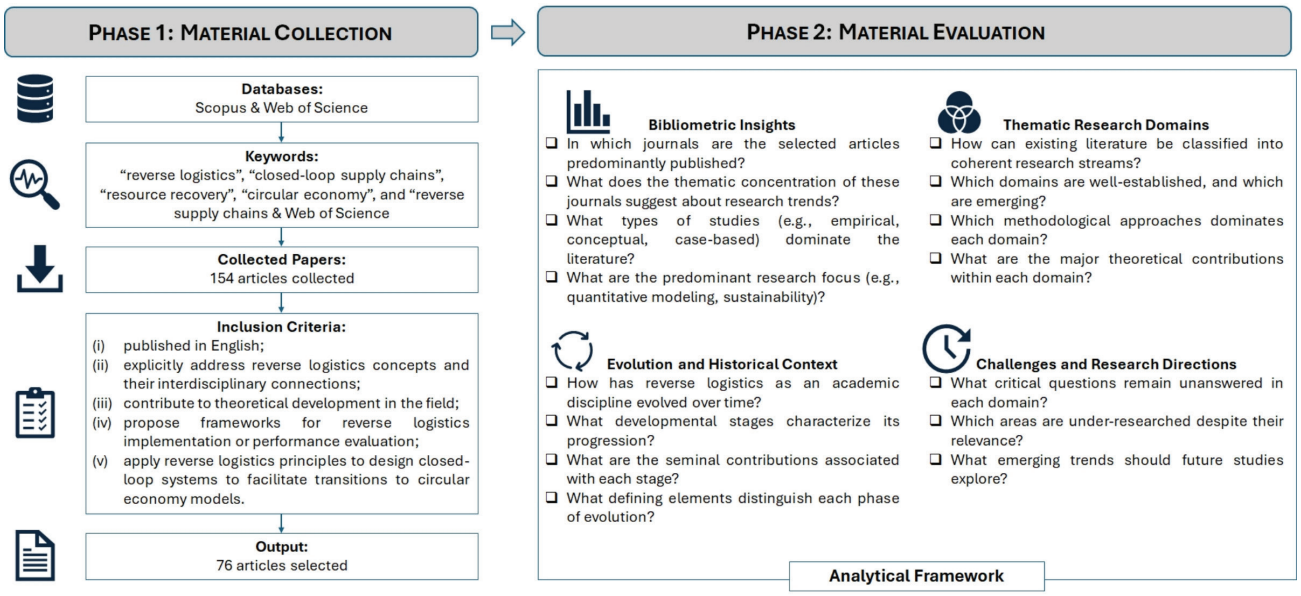

Figure 1. Methodology for content analysis.

Table 1. Selected references per category of study.

Category of study	Number of papers	Aims	Core references
Theoretical foundations	9	Contribute to conceptual models, frameworks, and definitions that underpin RL as a discipline.	Pohlen & Farris (1992), Dowlatshahi (2000), Tibben-Lembke (2002), and Sarkis *et al.* (2010).
Empirical case studies	15	Present real-world applications of RL, often in specific industries or regions.	Prahinski & Kocabasoglu (2006), Abdulrahman *et al.* (2014), Guarnieri *et al.* (2020), and Fernando *et al.* (2023).
Reviews	13	Synthesize the existing literature, identify gaps, and propose future research agendas.	Pokharel & Mutha (2009), Souza (2013), Govindan *et al.* (2015), and Rouhani *et al.* (2025).
Modeling approaches	13	Focus on mathematical, simulation, or optimization models for designing and making decisions in RL.	Atasu *et al.* (2008), Srivastava (2008), Cannella *et al.* (2016), and Bai & Sarkis (2019).
Sustainability-focused frameworks	12	Explicitly link RL with circular economy principles, green supply chains, and sustainable development.	Nikolaou *et al.* (2013), Mangla *et al.* (2016), Julianelli *et al.* (2020), and Sonar *et al.* (2024).

Figure 2 shows that the literature on RL covers environmental, managerial, and operations research fields, highlighting the field's growing interdisciplinary nature. The analysis of research focus by journal reveals three clusters. Sustainability and circular economy advocates make up 37 % of the references, highlighting environmental stewardship, resource circularity, and corporate social responsibility, with frequent publications in Resources, Conservation and Recycling, and the Journal of Cleaner Production. Methodology and operations-focused journals account for 28 %, covering network design, inventory management, disposition decisions, and cost reduction under uncertainty, with key outlets including the International Journal of Production Economics, Industrial Marketing Management, Omega, and the International Journal of Physical Distribution & Logistics Management. The remaining 28 % concentrate on organizational, behavioral, and strategic topics, exploring implementation barriers, return management policies, and integrating RL into corporate strategies, and are published in journals such as Production Planning & Control, the European Journal of Operational Research, California Management Review, and the International Journal of Logistics: Research and Applications.

Figure 3 shows the number of selected publications on reverse logistics per year. The trend clearly shows the growth of the field from a niche topic to a major area of research, especially in the last two decades.

