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Systematic Review

Mapping the Transition to Automotive Circularity: A Systematic Review of Reverse Supply Chain Implementation

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Abstract

The automotive industry's shift to a Circular Economy for global sustainability is vital, but it faces challenges when establishing efficient Reverse Supply Chains. Reverse Supply Chain implementation is dependent on multiple barriers and enablers, including eco-nomic, managerial, technological, regulatory, and social domains, thus making single-factor solutions ineffective. The purpose of this review is to conduct a systematic literature review to understand how these interconnected barriers and enablers can collectively shape Reverse Supply Chain implementation and performance, specifically within the automotive sector, which remains little known. The PRISMA framework was utilised, which resulted in 129 peer-reviewed articles being selected for review. Findings showed that the literature focuses primarily on Electric Vehicle batteries within developing economies, particularly China. Reverse Supply Chain implementation is governed not only by isolated barriers but by complex systemic interdependencies between enablers as well. This complex interrelationship between barriers and enablers can be categorised into five key dimensions: economic and financial; managerial and organisational; technological and infrastructural; policy and regulatory; and market and social. The study reveals two systemic patterns driving the transition: technology–policy interdependence and the conflicting relationship between large-scale production and value extraction. Our findings also presented a research agenda focusing on strategic value creation through material streams of automotive electronics, plastic, and composites with high potential value, and further insights are needed in regions such as the Middle East, Oceania, and the Americas. Organisations should consider Reverse Supply Chain as a strategic approach for securing critical material supplies, while policymakers could leverage the use of digital tools as the foundational infrastructure for subsidies allocation and prevent fraud.

Keywords: circular economy; reverse supply chain; reverse logistics; enabler; barrier; automotive industry

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1. Introduction

The Circular Economy (CE) functions as a sustainability framework which replaces the traditional linear "take-make-waste" system [1]. The CE is defined as an economic system that is restorative and regenerative by design [2,3], while Blomsma and Brennan [4] modified its mission to boost resource productivity through the resource loop strategy of slowing down resource use and loop closure and reduction. This modern approach stands in distinct contrast to the linear model of presenting unsustainability linking to the foundational metaphor of a "cowboy economy", an economy assuming limitless resources and capacity for pollution within the finite constraints of a "spaceship Earth" [5]. The CE presents an alternative economic framework that establishes a design-based system for product and material preservation to always maintain their maximum value and utility [2].

Currently, the world urgently needs to make this change because municipal solid waste production has reached 2.3 billion tonnes per year, and it is predicted to reach 3.8 billion tonnes by 2050 [6]. Although the CE concept receives increasing recognition, the state of its implementation shows limited progress, with only 9% circularity operating under the global economy [7], highlighting a critical gap between ambition and implementation. The global economy depends on this industry because it produces and uses enormous amounts of resources: half of global oil supplies, 20% of steel, and 10% of aluminium [8]. The worldwide vehicle market reached its highest sales point of 91 million units in 2019, which resulted in quick vehicle replacement and substantial waste from end-of-life vehicles (ELVs) [9]. Only in the EU, the automotive industry has generated around 6 million tonnes per year of waste from ELVs in recent years, peaking at 6.9 million in 2019 [10], which contains complex combinations of steel, plastics, and hazardous materials, showing a significant environmental management challenge [11]. The automotive sector needs to solve a significant sustainability problem because it deals with massive material quantities, which makes it essential to test circular solutions. The global situation requires CE to present itself as a strategic solution to these major difficulties. Not only being a mere environmental responsibility, CE principles will also support the automotive industry alone to create between USD 475 and 810 billion in economic value, specifically for remanufacturing and refurbishment, and material recovery that will surpass environmental standards by 2030 [12].

However, this transformative vision cannot be realised without a strong operational backbone. The practical implementation of CE hinges on the effectiveness of Reverse Supply Chain (RSC) and Reverse Logistics (RL) systems designed to manage the return and recovery of products, components, and materials [13]. While often used interchangeably, it is crucial to distinguish between these concepts. RL refers to the process of planning and controlling the efficient, cost-effective flow of materials from the point of consumption back to the point of origin to recapture value or ensure proper disposal [14]. RSC, in contrast, adopts a broader, more strategic perspective, encompassing the entire network of actors and processes dedicated to creating and capturing value from these return flows [15]. In essence, RL provides the operational engine for the backward flow, while RSC represents the primary strategic framework that drives it towards achieving circularity. The research field has indeed matured significantly, evolving from an initial focus on operational problems to a broader, more strategic understanding of closed-loop supply chains (CLSCs) as models for value creation [15]. Comprehensive reviews have provided invaluable overviews of RL and CLSC in the literature, mapping its theoretical landscape and common methodologies [16,17]. However, a critical gap persists. While these reviews contribute to analysing reverse flows across multiple industries or focusing on conceptual evolution, they predominantly present a list of implementation factors in isolation. Consequently, a comprehensive and systematic understanding of RSC and RL implementation specifically within the contemporary automotive sector is lacking. This fragmented perspective fails to capture the causal mechanisms that shape the industry's transition, for instance, how regulatory uncertainty can directly impact financial risk. The literature lacks a consolidated map of the interconnected barriers and enablers that collectively shape performance in this unique industrial context. What is needed, and what this review provides, is a holistic synthesis that moves beyond listing discrete factors to reveal their systemic interconnections. By shifting the attention from identifying individual factors to examining their interaction, this study addresses the limitations of single-factor analyses and provides a more integrated perspective for highlighting implementation challenges.

To address this gap, this systematic literature review (SLR) presents a comprehensive evaluation of academic research from the past eleven years (2014–2024) on RSC and RL implementation within the automotive industry's CE framework. In addition, to facilitate a structured and enquiry-driven analysis, this review's aims are framed as specific research questions (RQs). These RQs are intended to guide the reader through a coherent progression of the topic and discussion, ensuring that the gaps identified in the literature are addressed. These two RQs are as follows:

RQ1: What are the systemic interconnections among the principal barriers and enablers identified?

RQ2: What overarching systemic patterns and evolutionary dynamics characterise the automotive industry's transition towards a Circular Economy through the implementation of Reverse Supply Chain/Reverse Logistics?

This research stands apart from previous studies because it combines operational and strategic aspects of reverse flows, which apply to the market conditions. It extends previous studies by examining more environmental impacts, which recycling facilities produce [11], studying RL in various sectors [16], or exploring the conceptual evolution of CLSC before our period of study [15]; this review makes several distinct contributions. The research achieves three main objectives through this study: (i) developing a detailed conceptual framework which presents how RSC performance factors relate to each other through their systemic connections; (ii) discovering essential high-level patterns and evolutionary mechanisms which control the field; (iii) evaluating analysed research status to determine essential geographical and component-specific knowledge gaps.

To build a strong analysis further from the theoretical perspective and effectively navigate the complex landscape outlined in the introduction, this review is grounded in a synthesis of established and evolving concepts. It is crucial to recognise that the studies surrounding RSC and RL did not emerge in isolation to effectively situate this review. Instead, it is deeply embedded within the broader intellectual evolution of sustainability-oriented supply chain management. Beginning with Green Supply Chain Management, which focuses on integrating environmental thinking into all stages of the supply chain, from green design to end-of-life management [18], it was further broadened into Sustainable Supply Chain (SSC) Management, which expands the scope to incorporate the "triple bottom line" by balancing economic, environmental, and social performance [19]. This clear evolution from a narrower environmental focus to a comprehensive sustainability perspective directly informs and validates the rationale for this study's five-dimensional keyword search strategy. By designing the search to capture literature from these related but distinct paradigms, this review ensures comprehensive and theoretically sound coverage of the field. To fully appreciate the developments of the last decades, it is essential to understand the foundational work upon which recent research has been built. Seminal works provided the essential vocabulary, with Thierry et al. [20] creating a foundational typology of product recovery options (e.g., repair, remanufacturing, and recycling) and Rogers and Tibben-Lembke [14] offering one of the most widely adopted definitions of RL. This early period was also characterised by a strong focus on operational challenges, with influential reviews such as Fleischmann et al. [21] systematically mapping the quantitative models used to solve complex problems in distribution, inventory, and production planning for return flows. After maturing the field, scholars began to trace its intellectual trajectory, with Guide and Van Wassenhove [15] providing a definitive historical perspective on the evolution of CLSC research. This foundational era reached a peak in critical reviews, such as that by Souza [17], which synthesised the state of knowledge and called for a move beyond

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purely mathematical models towards more empirical work and a deeper understanding of strategic issues.