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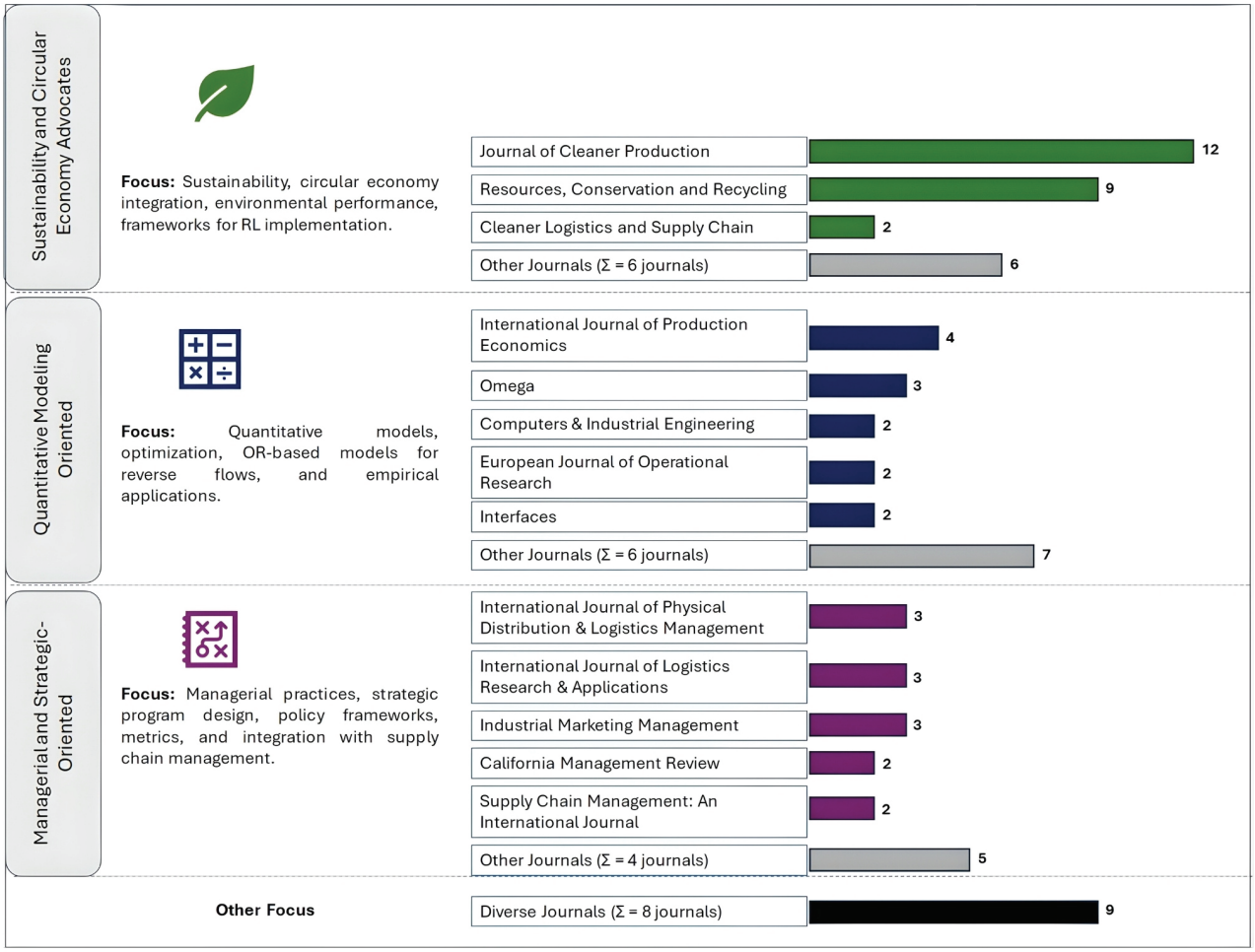

Figure 2. Distribution of RL literature by journal and primary focus of research.

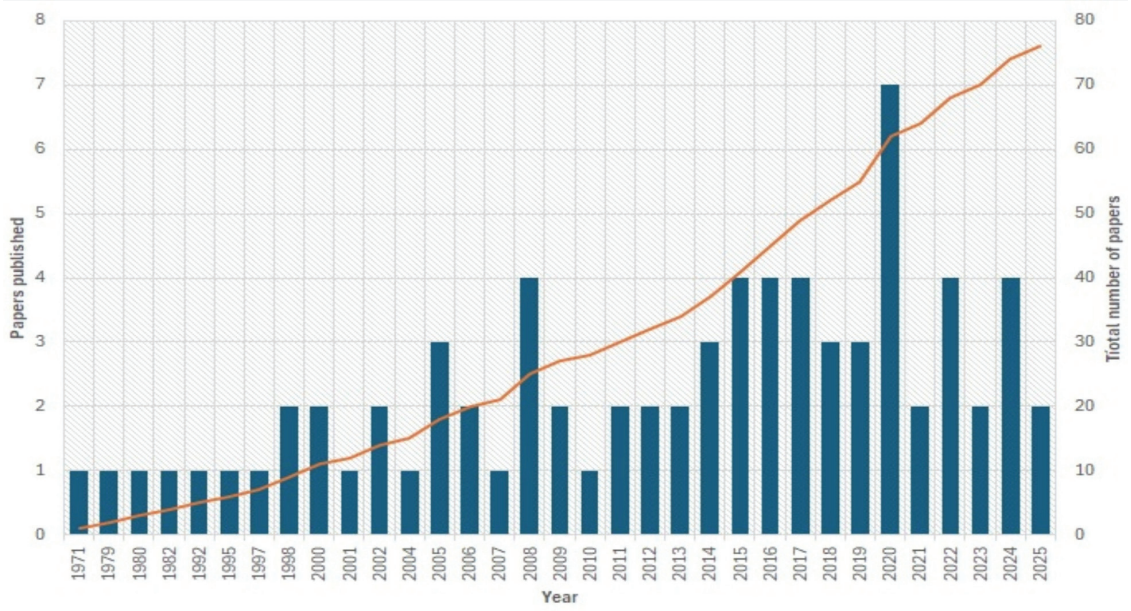

Figure 3. Number of publications on reverse logistics per year.

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Figure 4 presents the co-citation, co-authorship, and co-occurrence networks of the selected papers obtained from VOSviewer, aiming to visualize the relationships among articles, authors, and keywords. The co-citation map (Figure 4a) illustrates how the selected papers are interrelated through citation links. The co-authorship map (Figure 4b) reveals distinct research collaboration groups among authors. Finally, the co-occurrence map (Figure 4c) depicts the evolution of research focus over time. For instance, terms such as circular economy and content analysis appear as recurrent themes in publications around 2020, whereas recycling and cost were more prominent in studies published around 2005.

Evolution and historical context

The analysis of historical development and context begins with a systematic review of twelve previous literature articles, which collectively trace the evolution of RL from its early days as environmentally focused recycling channels to its status as a well-established, interdisciplinary field involving operations research, strategic management, and emerging technologies (see Figure 3).

The foundational reviews (Pohlen & Farris, 1992; Fleischmann *et al.*, 1997; Carter & Ellram, 1998; Dekker *et al.*, 1998) established critical frameworks, typologies, and operations research models addressing distribution, inventory, and production planning in RL. Subsequent reviews (Rubio *et al.*, 2008; Pokharel & Mutha, 2009) broadened the field's scope by introducing strategic, tactical, and operational classifications while emphasizing the need for enhanced strategic alignment and behavioral considerations. Later contributions (Agrawal *et al.*, 2015; Govindan *et al.*, 2015; Govindan & Soleimani, 2017; Prajapati *et al.*, 2019) shifted focus toward decision-support methodologies, particularly multi-criteria decision-making approaches, sector-specific implementation challenges, and key barriers and enablers. The most recent reviews (Mallick *et al.*, 2024; Bhowmik *et al.*, 2024; Rouhani *et al.*, 2025) reveal three significant paradigm shifts:

1. Alignment with circular economy principles.
2. Integration of artificial intelligence and digital technologies.
3. Incorporation of global comparative and policy perspectives.

These developments collectively signify the emergence of technologically advanced, sustainability-driven, and context-sensitive RL systems (Figure 5).

Building on this analysis, the rest of this section traces how the field has evolved through four stages:

1. The initial operational focus.
2. The rise of environmental and regulatory drivers.

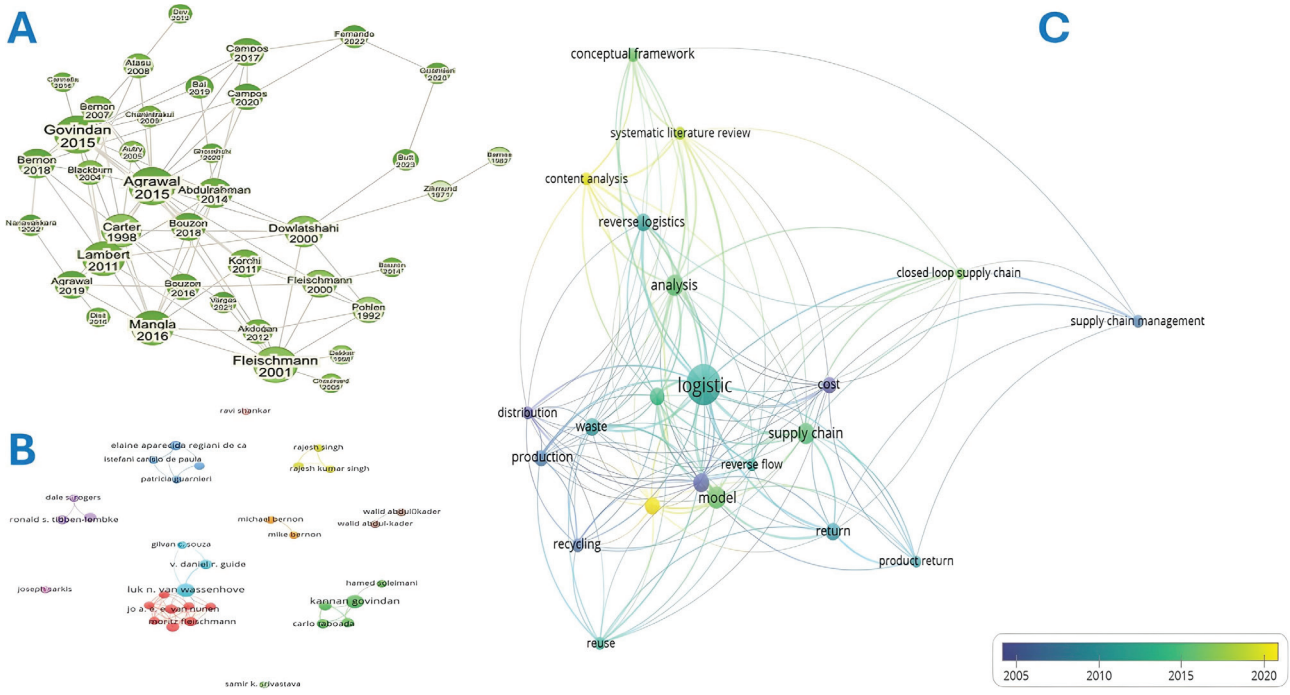

Figure 4. Co-citation, co-authorship, and co-occurrence networks.