2. Materials and Methods

As illustrated in Figure 1, this review study follows established SLR frameworks [22] and applies a rational SLR methodology aligning with the PRISMA statement for maintaining transparency and achieving reproducibility (see Supplementary Materials) [23]. The review protocol was not registered.

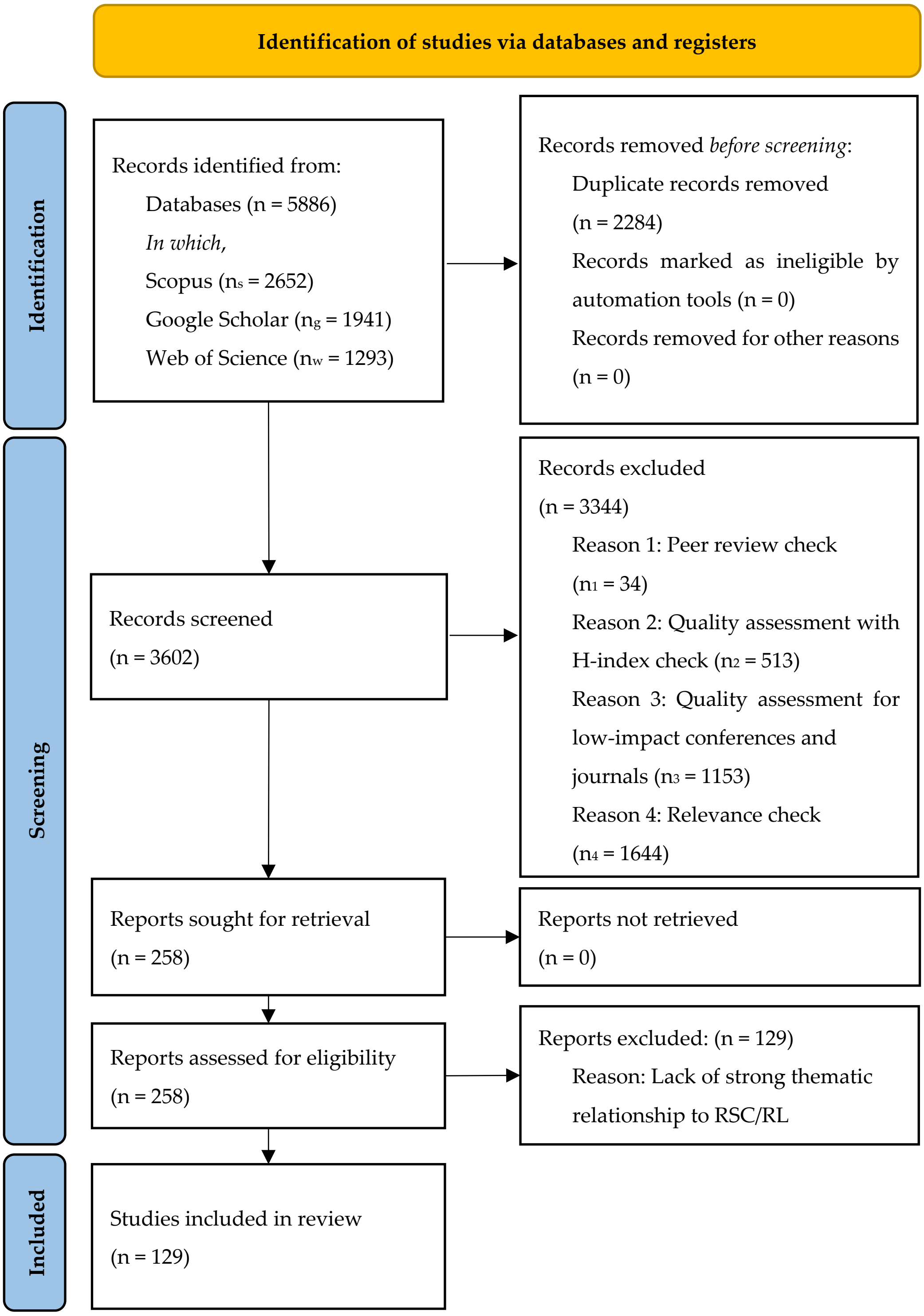

Figure 1. PRISMA 2020 flow diagram.

2.1. Searching Strategy

This study established a five-dimensional keyword search system to execute full literature retrieval according to PRISMA guidelines for explicit search strategies (Item 7). The search included three prominent academic databases, Google Scholar, Scopus, and Web of Science, to achieve maximum coverage and reduce indexing bias according to PRISMA recommendations for information sources (Item 6). The complete search protocol describes the hierarchical system which retrieves essential RSC/RL studies as well as broader sustainability research.

To ensure precision and relevance, the search strategy was tailored to the specific indexing capabilities of each database. For Scopus and Web of Science, it was applied to the Title, Abstract, and Keywords fields. In contrast, due to the search interface limitations of Google Scholar, it was restricted to the Title field only. To align with the review's scope, the retrieval results were strictly filtered to include only publications written in English and published between 2014 and 2024. Then, five distinct thematic dimensions were structured to capture the comprehensiveness and transdisciplinary nature of the field: (1) "Reverse Supply Chain" OR "Reverse Logistics"; (2) "Reverse Distribution"; (3) "Closed-loop Supply Chain"; (4) "Green Supply Chain"; and (5) "Sustainable Supply Chain". To ensure specific relevance to circularity within the broader sustainability (supply chain) dimensions (3, 4, and 5), these terms were constrained by using specific terms of "Recycle" OR "Recycling" OR "Return". This comprehensive retrieval process yielded a total of 5886 records, distributed as follows: 1941 records of Google Scholar, 2652 records of Scopus, and 1293 records of Web of Science. Following a rigorous cross-database deduplication process, 2284 duplicate records were excluded, resulting in a final consolidated pool of 3602 publications that proceeded to the screening phase.

2.2. Screening Process

This review employed a PRISMA-guided multi-level screening protocol. The 3602 publications from the duplicate removal process entered a five-stage screening process, which evaluated both their quality and relevance. This protocol defines a specific method for the Selection Process (Item 8) through its stages, while the Eligibility Criteria (Item 5) continues to be applied at every stage. The ranking system and relevant indicators in this protocol refer to SCImago Journal and Country Rank [24].

2.2.1. Peer-Reviewed Assessment

This initial process's primary goal is to evaluate conference publications for selecting full papers from peer-reviewed proceedings. The research excluded all sources that do not undergo peer review, including dissertations, conference abstracts, and presentations. At this stage, 34 such publications were excluded, leaving 3568 articles for the next level of assessment. The peer-review standard for conference materials was confirmed at this point, but the Second Quality Assessment functioned as a further step to ensure peer-review quality for journal articles.

2.2.2. Quality Assessment

For journal articles, only Q1 and Q2 quartile journals are selected, since they represent the top 50% in a specific subject category, which indicates significant influence, rigorous peer review, and strong editorial standards [24]. As for conference proceedings/papers, a two-stage quality assessment approach utilising both the H-index and the SJR indicator is used, which is aimed at mitigating the inherent statistical instability found in single-metric evaluation, whereby citation-based indicators may exhibit extreme skewness, in which a small fraction of publications accounts for the vast majority of impact [25].