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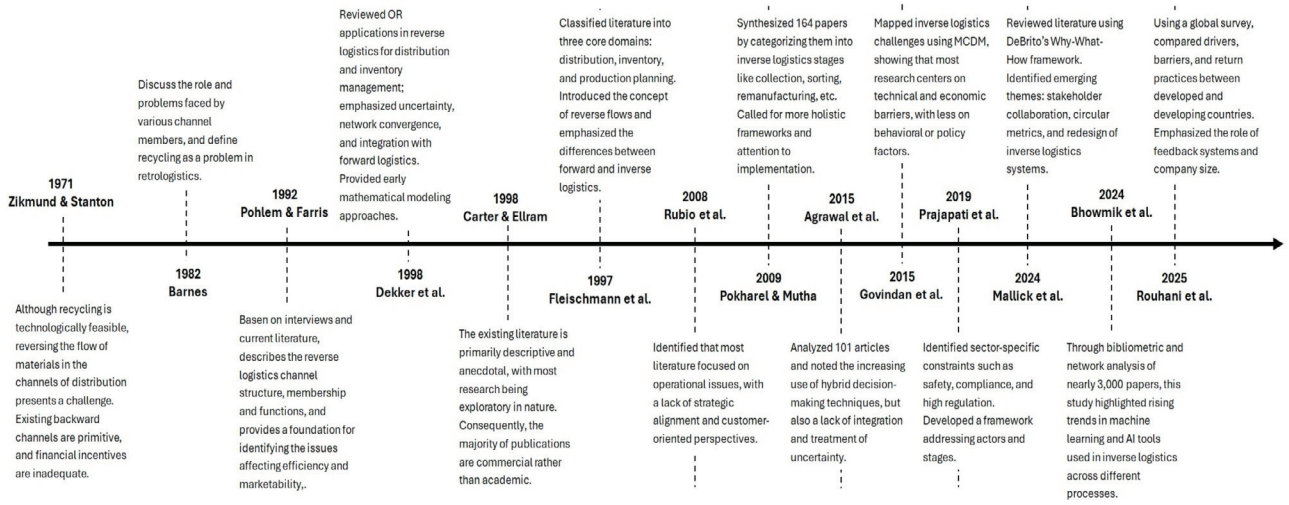

Figure 5. Relevant literature review papers.

3. Its strategic integration into supply chain management.
4. The current focus on the circular economy and digitalization.

Early operational focus (1970s-1980s)

The roots of RL research lie in the operational management of product returns, repairs, recycling, and remanufacturing activities (Zikmund & Stanton, 1971; Barnes, 1982). During this period, reverse flows were generally seen as isolated operational problems, handled within after-sales services, warranty returns, and surplus inventory management (Peronnet, 1979; Schuldenfrei & Shapiro, 1980). Studies at this stage were mostly descriptive, highlighting the importance of managing returned goods efficiently to cut costs and reduce disruptions to forward logistics processes. Formal theoretical development was limited, and RL was rarely recognized as a distinct research area. Early key contributions focused on warranty management and service logistics, inventory control models that included returns and refurbishing, and practical issues in managing defective or surplus products.

Environmental and regulatory drivers (1990s)

The 1990s marked a crucial decade for RL, driven by increased environmental awareness and the adoption of regulatory frameworks, particularly Extended Producer Responsibility (EPR) laws and product take-back mandates in European and Asian markets. During this time, there was a growing recognition among scholars of the environmental and social impacts of RL in managing products at the end of their life cycle.

Pohlen &Farris (1992) conducted one of the earliest systematic studies of RL through their analysis of plastic container recycling systems. Their work laid the theoretical groundwork and highlighted practical challenges in implementation, especially regarding economic feasibility and collection infrastructure. Dekker *et al.* (1998) later summarized operations research contributions to RL, creating conceptual frameworks and quantitative models that specifically tackle distribution planning and inventory management issues. Their work also crucially distinguished RL from traditional forward supply chains and emphasized the unique uncertainties of reverse flows. Together, these foundational studies established key research pillars: Pohlen & Farris (1992) identified economic and operational barriers, while Dekker *et al.* (1998) enhanced modeling techniques for reverse network optimization.

This evolutionary phase saw significant conceptual expansion, including recycling and reuse systems, integrating waste management into supply chains, adopting life cycle assessment methods, and embracing closed-loop supply chain models. Methodologically, researchers developed innovative quantitative models for RL network design, focusing on facility location optimization and cost-effective recycling operations. Fleischmann *et al.* (1997) made key contributions through their detailed taxonomy of RL challenges, classifying problems into distribution planning, inventory control, and production planning, while establishing quantitative modeling approaches for reuse systems. Comparative analyses from this period showed distinct regional drivers: economic factors (e.g., remanufacturing potential) were more influential in U.S. research, while ecological considerations (e.g., regulatory compliance) were more prominent in European studies.

Strategic integration into supply chain management (2000s)

In the 2000s, RL became strategically integrated into supply chain management frameworks. Scholars recognized its potential to improve customer satisfaction, cut costs, and promote sustainability initiatives. Dowlatshahi (2000) established a foundational framework, identifying five strategic and six operational factors, and advocating for the systematic integration of corporate functions. Fleischmann *et al.* (2000) advanced quantitative modeling, comparing network designs (e.g., centralized vs. decentralized) and highlighting methodological gaps between reverse and traditional logistics.

Empirical contributions emerged from Rogers & Tibben (2001), whose U.S. industry survey revealed reactive, customer-driven returns management and a lack of performance metrics. Tibben & Rogers (2002) further contrasted forward and RL, noting the latter's fragmentation and lower prioritization. Tibben (2002) linked returns management to product life cycle stages, emphasizing adaptive strategies for end-of-life phases.