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The first stage of the filtering process adopts the median H-index as the primary exclusion criterion. According to Kiesslich et al. [25] and Bornmann, Leydesdorff, and Mutz [26], the mean is an unsuitable measure of central tendency for skewed bibliometric data because it is disproportionately influenced by extreme outliers, which is evident in this study with a heavily skewed result (MRD 308.93%). Thus, the median H-index value of ≥49 provides a more robust non-parametric "centre" that represents the typical performance of the Q2 journal baseline without being skewed by top-tier outliers. Utilising the median value as a core filter ensures that the selected conferences meet the base threshold of the majority of Q2 journals. This first quality filter eliminated 513 papers, which left 3059 publications in the pool.

The second stage involves the use of a refined SJR threshold value of ≥0.497, which is derived from the formula $\mu - 0.5\sigma$ rather than the sample's minimum Q2 journal median or mean value. This is supported by the Percentile Rank Classes methodology, calculating $\mu - 0.5\sigma$, which serves as a Robust Truncation method to identify the "Core Excellence Cluster" of the sample [26]. Therefore, the SJR value of 0.497 indicates a better representation of the Q2 journal quality standard. This benchmark system removed 1153 more papers from the analysis, which resulted in 1902 articles for content relevance assessment.

2.2.3. Content Relevance Assessment

This last filtering phase contains two stages to consolidate the rigour of analysing the literature. First, the remaining set needed screening for automotive sector relevance with automotive-related keywords (e.g., vehicle, automobile, automotive, and ELV) to the literature's research targets. This step removed 1644 papers from the analysis because of a lack of concentration on the automotive industry, which resulted in a set of 258 highly industry-relevant articles. Second, a complete text evaluation of 258 articles confirmed their strong thematic relationship with RSC/RL. This last filtering process removed 129 additional papers and constructed a pool of 129 publications to be analysed in the following sections.

2.3. Data Extraction Process

The final set of 129 papers, consisting mainly of journal articles (95.35%), addressed a systematic data extraction process based on items 9 and 10 of the PRISMA guidelines. A full extraction framework was utilised to extract bibliometric data and extract useful information. The framework contained multiple essential categories, which structured data into Bibliometric Information (e.g., year and journal), Contextual Information (e.g., geography, keywords, industry sub-sector, and methodology), Stakeholder Focus (e.g., business, consumer, and government), and Conceptual Information (e.g., theoretical foundations, identified barriers and enablers, and key findings). This study first tested the framework on a few papers before applying it to the complete document set to check for accuracy and consistency. It performed data coding for each paper while conducting frequent reliability checks to ensure accuracy. This structured dataset formed the foundation for the thematic synthesis and analysis presented in Sections 3 and 4.

3. Results and Analysis

Table 1 presents a brief overview summary of the 129 studies included in the systematic literature review.

Table 1. Overview summary of the studies included in the systematic review.

Study	Country/Region	RSC Sector	Type of Component	Stakeholders Focus	Methodology
Zhang et al., 2023 [9]	Not specify	Collection, Reuse, Remanufacturing, Recycling, Waste Management/Disposal	Multi-components	Business; Consumer; Government	Systematic literature review
Abdulrahman et al., 2014 [27]	China	Collection, Reuse, Remanufacturing, Recycling, Waste Management/Disposal	Multi-components	Business	Quantitative
Demirel et al., 2016 [28]	Turkey	Collection, Remanufacturing, Reuse, Recycling, Waste Management/Disposal	Multi-components	Consumer; Business; Government	Quantitative Case study
Yao 2024 [29]	China	Collection, Remanufacturing, Recycling, Waste Management/Disposal	Multi-components	Consumer; Business	Quantitative Case study
Zhang et al., 2024 [30]	China	Collection, Reuse, Recycling, Remanufacturing	EV batteries	Business; Consumer; Government	Quantitative
Xiao et al., 2024 [31]	Not specify	Collection, Recycling, Remanufacturing	EV batteries	Business; Consumer	Quantitative
Liu & Wang 2021 [32]	China	Collection, Recycling, Remanufacturing	EV batteries	Government; Business; Consumer	Quantitative
Zhu & Li 2020 [33]	China	Collection, Recycling, Remanufacturing	EV batteries	Business; Consumer; Government	Quantitative
Shankar et al., 2018 [34]	India	Collection, Remanufacturing, Recycling, Manufacturing	Multi-components	Business; Consumer	Case Study Quantitative
He et al., 2020 [35]	Not specify	Collection, Reuse, Remanufacturing, Recycling, Waste Management/Disposal (scope of literature review)	Multi-components	Consumer; Business; Government	Systematic literature review
Forouzanfar et al., 2018 [36]	Iran	Manufacturing, Collection, Remanufacturing, Recycling	Multi-components	Business; Consumer	Quantitative
Xiao et al., 2019 [37]	China	Collection, Remanufacturing, Recycling, Waste Management/Disposal	Multi-components	Government; Business; Consumer	Quantitative Case study
Xiao et al., 2024 [38]	China	Collection, Recycling, Remanufacturing	EV batteries	Business; Consumer; Government	Quantitative
Gao et al., 2023 [39]	China, Japan, EU	Collection, Reuse (cascade use implied), Recycling, Remanufacturing	EV batteries	Government; Business	Quantitative

Table 1. *Cont.*

Study	Country/Region	RSC Sector	Type of Component	Stakeholders Focus	Methodology
Wu et al., 2022 [40]	China	Collection, Reuse, Recycling, Remanufacturing	EV batteries	Business; Consumer; Government	Quantitative
Trivyza et al., 2022 [41]	EU	Collection, Recycling, Manufacturing	Carbon Fibre Reinforced Plastics	Business; Government	Quantitative
Dhouib 2014 [42]	Tunisia	Recycling, Reuse, Waste Management/Disposal	Tyres	Business; Government; Others	Quantitative Case study
Chaabane et al., 2021 [43]	Canada	Collection	Multi-components	Business; Government	Quantitative Case study
Jindal & Sangwan 2015 [44]	India	Collection	Multi-components	Business; Consumer	Quantitative Case study
Ma et al., 2024 [45]	China	Collection, Reuse, Recycling	EV batteries	Consumer; Business; Government	Quantitative Case study
Karagoz et al., 2020 [46]	Not specify	Collection, Reuse, Remanufacturing, Recycling, Waste Management/Disposal (scope of literature review)	Multi-components	Business; Government	Systematic literature review
Karagoz et al., 2022 [47]	Turkey	Collection, Reuse/Remanufacturing, Recycling, Waste Management/Disposal	Multi-components	Consumer; Business; Government	Quantitative Case study
Klenk et al., 2022 [48]	Turkey	Collection, Remanufacturing	Multi-components	Business	Qualitative Conceptual/Theoretical Analysis
Lind et al., 2014 [49]	Germany, Sweden, Spain	Remanufacturing, Collection	Multi-components	Business	Quantitative Case study
Subramanian et al., 2014 [50]	China	Collection, Remanufacturing, Recycling, Waste Management/Disposal	Multi-components	Business; Government; Consumer	Qualitative Case Study
Kaviani et al., 2020 [51]	Iran	Collection, Reuse, Remanufacturing, Recycling, Waste Management/Disposal (scope of barrier analysis)	Multi-components	Business; Government; Others	Qualitative Quantitative
Lin et al., 2023 [52]	China	Collection, Reuse, Remanufacturing, Recycling, Waste Management/Disposal	EV batteries	Business; Government	Quantitative Case study

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Table 1. *Cont.*

Study	Country/Region	RSC Sector	Type of Component	Stakeholders Focus	Methodology
Ravi 2014 [53]	India	Collection (warranty returns), Waste Management/Disposal (current primary outcome), Remanufacturing, Recycling	Multi-components	Business; Consumer	Qualitative Case Study
Azadnia et al., 2021 [54]	EU	Collection, Reuse, Remanufacturing, Recycling, Waste Management/Disposal	Batteries	Business; Government; Others	Qualitative
Gardas et al., 2018 [55]	Iran	Collection, Recycling	Used-oil recovery	Government; Business; Consumer	Qualitative
Grandjean et al., 2019 [56]	UK	Collection, Reuse, Remanufacturing	EV batteries	Business; Government	Quantitative Experimental
Ravi & Shankar 2017 [57]	India	Collection, Reuse, Remanufacturing, Recycling, Waste Management/Disposal	Multi-components	Business; Government; Consumer; Others	Qualitative
Ene & Öztürk 2017 [58]	Turkey	Collection	Multi-components	Business; Government; Consumer	Quantitative
Marcos et al., 2021 [59]	Not specify	Manufacturing, Collection, Reuse, Recycling	EV batteries	Business; Government	Qualitative
Scur et al., 2022 [60]	Brazil	Manufacturing, Collection, Recycling	Lead-Acid Batteries	Business; Government	Qualitative Case Study
Trang & Li 2023 [61]	Not specify	Collection, Reuse, Remanufacturing, Recycling, Waste Management/Disposal	Multi-components	Business; Government; Consumer	Systematic literature review
Daaboul et al., 2014 [62]	EU	Recycling, Collection	Multi-components	Business; Others	Quantitative Case study Conceptual/Theoretical Analysis
Demirel et al., 2014 [63]	Not specify	Manufacturing, Consumption/Use, Collection, Remanufacturing, Recycling, Waste Management/Disposal	Not specify	Business	Quantitative
Kuşakcı et al., 2019 [64]	Turkey	Collection, Reuse, Recycling, Waste Management/Disposal	Multi-components	Business; Government	Quantitative Case study

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Table 1. *Cont.*

Study	Country/Region	RSC Sector	Type of Component	Stakeholders Focus	Methodology
Li et al., 2018 [65]	US	Remanufacturing, Collection, Recycling, Waste Management/Disposal	EV batteries	Business	Quantitative Conceptual/Theoretical Analysis
Özceylan et al., 2017 [66]	Turkey	Manufacturing, Collection, Remanufacturing (component recovery), Recycling, Waste Management/Disposal	Multi-components	Business; Consumer; Government	Quantitative Case study Conceptual/Theoretical Analysis
Ghasemzadeh et al., 2021 [67]	Iran	Manufacturing, Collection, Remanufacturing (retreading), Recycling, Waste Management/Disposal	Tyres	Business; Government	Quantitative Case study
Omosa et al., 2023 [68]	Malaysia, Poland, Japan, Romania, UK, Kenya, Cameroon	Collection, Remanufacturing (dismantling), Recycling	Multi-components	Business; Government; Consumer; Others	Qualitative Quantitative
Chavez & Sharma 2018 [69]	Mexico, Japan	Collection, Recycling	PET Components (seat textiles)	Business; Consumer; Government; Others	Case Study Qualitative Quantitative
Guan et al., 2023 [70]	China	Collection, Reuse, Recycling, Remanufacturing	EV batteries	Business; Government	Quantitative
Zhang et al., 2023 [71]	China, Japan, EU	Collection, Reuse (repurposing implied), Recycling, Remanufacturing	EV batteries	Consumer; Business; Government	Quantitative Conceptual/Theoretical Analysis
Zhang et al., 2024 [72]	China	Collection, Reuse, Remanufacturing	EV batteries	Business; Consumer; Government	Quantitative Case study
Zhou et al., 2018 [73]	China	Collection, Remanufacturing, Recycling, Waste Management/Disposal	Multi-components	Business; Government	Quantitative Case study Conceptual/Theoretical Analysis
Bouvier et al., 2024 [74]	EU	Collection (packaging), Manufacturing, Consumption/Use (packaging logistics)	Packaging	Business; Others	Quantitative Case study

Table 1. *Cont.*

Study	Country/Region	RSC Sector	Type of Component	Stakeholders Focus	Methodology
Bag & Gupta 2020 [75]	South Africa	Collection, Remanufacturing, Recycling, Manufacturing (human capital aspect)	Multi-components	Business; Others	Quantitative
Bajar et al., 2024 [76]	Not specify	Collection, Remanufacturing, Recycling	Multi-components	Business; Consumer; Government	Quantitative Qualitative
da Cruz et al., 2022 [77]	Brazil	Manufacturing, Consumption/Use (Packaging logistics)	Packaging	Business	Quantitative Qualitative
Wu et al., 2015 [78]	Vietnam	Recycling, Collection, Manufacturing	Multi-components	Business; Government; Others	Quantitative
Pinho Santos & Proença 2022 [79]	Portugal	Collection, Reuse, Remanufacturing, Recycling (Strategic/Policy level)	Multi-components	Business; Government	Qualitative
Zhu & Yu 2019 [80]	China	Collection, Recycling, Remanufacturing	EV batteries	Business; Government	Quantitative
Garrido-Hidalgo et al., 2020 [81]	Spain	Collection, Reuse, Remanufacturing, Recycling (focus on enabling information systems)	EV batteries	Business; Government	Case Study Qualitative
Casper & Sundin 2018 [82]	Germany, France, Sweden	Collection, Remanufacturing	Engine gearboxes	Business; Government	Qualitative Conceptual/Theoretical Analysis
Sorooshian et al., 2024 [83]	Asia	Manufacturing, Collection, Remanufacturing, Recycling	EV batteries	Business; Government	Quantitative Case study
Xing & Yao 2022 [84]	China	Collection, Reuse, Recycling	EV batteries	Business; Consumer; Government	Quantitative
Lin et al., 2018 [85]	China	Collection, Remanufacturing, Recycling	Multi-components	Business	Quantitative
Zarbakhshnia et al., 2018 [86]	Iran	Collection, Remanufacturing, Recycling	Multi-components	Business; Government; Others	Quantitative
Alkahtani & Ziout 2019 [87]	Saudi Arabia	Collection, Remanufacturing	Proton Exchange Membrane Fuel Cell Batteries	Business; Government; Others	Quantitative Case study
Yang et al., 2022 [88]	China	Collection, Remanufacturing, Recycling (as 3PRLP services)	EV batteries	Business; Consumer; Government	Quantitative Conceptual/Theoretical Analysis

Table 1. *Cont.*

Study	Country/Region	RSC Sector	Type of Component	Stakeholders Focus	Methodology
Son et al., 2022 [89]	Germany	Collection, Remanufacturing	Multi-components	Business; Consumer	Qualitative Conceptual/Theoretical Analysis
Scheller et al., 2023 [90]	EU, UK, Turkey	Manufacturing, Collection, Reuse (repurposing), Recycling	EV batteries	Business; Government	Quantitative Case study
Zheng et al., 2025 [91]	China	Collection, Remanufacturing, Recycling (as 3PRLP services)	EV batteries	Business; Government	Quantitative Qualitative
Tan et al., 2023 [92]	China	Collection, Recycling	EV batteries	Business; Consumer; Government	Quantitative Case study
Wang et al., 2024 [93]	China	Collection, Remanufacturing, Recycling (logistics focus)	Multi-components	Business; Government	Quantitative Case study
Liao & Luo 2022 [94]	China	Collection, Remanufacturing, Recycling, Waste Management/Disposal	EV batteries	Business; Government	Quantitative
Govindan & Gholizadeh 2021 [95]	Iran	Collection, Reuse/Remanufacturing, Recycling, Waste Management/Disposal	Multi-components	Consumer; Business; Government	Quantitative Case Study
Hamidi Moghaddam et al., 2021 [96]	Iran	Manufacturing, Collection, Remanufacturing, Waste Management/Disposal	Multi-components	Business; Consumer	Quantitative Conceptual/Theoretical Analysis Case Study
Kumar Jauhar et al., 2024 [97]	India	Collection, Recycling, Remanufacturing	EV batteries	Business; Government; Consumer	Quantitative
Sathiya et al., 2021 [98]	India	Collection, Reuse/Remanufacturing (repair for resale)	Multi-components	Business	Conceptual/Theoretical Analysis Quantitative Case Study
Phuc et al., 2017 [99]	EU, Japan, China	Collection, Reuse, Remanufacturing, Recycling, Waste Management/Disposal	Multi-components	Consumer; Business; Government	Quantitative
Hao et al., 2018 [100]	China	Collection	Multi-components	Business; Government	Quantitative
Abdolazimi et al., 2020 [101]	Iran	Manufacturing, Collection, Recycling, Waste Management/Disposal	Tyres	Business; Consumer	Quantitative Case study