Blackburn *et al.* (2004) was one of the first to strategically frame RL within supply chain management theory, borrowing from Fisher's functional *vs.* innovative product framework. It introduced time-based competition and the concept of preponement as core design principles, moving the field beyond cost-minimization to value-maximization through speed.

Subsequent research refined strategic approaches. Autry (2005) empirically linked return policies and RL capabilities (including returns handling and repair/rework) to program effectiveness, while Richey *et al.* (2005) demonstrated how formalization, policy restrictiveness, and innovation enhanced performance. Chouinard *et al.* (2005) introduced a multi-objective tool for sustainable network design, integrating economic and environmental criteria. Region-specific insights were provided by Srivastava & Srivastava (2006), who modeled returns in India using system dynamics.

Theoretical advancements included Bernon & Cullen's (2007) ICE model (Integration, Collaboration, Evaluation), which highlights the impacts of upstream decisions, and Rubio *et al.* (2008), who called for strategic organizational theories. Pokharel and Mutha (2009) synthesized 164 articles, categorizing research by domain and methodology. Sarkis *et al.* (2010) expanded the discourse by embedding social sustainability into the realm of RL, complementing traditional economic and environmental foci.

Key developments included:

1. Strategic frameworks for integration.
2. Studies linking RL performance to supply chain competitiveness.
3. The rise of closed-loop supply chain models that optimize both forward and reverse flows simultaneously.
4. Early exploration of RL within corporate sustainability and green supply chain initiatives.

Methodologically, the field became more advanced, with empirical research, multi-criteria decision-making, and simulations addressing operational trade-offs. This period established RL as a strategic discipline, connecting theory and practice while advancing sustainability-focused supply chain design.

Expansion and consolidation (2011-2017)

From 2011 to 2017, RL research experienced significant growth and consolidation, with the development of comprehensive, industry-specific frameworks and advanced performance measurement systems. Scholars increasingly aimed to integrate forward and reverse supply chains through closed-loop systems, requiring sophisticated multi-criteria decision-making frameworks to meet the needs of multiple stakeholders and competing objectives (Agrawal *et al.,* 2015; Prajapati *et al.,* 2019).

El Korchi & Millet (2011) made a key contribution by proposing a design framework with 18 generic structures for sustainable RL networks. This clear classification helped organizations align network setups with strategic sustainability goals while taking operational capabilities into account. At the same time, Lambert *et al.* (2011) developed an improved methodological approach using system dynamics modeling, demonstrating how fluctuations in return rates significantly impact inventory management and lead times, and highlighting the importance of robust control mechanisms in RL systems.

Industry-specific research provided key insights, with Akdoğan and Coşkun (2012) applying the Analytic Hierarchy Process (AHP) methodology to identify economic factors and corporate citizenship as main drivers of RL adoption in the household appliance sector. This period also saw increasing recognition of the strategic value of RL, as shown by Nikolaou *et al.* (2013), who found positive links between the implementation of RL and improved Corporate Social Responsibility (CSR) performance in Greek manufacturing.

Technological and analytical advancements made significant strides during this era. Hazen *et al.* (2015) examined the transformative potential of big data analytics in improving returns forecasting and custo-

mer service. Meanwhile, Abdulelahman *et al.* (2014) and Cannella *et al.* (2016) developed sophisticated optimization models to address carbon emissions and closed-loop supply chain dynamics, respectively. These studies demonstrated that environmental considerations fundamentally alter optimal supply chain configurations, often favoring decentralized networks.

The research landscape broadened geographically, with Sobokta & Czaja (2015) examining implementation barriers in Polish companies and Mangla *et al.* (2016) developing context-specific success factors for Indian manufacturers. Behavioral dimensions gained more attention through works like Dixit and Badgaiyan (2016), who expanded the theory of planned behavior to analyze electronic waste return patterns.

Key theoretical and practical contributions of this period included:

1. Advanced performance measurement frameworks integrating qualitative and quantitative metrics (Shaik & Abdul, 2014).
2. Comprehensive analyses of supply chain contracts and coordination mechanisms (Guo *et al.*, 2017). Operational frameworks linking RL activities to key performance indicators (Sangwan, 2017).
3. Life cycle assessment approaches quantifying environmental benefits of RL (Bouzon *et al.*, 2016).

Methodologically, this era witnessed increased sophistication through the combination of hybrid analytical techniques, including AHP with Decision Making Trial and Evaluation Laboratory (DEMATEL) (Mangla *et al.*, 2016), multi-objective optimization (Abdulelahman *et al.*, 2014), and integrated simulation approaches (Cannella *et al.*, 2016). The research collectively advanced RL from an operational consideration to a strategic function embedded within broader sustainability and circular economy objectives.

Circular economy and digitalization era (2018-2025)

The current phase of RL research reflects the growing influence of circular economy principles and digital transformation. Scholars increasingly view RL as a vital enabler of sustainable business models that optimize resource efficiency and reduce environmental impact (Rouhani *et al.*, 2025). This period has seen notable theoretical and methodological progress, with a focus on technological integration and systemic approaches to value recovery.

Theoretical advancements include Bouzon *et al.* (2018), who established a foundational framework for overcoming implementation barriers, highlighting organizational culture and information systems as key internal challenges, while economic instability was identified as a major external constraint. Simultaneously, Bernon *et al.* (2018) improved capability assessment with their maturity model, connecting process improvement to circular economy goals. Methodological innovations featured Agrawal & Singh's (2019) structural equation modeling approach, which empirically linked disposition decisions to triple bottom line performance in India's electronics sector.