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Table 1. *Cont.*

Study	Country/Region	RSC Sector	Type of Component	Stakeholders Focus	Methodology
Shahparvari et al., 2021 [102]	Iran	Collection, Recycling, Waste Management/Disposal, Remanufacturing	Multi-components	Business; Government	Quantitative
Hao et al., 2021 [103]	China	Collection (recall), Reuse (echelon use)	EV batteries	Business; Government	Quantitative
Dehghani Sadrabadi et al., 2024 [104]	Iran	Collection, Recycling, Remanufacturing	EV batteries	Business; Consumer; Government	Quantitative Case study
Mu et al., 2023 [105]	China	Collection, Reuse, Remanufacturing, Recycling, Waste Management/Disposal	EV batteries	Business; Consumer; Government	Quantitative
Chen et al., 2024 [106]	China	Manufacturing, Collection, Remanufacturing, Recycling	Multi-components	Consumer; Business; Government	Quantitative
He et al., 2024 [107]	China	Collection, Reuse, Remanufacturing, Recycling, Waste Management/Disposal	Multi-components	Consumer; Business; Government	Quantitative Case study
Tian et al., 2019 [108]	China	Collection	Multi-components	Government; Business; Others	Quantitative
Gorji et al., 2021 [109]	Iran	Collection, Reuse/Remanufacturing (repair centre)	Multi-components	Government; Business; Consumer	Quantitative
Zeng et al., 2024 [110]	China	Collection, Recycling, Remanufacturing	EV batteries	Business; Consumer; Government	Quantitative
Günther et al., 2015 [111]	Not specify	Manufacturing, Consumption/Use, Collection, Recycling	Multi-components	Business; Government; Consumer	Quantitative
Zhao et al., 2022 [112]	China	Collection, Remanufacturing, Recycling	EV batteries	Business; Government; Consumer	Quantitative
Narang et al., 2024 [113]	India	Collection, Reuse, Recycling, Remanufacturing	EV batteries	Business; Government; Consumer	Quantitative Case study
Yin & Liu 2021 [114]	China	Manufacturing, Collection, Remanufacturing, Recycling	Multi-components	Business; Government	Quantitative
Qi et al., 2024 [115]	China, EU	Collection, Reuse, Recycling, Remanufacturing	EV batteries	Business; Government; Consumer	Quantitative
Zhang et al., 2024 [116]	China	Collection, Reuse, Remanufacturing	EV batteries	Business; Consumer; Government	Quantitative Case study

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Table 1. *Cont.*

Study	Country/Region	RSC Sector	Type of Component	Stakeholders Focus	Methodology
Xia et al., 2024 [117]	China	Collection, Remanufacturing, Waste Management/Disposal	Multi-components	Consumer; Business; Government; Others	Quantitative
Liu et al., 2023 [118]	China	Collection, Remanufacturing, Recycling	Multi-components	Business; Government	Quantitative
Wang 2024 [119]	China	Collection, Remanufacturing	EV batteries	Business; Government	Quantitative
Wang & He 2024 [120]	Not specify	Collection, Remanufacturing	Multi-components	Business; Consumer	Quantitative
Gong et al., 2024 [121]	Not specify	Collection, Reuse (second-life), Recycling	EV batteries	Business; Government	Quantitative
Rajabzadeh et al., 2023 [122]	Iran	Collection, Reuse (second-hand sales), Remanufacturing, Recycling	Multi-components	Business; Consumer	Quantitative Case study
Liu et al., 2024 [123]	China	Manufacturing, Collection, Reuse, Remanufacturing	EV batteries	Business; Consumer; Government	Quantitative Case study
Latpate et al., 2024 [124]	India, South Africa, Southeast Asia	Collection, Remanufacturing	Multi-components	Consumer; Business; Government	Quantitative Case study
Zhou et al., 2024 [125]	China	Collection, Remanufacturing, Recycling	Multi-components	Business; Consumer; Government	Quantitative Case study
Tognetti et al., 2015 [126]	Germany, EU	Manufacturing	Multi-components	Business; Government	Quantitative Case study
Chai et al., 2024 [127]	China	Manufacturing, Collection, Remanufacturing	EV batteries	Business; Government; Consumer	Quantitative Case study
Kalverkamp & Young 2019 [128]	Japan, Chile, Canada	Reuse (vehicle export), Remanufacturing, Recycling	Multi-components	Business; Government	Qualitative Conceptual/Theoretical Analysis Case study
Rentizelas & Trivyza 2022 [129]	UK	Collection, Remanufacturing, Recycling, Manufacturing	Car frames	Business; Government	Quantitative Case study
Liu & Zhu 2024 [130]	China	Collection, Recycling, Remanufacturing	EV batteries	Business; Government; Consumer	Quantitative
Li et al., 2024 [131]	Not specify	Collection, Recycling, Remanufacturing	EV batteries	Business; Consumer	Quantitative

Table 1. *Cont.*

Study	Country/Region	RSC Sector	Type of Component	Stakeholders Focus	Methodology
Zhou et al., 2023 [132]	Singapore	Collection, remanufacturing, recycling	EV batteries	Government; Business; Consumer	Quantitative
Zhang & Zhang 2022 [133]	China	Collection, Remanufacturing, Recycling	EV batteries	Business; Consumer	Quantitative
Yildizbaşi et al., 2018 [134]	Turkey	Manufacturing, Collection, Remanufacturing, Recycling, Waste Management/Disposal	Multi-components	Business; Consumer	Quantitative
Kumar et al., 2021 [135]	India	Manufacturing, Collection, Reuse, Recycling	EV batteries	Others; Government	Qualitative Quantitative
Fernando et al., 2023 [136]	Malaysia	Collection, Reuse, Remanufacturing	Multi-components	Business	Quantitative
Akram & Abdul-Kader 2021 [137]	Canada	Remanufacturing, Reuse (Repurposed), Recycling, Collection	EV batteries	Business; Government	Quantitative Qualitative
Grandjeanet al., 2019 [138]	UK	Collection, Reuse, Recycling	EV batteries	Business; Government	Quantitative Experimental
Alamerew & Brissaud 2020 [139]	France	Collection, Reuse (repurposing), Recycling, Manufacturing (design influence), Waste Management/Disposal	EV batteries	Business; Government	Conceptual/Theoretical Analysis Qualitative Quantitative
He et al., 2024 [140]	China	Collection, Reuse, Remanufacturing, Recycling, Waste Management/Disposal	EV batteries	Consumer; Business; Government	Quantitative Case study
Makarova et al., 2021 [141]	Not specify	Manufacturing, Consumption/Use, Collection, Remanufacturing	Multi-components	Business; Consumer	Conceptual/Theoretical Analysis Quantitative Case Study
Fan et al., 2023 [142]	China	Collection, Reuse, Remanufacturing, Recycling	EV batteries	Business; Government	Quantitative
Gonzales-Calienes et al., 2022 [143]	Canada	Collection, Recycling	EV batteries	Business; Government	Quantitative Case study

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Table 1. *Cont.*

Study	Country/Region	RSC Sector	Type of Component	Stakeholders Focus	Methodology
Gu et al., 2018 [144]	Not specify	Reuse, Remanufacturing, Recycling, Collection	EV batteries	Business; Consumer	Quantitative Conceptual/Theoretical Analysis
Li et al., 2023 [145]	China	Collection, Recycling, Remanufacturing	EV batteries	Business; Government	Quantitative
Guo et al., 2024 [146]	China	Collection, Recycling, Remanufacturing	EV batteries	Business; Consumer; Government	Quantitative
Song & Chu 2019 [147]	China	Collection, Remanufacturing, Recycling	EV batteries	Business; Government; Consumer	Quantitative
Zhang et al., 2023 [148]	China	Collection, Reuse, Recycling	EV batteries	Business; Government; Consumer	Quantitative
Daaboul et al., 2016 [149]	EU	Recycling, Collection, Manufacturing	Front lower control arm (aluminium)	Business	Quantitative Case study Conceptual/Theoretical Analysis
Wang et al., 2023 [150]	China	Collection, Reuse, Remanufacturing, Recycling	EV batteries	Business; Government	Quantitative Case study
Manoj Kumar 2023 [151]	India	Collection, Recycling	Tyres	Business	Conceptual/Theoretical Analysis Experimental Case Study
Yuik et al., 2023 [152]	Not specify	Collection, Remanufacturing, Recycling	Multi-components	Others	Systematic literature review
He et al., 2024 [153]	China	Collection, Remanufacturing, Recycling (logistics focus)	EV batteries	Consumer; Business; Government	Quantitative Case study
Gu et al., 2018 [154]	Not specify	Manufacturing, Remanufacturing, Reuse, Collection, Recycling	EV batteries	Business; Consumer	Quantitative

Source: Authors' synthesis based on systematic literature review studies.

3.1. Descriptive Analysis

Academic research about RSC and RL in the automotive industry shows an increasing trend of growth during the last eleven years (see Figure 2). The field has evolved from being a specific subject to becoming a fundamental part of SSC management through this growth, which builds on earlier studies that tracked the field's evolution from before our research period (e.g., [17]). The publication output demonstrates three distinct phases: starting with a moderate activity period from 2014 to 2017, which focused on barrier identification (e.g., [27]) and network design optimisation (e.g., [28,29]). Then, the market experienced its initial expansion from the above period, followed by a second growth phase from 2018 to 2020, before it entered a significant growth phase in 2021. The 2023–2024 period makes up 41.1% of all research publications that scholars studied. Research activity has increased because of various external elements which unite worldwide interest in CE principles with new environmental rules that require studies about carbon trading policy impacts (e.g., [30]) and blockchain technology (e.g., [31]).

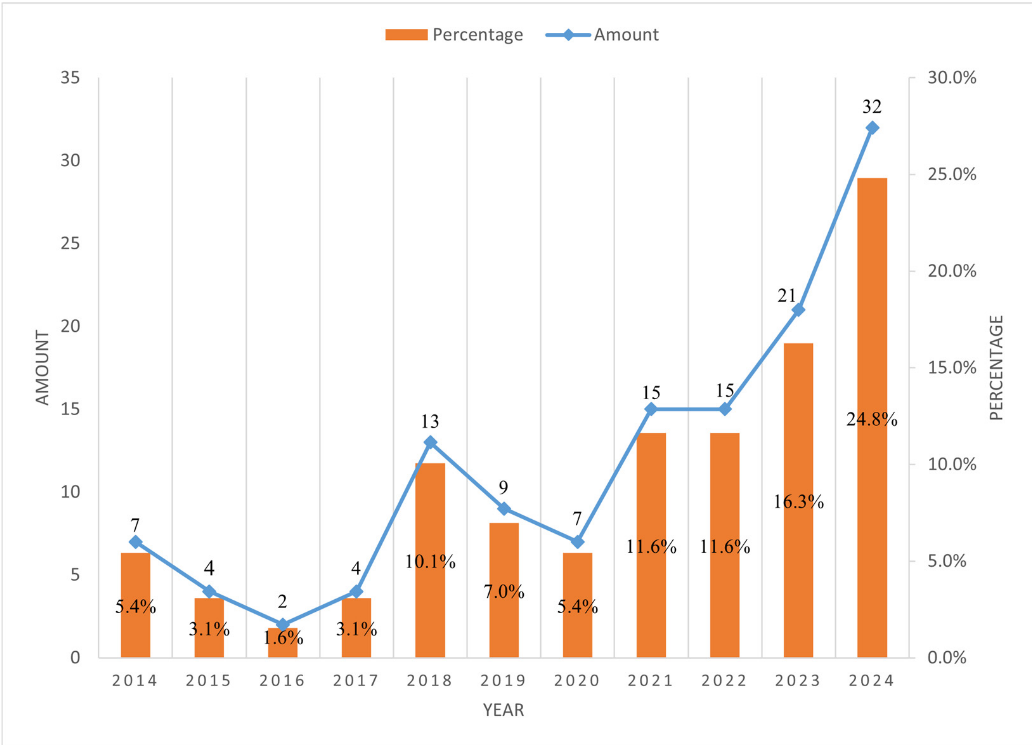

Figure 2. Annual publication trend (2014–2024).

The research material exists in 67 academic journals, which demonstrate the wide-ranging nature of the subject (see Figure 3). The leading publications for this research field include the Journal of Cleaner Production, Sustainability (Switzerland), and Computers and Industrial Engineering, with a notable 81.4% of all papers appearing in Q1-ranked journals. This research distribution shows a major emphasis on sustainability and environmental science, together with a substantial number of studies in operations research and industrial engineering. The discipline shows its disciplinary orientation through its methodological tools and methods, among which the most used are quantitative (86.82%) and case study (37.98%). Within quantitative studies, two primary clusters are prevalent: (i) game theory uses Stackelberg models and Nash equilibrium with a total of 27.13% analysis to study strategic interactions and pricing decisions for government policy interventions (e.g., [32–34]); (ii) mathematical optimisation through Mixed-Integer Linear Programming occupies 20.16%, such as to address complex logistical issues including network design and facility location problems (e.g., [35–37]).

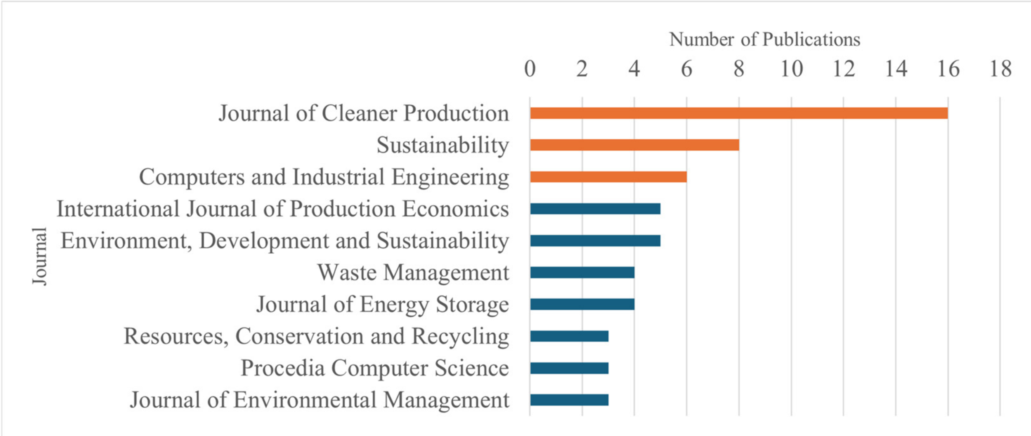

Figure 3. Leading academic journals contributing to the field (ranked by publication volume).

Geographically, as illustrated in Table 2, the research is heavily concentrated in developing economies, which are the subject of 71.3% of the papers, while showing that China leads all countries with 40.31% of total studies. The high level of attention stems from the urgent need to create organised ELV management systems, which must operate in environments where vehicles are being rapidly introduced and informal recycling networks exist (e.g., [38]). In contrast, a significant geographical gap reveals a complete absence of studies focusing on Oceania, and only minimal research attention is paid to the contexts of Africa and the Americas.

Table 2. Geographical distribution of publications.