Digital technologies have reshaped RL research, with several notable contributions. For instance, Bai and Sarkis (2019) developed a novel Multi-Criteria Decision-Making (MCDM) model that incorporates fuzzy and rough set theories to optimize the selection of third-party providers. de Campos *et al.* (2020) demonstrated how Information Technology (IT) competence and collaboration enhance RL capabilities and economic performance. Butt *et al.* (2024) established the potential of blockchain to improve pharmaceutical RL through enhanced traceability and reduced fraud. Yu and Han (2025) pioneered the application of digital twins for dynamic network optimization in remanufacturing contexts.

Contemporary research employs advanced analytical frameworks, including Ghoushchi and Hushyar (2020), who developed a mixed-integer programming model for joint Third Party Logistics (3PL) and supplier selection; Dev *et al.* (2020) created a closed-loop supply chain model that considers multiple end-of-life options under demand uncertainty; Ayvaz *et al.* (2021) introduced a fuzzy mathematical model for vehicle RL networks; and Sun *et al.* (2022) combined machine learning with environmental impact assessment for medical waste management.

Industry-focused studies have produced significant findings. For instance, Nanayakkara *et al.* (2022) identified barriers in the apparel industry, such as consumer awareness gaps and regulatory hurdles. Mallick *et al.* (2024) created a healthcare-specific framework for medical device RL, and Sonar *et al.* (2024) assessed Industry 4.0 enablers for Indian manufacturing.

Current research highlights four main areas:

1. Circular economy integration: Incorporating RL as a key part of circular business models.
2. Digital transformation: Improving traceability and efficiency using Internet of Things (IoT), blockchain, and Artificial Intelligence (AI).
3. Advanced optimization: Developing models that address sustainability trade-offs and allow for dynamic network reconfiguration.

4. Impact assessment: Thoroughly evaluating social and environmental outcomes.

This era shows impressive interdisciplinary convergence, drawing on insights from environmental science, information systems, and industrial ecology. The field has shifted from an operational focus to strategic systemic thinking, with digital technologies providing unprecedented visibility and responsiveness in reverse supply chains. Research methods have also improved, combining qualitative and quantitative approaches with new computational techniques to tackle complex, multi-stakeholder problems in circular systems.

Thematic research domains

The systematic analysis shows that RL has shifted from being mainly operational to adopting a strategic, systemic approach, characterized by the integration of digital technologies, advanced modeling techniques, and increased responsiveness in reverse supply chains. Building on this evolution, the reviewed literature can be organized into six main research areas. Each area represents different stages of theoretical development and methodological complexity while also addressing practical implementation challenges.

Strategic and organizational design

This domain examines the structural and managerial aspects of RL implementation, highlighting how organizational strategies, governance mechanisms, and cross-functional alignment impact the effectiveness of RL programs. It investigates capability development, policy formulation, and maturity modeling to embed RL within corporate strategy and supply chain integration. This domain stands out as one of the most well-established areas. Foundational studies (Thierry *et al*., 1995; Dowlatshahi, 2000; Rogers & Tibben, 2001) emphasized the need to view RL not merely as an operational burden, but as a strategic capability embedded within broader supply chain and sustainability objectives. Subsequent empirical work reinforced the importance of governance structures (Richey *et al*., 2005), cross-functional coordination, and formalized return policies. Subsequent empirical work reinforced the importance of governance structures (Richey *et al*., 2005), cross-functional coordination, and formalized return policies (Autry, 2005). More recent contributions introduced capability maturity models (Bernon *et al*., 2018) to assess RL integration, analyze organizational barriers and enablers (Bouzon *et al*., 2018) of RL programs' success, and empirically link RL capabilities with firm competitiveness (Fernando *et al*., 2023).

This domain is dominated by qualitative case studies, cross-sectional surveys, and conceptual models, underscoring the need for greater integration with operational and digital perspectives. Most findings derive from large firms or specific industries (e.g., automotive and electronics), thereby limiting their applicability to small and medium-sized enterprises (SMEs) and developing economies. Moreover, limited integration with organizational behavior, change management, and institutional theory constrain a deeper understanding of RL adoption drivers. Although maturity models are evolving, they often fail to incorporate dynamic capabilities that facilitate adaptation to circular economy transitions and digital disruptions.

Network design and optimization

This domain focuses on the quantitative modeling of RL networks, with a focus on designing, configuring, and optimizing the performance of reverse flows. It includes both deterministic and stochastic approaches, considering cost, time, environmental impact, and service levels under uncertainty. This domain is arguably the most mature and quantitatively developed area within the field of RL. Early contributions (e.g., Dekker *et al*., 1998; Fleischmann *et al*., 2000) laid the foundation for modeling reverse flows using facility location and inventory control techniques. Conceptual frameworks that combine descriptive modeling with optimization techniques have also been proposed to design RL networks (Srivastava, 2008). These studies positioned RL as a subset of closed-loop supply chains (Ayvaz *et al*., 2021), where minimizing cost, handling lead time variability, and optimizing recovery options are key decision areas. Building upon this, Dev *et al.* (2020) proposed stochastic network models incorporating remanufacturing, recycling, and multiple echelons. Cannella *et al*. (2016) added a dynamic dimension by applying system dynamics to examine the performance of reverse supply chains under uncertainty. Yun & Han (2025) propose a network design model to optimize facility location, capacity allocation, and transportation, considering system variations such as repair orders, machine utilization, and the number of parts in service and in queue.