Country	Number of Publications	Percentage
China	52	40.31%
Iran	12	9.30%
India	10	7.75%
Turkey	8	6.20%
Japan	6	4.65%
United Kingdom	5	3.88%
Canada	4	3.10%
Germany	4	3.10%
Brazil	2	1.55%
France	2	1.55%
Malaysia	2	1.55%
Spain	2	1.55%
Sweden	2	1.55%
United States (or Others *)	1	0.78%

Source: Authors' synthesis based on literature analysis. * Other countries which relate to one publication: Cameroon, Chile, Kenya, Mexico, Poland, Portugal, Saudi Arabia, Spain, Tunisia, Vietnam, Romania, and Singapore.

Thematically, as detailed in Figure 4, the research rooting in specific sub-components of vehicles focuses mainly on one aspect, which is Electric Vehicle (EV) batteries, because 44.19% of all studied papers concentrate on this subject, and 82.5% of these studies emerged after 2021, while multiple recent investigations analyse battery recovery through policy and technological and behavioural perspectives (e.g., [31,39,40]). The academic sector shows high awareness of industrial developments because research paths follow the worldwide transition to EVs. The research contains 44.19% of studies, which evaluate RSC performance across different sectors by conducting vehicle-level assessments (e.g., [9,41,42]). Nevertheless, this review revealed a major component-specific gap that scientists have studied ELV material streams only through the lens of batteries and have neglected tyres and advanced composites and automotive electronics [9].

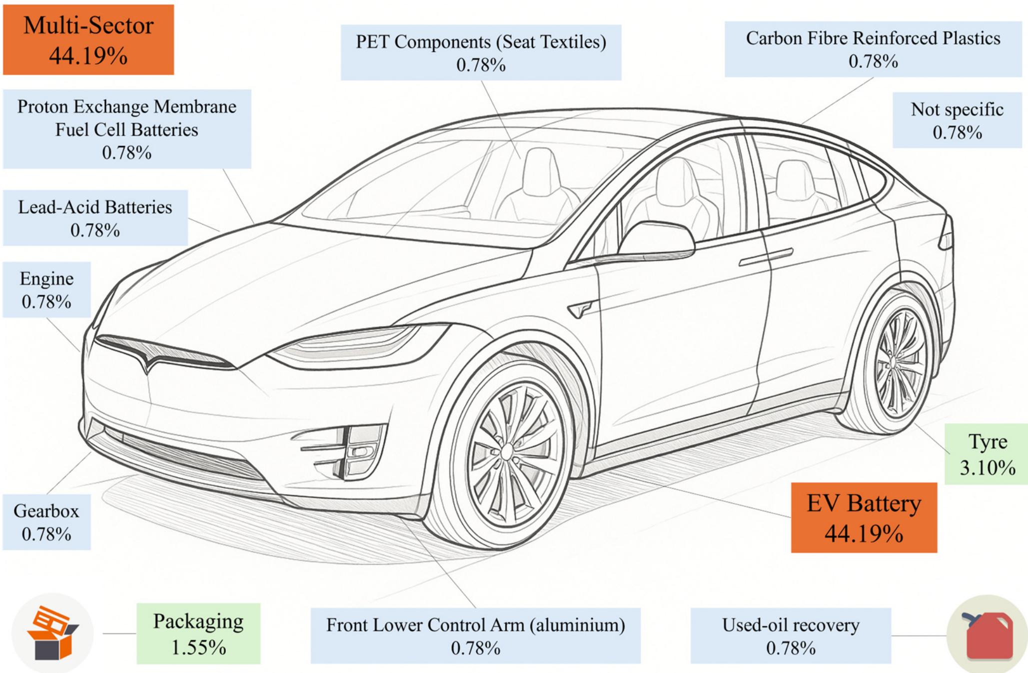

Figure 4. Distribution of research focus across automotive sub-sectors.

The lifecycle map (see Figure A1) demonstrates that research studies within the whole automotive RSC lifecycle have dedicated their work to basic activities. Most research papers (96.9%) include collection processes, which form the core of all RL operations due to the analysis of the intricate vehicle routing challenges (e.g., [43–45]). Furthermore, the principal value recovery strategies central to CE models receive substantial coverage. Recycling is examined in 78.3% of the literature, often with a focus on optimising regional networks for material recovery (e.g., [35,46,47]), while Remanufacturing is analysed in 75.2% of studies, with a focus on high-value components where strategic business relationships are vital (e.g., [9,48–50]). The distribution shows that the literature focuses heavily on the main methods for handling ELV products and recovering their remaining worth.

Lastly, as shown in Figure 5, the keyword occurrences inspection reveals patterns about how scholars define RSC in automotive applications. The most used terms, which indicate the field's focus on material recovery and supply chain transformation for new mobility systems, in the field show Supply chain (109, aggregated across "Supply chains", "Supply chain management" and "Closed-loop supply chain"), Recycling (63), Closed-loop (60, aggregated across "Closed-loop" and "Closed-loop supply chain"), Reverse Logistics (46), Electric Vehicle (38, aggregated across "Electric Vehicle" and "Electric Vehicles"), etc. Among the most frequently appearing keywords, three thematic pillars are presented: (i) the operational and managerial focus, such as Supply chain, Reverse logistics, and Decision making; (ii) the strategic and economic drivers like Decision making and Profitability; and (iii) the dominant technological focus like Electric vehicle. These pillars are unified by the vital goal of sustainable development, illustrating how the field translates specific technical and business challenges into broader contributions towards CE and rationally meeting the UN's Sustainable Development Goals (SDGs). From a systemic perspective, as shown in Figure 6, the link strength between terms not only emphasises between vital terms in the context of CE such as Supply chain (858, aggregated across "Supply chains", "Supply chain management", and "Closed-loop supply chain") and Recycling (543), but apparently points to the clusters around sustainable development (Sustainable Development, 194; Waste management, 162) and specific end-of-life challenges (End-of-life vehicles, 168; Secondary batteries, 164). The field maintains its intellectual foundation through its connection to SDGs and particular technical obstacles in battery technology and electronic waste disposal in the context of RSC/RL.

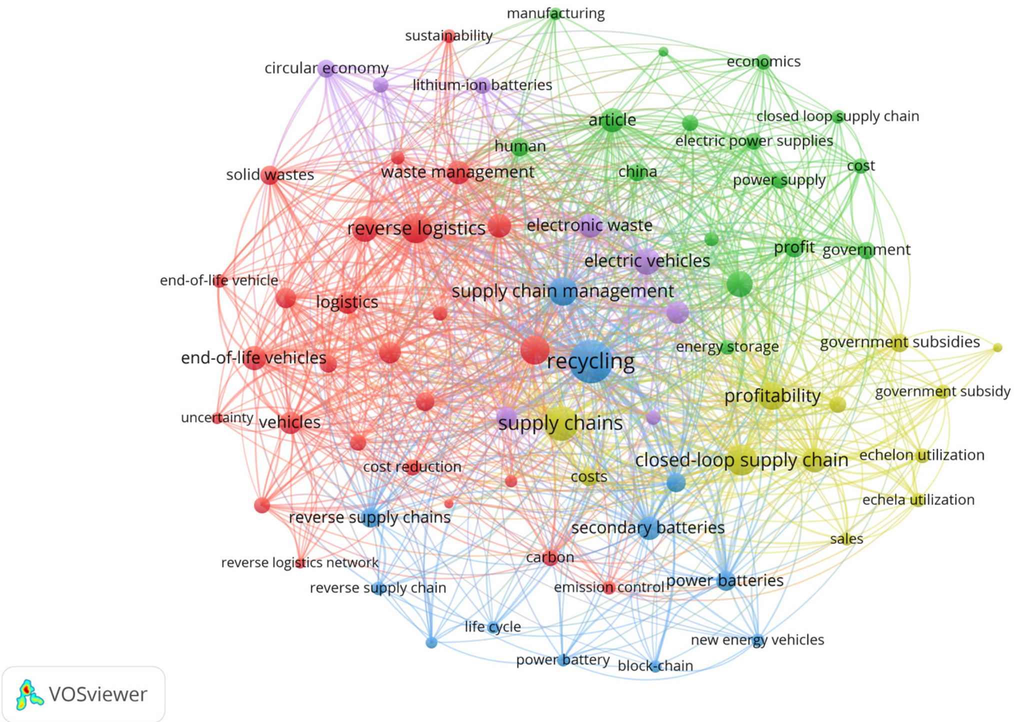

Figure 5. Keyword co-occurrence analysis (minimum = 5, software supported by VOSviewer version 1.6.20).