Dominated by mathematical optimization, simulation, and algorithmic approaches, this domain offers robust technical depth, although it remains relatively disconnected from insights into organizational and behavioral aspects. Many models assume ideal conditions, often with limited validation, in complex, real-world environments, particularly in informal or under-regulated

economies. Weak links with policy studies, behavioral economics, or urban logistics that impact the feasibility of real-world reverse networks. Additionally, digital tools such as additive manufacturing and cloud-based remanufacturing are only recently being modeled; the integration of digital twins and IoT into network optimization remains underexplored.

Consumer behavior and disposition decisions

This domain investigates the behavioral, psychological, and socio-cultural factors that influence consumer participation in return, recycling, and take-back programs. It also explores how firms make disposition decisions based on product characteristics, cost, regulations, and sustainability goals. This domain is a relatively recent and still-emerging strand of RL research. It moves the analytical lens from systems design to the behavioral drivers behind product returns and post-consumption choices. Dixit & Badgaiyan (2016) applied the Theory of Planned Behavior (TPB) to investigate consumer intentions regarding product returns, revealing the influence of personal norms and behavioral control. Agrawal & Singh (2019) advanced this perspective by linking consumer disposition strategies to triple bottom line outcomes, integrating environmental, economic, and social considerations.

Methodologically, this field relies on survey research, regression analysis, and structural equation modeling, often employing behavioral science frameworks. Yet, the integration of these insights with operational models for returns forecasting, recovery logistics, or digital tracking remains underdeveloped, restricting their usefulness for system-level planning.

Sustainability, circular economy, and environmental performance

This domain positions RL as a key driver of the circular economy, exploring its environmental and social sustainability effects. It examines how RL aids in material recovery, waste reduction, and compliance with green regulations, with increasing focus on lifecycle impacts and multi-criteria trade-offs. This field has become one of the most influential areas of research recently. Scholars have increasingly recognized RL as essential for circular economy strategies, emphasizing product life extension, resource recovery, and waste reduction. Studies by Sarkis *et al.* (2010) and Julianelli *et al.* (2020) have established the links between RL and circularity. Meanwhile, Mangla *et al.* (2016) and Mallick *et al.* (2024) employed MCDM tools, such as AHP, Best-Worst Method (BWM), and fuzzy logic, to rank sustainability obstacles and drivers. The combination of the Natural Resource-Based View (NRBV) and circular economy frameworks has broadened the theoretical basis of this area.

Although these studies are methodologically comprehensive, many remain conceptual or rely on perception surveys, underscoring the need for empirical validation using standardized performance metrics like carbon savings, material circularity, or waste diversion rates. There are few empirical connections between RL practices and specific circular economy metrics such as resource productivity and circularity indicators.

Digitalization and emerging technologies

This domain has gained interest, particularly in post-2015 literature. It examines how digital technologies (e.g., blockchain, big data analytics, digital twins, and IoT) can address traditional RL challenges such as traceability, coordination, and responsiveness. Hazen *et al.* (2015) laid early groundwork by discussing big data applications in RL forecasting, while Butt *et al.* (2024) investigated blockchain-enabled traceability in pharmaceutical returns. Yaspal *et al.* (2023) propose a data-driven digital framework to improve medical waste management. Yu & Han (2025) represent a cutting-edge contribution, proposing a digital twin framework integrated with deep reinforcement learning to dynamically manage remanufacturing processes.

Conceptual frameworks and simulation models dominate this field, often relying on socio-technical systems theory and digital transformation literature. However, most research remains at a theoretical or experimental phase, with limited practical evaluation of technology adoption, system integration, or scalability in real-world logistics settings.

Performance measurement, risk, and decision support models

This domain is a well-established field that intersects with nearly all other domains related to RL. This area addresses the need to evaluate the effectiveness and efficiency of RL systems using multi-dimensional performance indicators. Early work by Shaik & Abdul (2014) proposed a performance measurement model incorporating financial, environmental, and operational Key Performance Indicators (KPI). Subsequent studies, including Sangwan (2017), Kaviani *et al.* (2020), and Guarnieri *et al.* (2020), employed hybrid decision-making models combining fuzzy logic, MCDM, and dashboard-based decision support systems to prioritize improvement actions and manage risk. These contributions have been instrumental in

translating RL strategy into measurable outcomes. Nevertheless, the lack of standardized or universally accepted indicators, especially for environmental and circular economy goals, remains a constraint on benchmarking and policy evaluation. Indicators are often firm-centric and fail to capture multi-stakeholder performance, reinforcing the importance of dynamic, multi-stakeholder metrics in managing RL performance and risk.

Critical challenges & future agenda

Based on the previous analysis, this research identified critical challenges, under-researched areas, and emerging trends, organized into six key research domains. This culminates in a research agenda to guide future inquiry and strengthen the academic and practical impact of the RL field.

Strategic and organizational design

This domain is fundamental to the field but still faces important unanswered questions, such as: how can RL be incorporated into core corporate strategies across various industrial sectors? What are the best governance frameworks to support cross-functional RL integration in decentralized or global supply chains? And how does organizational culture influence the adoption and long-term success of RL systems?

Although maturity models and resource-based perspectives have been proposed, the mechanisms by which RL capabilities develop over time and contribute to strategic differentiation remain poorly understood. Additionally, little is known about how organizational culture, leadership behavior, and cross-functional collaboration influence the successful institutionalization of RL programs. Underexplored areas include longitudinal case studies that track RL integration over long periods, especially in SMEs and service industries. Future research should also explore emerging trends, such as the role of RL in achieving environmental, social, and governance (ESG) goals, as well as its integration into sustainability-focused business models, including product-as-a-service and leasing strategies.

Network design and optimization

The literature in this domain is rich in modeling approaches, yet it continues to face significant challenges. Central questions include: how can RL networks be designed to handle volatile return volumes and uncertain product quality? What is the optimal balance between centralized and decentralized reverse operations in global networks? And how can real-time data streams be integrated into dynamic RL network optimization?

While many studies utilize deterministic and stochastic optimization models, few incorporate real-time adaptability or environmental constraints such as carbon pricing or waste reduction targets. Additionally, there is limited research on the design and performance of RL networks in emerging economies, where logistical infrastructure and regulations differ considerably from those in developed countries. Despite its significance, optimizing urban RL, particularly within the context of circular cities and last-mile recovery, remains underexplored. Emerging trends, such as AI-driven analytics, digital twins, and real-time sensing technologies, offer promising opportunities to develop more resilient and adaptive RL networks.

Consumer behavior and disposition decisions

This domain, while becoming more relevant, still lacks depth and breadth in its analytical scope. Key questions include: what psychological, cultural, and contextual factors most significantly influence consumers' participation in return and recovery programs? And how do these factors vary across different demographic and geographic groups?

While existing research utilizes behavioral theories like the TPB, studies often fall short of connecting behavioral intentions with actual return behaviors observed through firm-level or platform data. Underexplored areas include the influence of trust, perceived convenience, and digital touchpoints in guiding return decisions, especially in omni-channel retail environments. Additionally, few studies examine how consumers react to sustainability-related cues or incentives embedded in RL processes. Future research could focus on integrating behavioral economics and digital marketing strategies to create return-systems that actively promote sustainable consumer behavior.

Sustainability, circular economy, and environmental performance

This domain is key to the strategic value of RL, yet several important gaps still exist. One urgent question is how to effectively measure and verify the circularity and sustainability effects of RL activities using standardized metrics. Although many studies support the role of RL in reducing waste and increasing resource efficiency, there is a lack of strong empirical data to back these claims, especially regarding lifecycle carbon impacts or material recovery rates. Additionally, trade-offs between economic, environmental, and social

objectives in RL systems are seldom modeled or empirically evaluated. Under-explored areas include sector-specific circularity metrics, the application of lifecycle assessment (LCA) in reverse flow analysis, and how RL contributes to corporate climate transition plans. Future research should focus on designing RL systems that enable the complete separation of economic growth from environmental harm, while also meeting science-based sustainability goals.

Digitalization and emerging technologies

This domain has experienced growth in conceptual development but remains limited in empirical research. Key unanswered questions include how to address the organizational, technical, and economic challenges of implementing digital RL technologies such as blockchain, IoT, and AI. There is a limited understanding of the interoperability issues and return-on-investment considerations that companies face when digitizing reverse flows. Additionally, the effects of digital RL on data privacy, cybersecurity, and labor displacement have not been thoroughly explored. Under-explored areas include the empirical validation of digital twin platforms, predictive analytics for return forecasting, and AI-powered triage and disposition decision-making systems. Future research is likely to be shaped by trends such as the integration of digital technologies into comprehensive RL platforms and the application of machine learning for anomaly detection, failure prediction, and autonomous return management.

Performance measurement, risk, and decision support models

This domain has made significant contributions but still needs better alignment with broader sustainability and resilience goals. Key questions include which performance indicators can provide a comprehensive and comparable evaluation of RL effectiveness across industries and regions. Although hybrid MCDM methods and fuzzy logic models are widely used, standardized and actionable KPI frameworks, especially those aligned with circular economy principles and ESG reporting, remain underdeveloped. Additionally, the ability of RL systems to adapt to risk and uncertainty, such as supply chain disruptions caused by geopolitical or climatic shocks, is rarely included in performance evaluation frameworks. Under-researched areas include real-time decision support systems that combine risk modeling, stakeholder feedback, and dynamic data streams. Future research should aim to develop intelligent dashboards and simulation platforms to facilitate multi-objective decision-making under uncertainty, aligning operational metrics with strategic sustainability goals.

Conclusions

The reviewed literature shows that RL has experienced significant development, evolving from a reactive cost center to a strategically embedded function essential to sustainable and circular supply chain management. The field is organized around six main areas: strategic and organizational design, network optimization, consumer behavior, sustainability integration, digital transformation, and performance measurement, each showing different levels of maturity and scholarly focus. While areas such as network optimization and organizational design are well-developed, others, like digitalization and behavioral integration, are still emerging but quickly growing in importance.

The literature shows significant methodological diversity, including mathematical optimization, simulation models, behavioral surveys, and multi-criteria decision-making tools. However, several common limitations remain. These include the lack of long-term and comparative studies, limited empirical validation of sustainability results, fragmented integration of behavioral and digital insights, and underrepresentation of developing economies and informal systems. Additionally, despite the increasing focus on the circular economy and Industry 4.0, few studies thoroughly evaluate real-world RL practices or address organizational, cultural, and infrastructural barriers to scalable implementation.

To bridge these gaps, the future research agenda must prioritize interdisciplinary integration and empirical depth. Scholars should focus on developing frameworks that connect strategic intent with operational execution, behavioral motivation with logistics system design, and digital capabilities with measurable sustainability outcomes. There is a pressing need for robust metrics that align RL evaluation with circularity principles and ESG standards. Furthermore, as global supply chains face increasing disruption and scrutiny, RL systems must be rethought not only as tools for waste recovery but also as mechanisms for resilience, agility, and value renewal.

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