3.2. Thematic Analysis of RSC/RL Implementation: Barriers and Enablers

The following section analyses the elements that affect the implementation of RSC and RL within their thematic context. The analysis shows the interconnected system of performance factors, which go beyond basic issue identification. According to Figures 7 and 8, the research studies show that automotive RSC implementation performance factors function as an integrated system, which produces the results. It shows a distinct pattern because several fundamental principal problems and their related solutions keep repeating throughout the conversation. Among the obstacles are significant financial hurdles, particularly the high initial investment required for RL infrastructure [27,28,44,51–53]; the absence of defined government policies that receive proper enforcement [27,50,51,55–57]; and the deep uncertainty about the amount and type of returns [27,49,53,58,59]. The most effective enablers function as specific solutions that directly combat these obstacles. Research shows that Extended Producer Responsibility (EPR) legislation with strong enforcement serves as the main factor, which leads to the development of formal recycling systems [27,46,60,61]. The main financial reason for investment stems from the large revenue produced by material recovery [43,62–66], and supply chain coordination serves as the core organisational framework, which enables organisations to manage system complexities [38,49]. To systematically analyse this complex interaction, the detailed analysis of these and other factors has been structured into five key dimensions consistent with foundational frameworks [16,155]: Economic and Financial; Managerial and Organisational; Technological and Infrastructural; Policy and Regulatory; and Market and Social. The following subsections will examine each of these dimensions in detail.

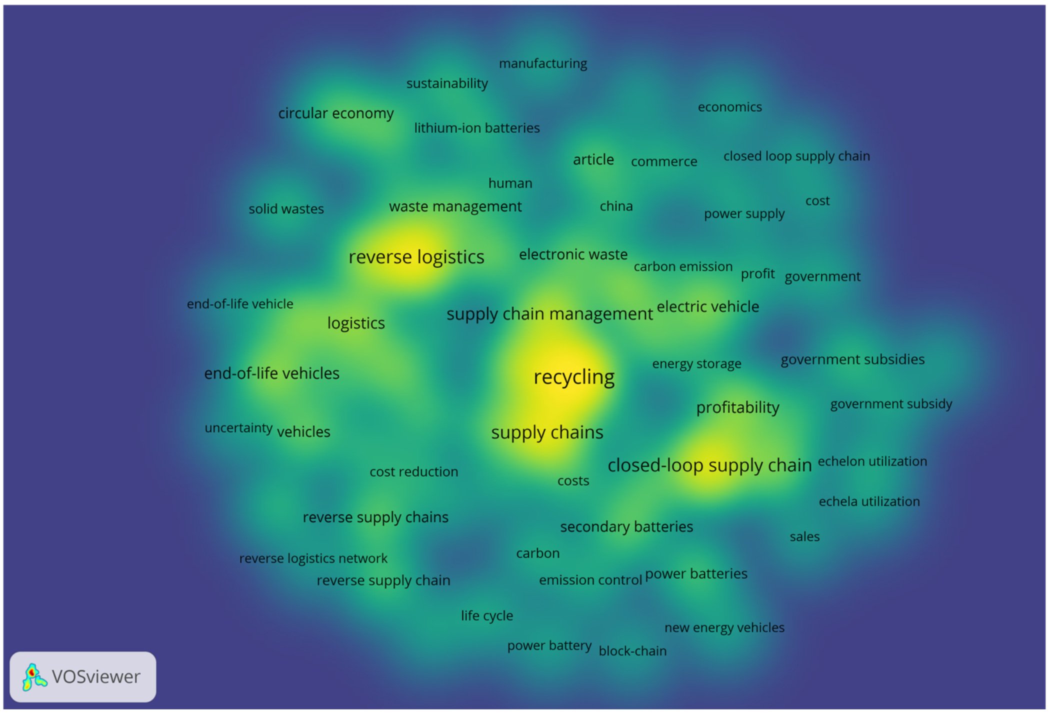

Figure 6. Keyword link strength analysis (minimum = 5, software supported by VOSviewer version 1.6.20).

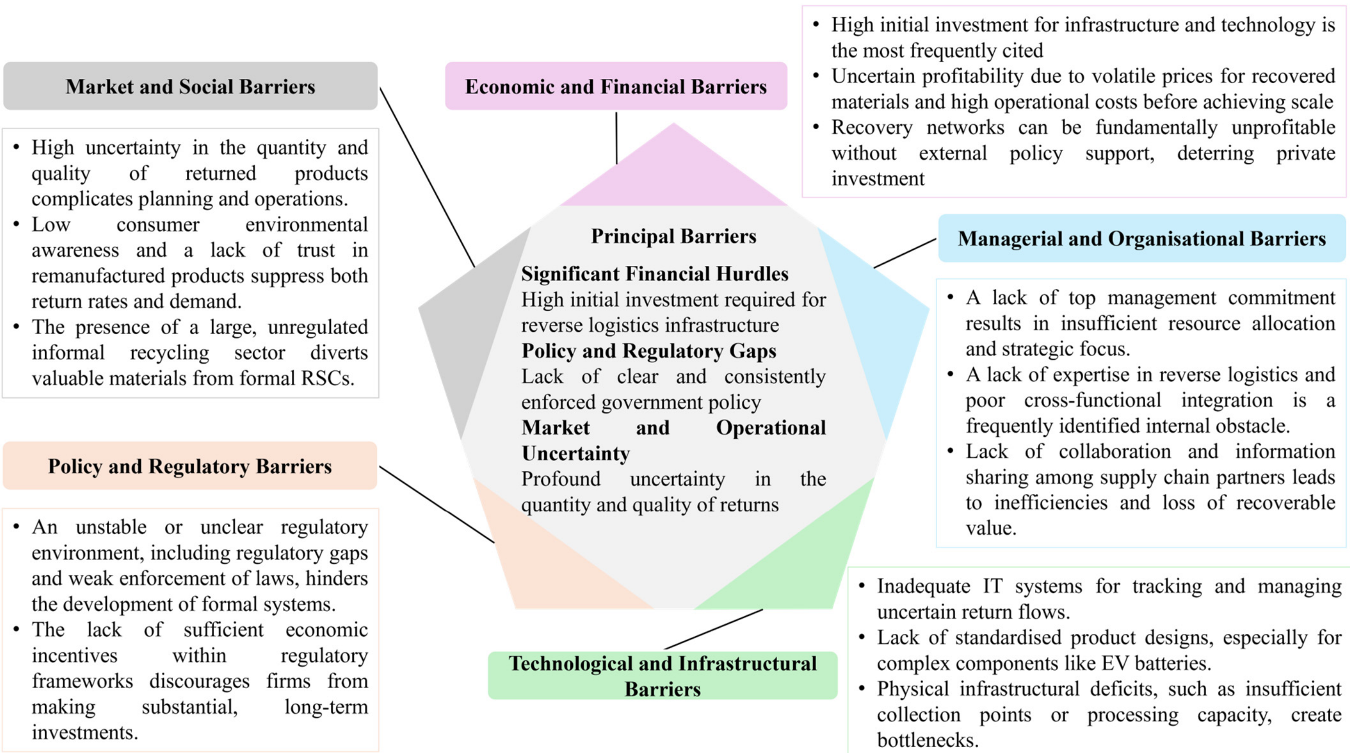

Figure 7. Visual synthesis of major barriers to RSC implementation. Source: Authors' synthesis based on literature analysis.

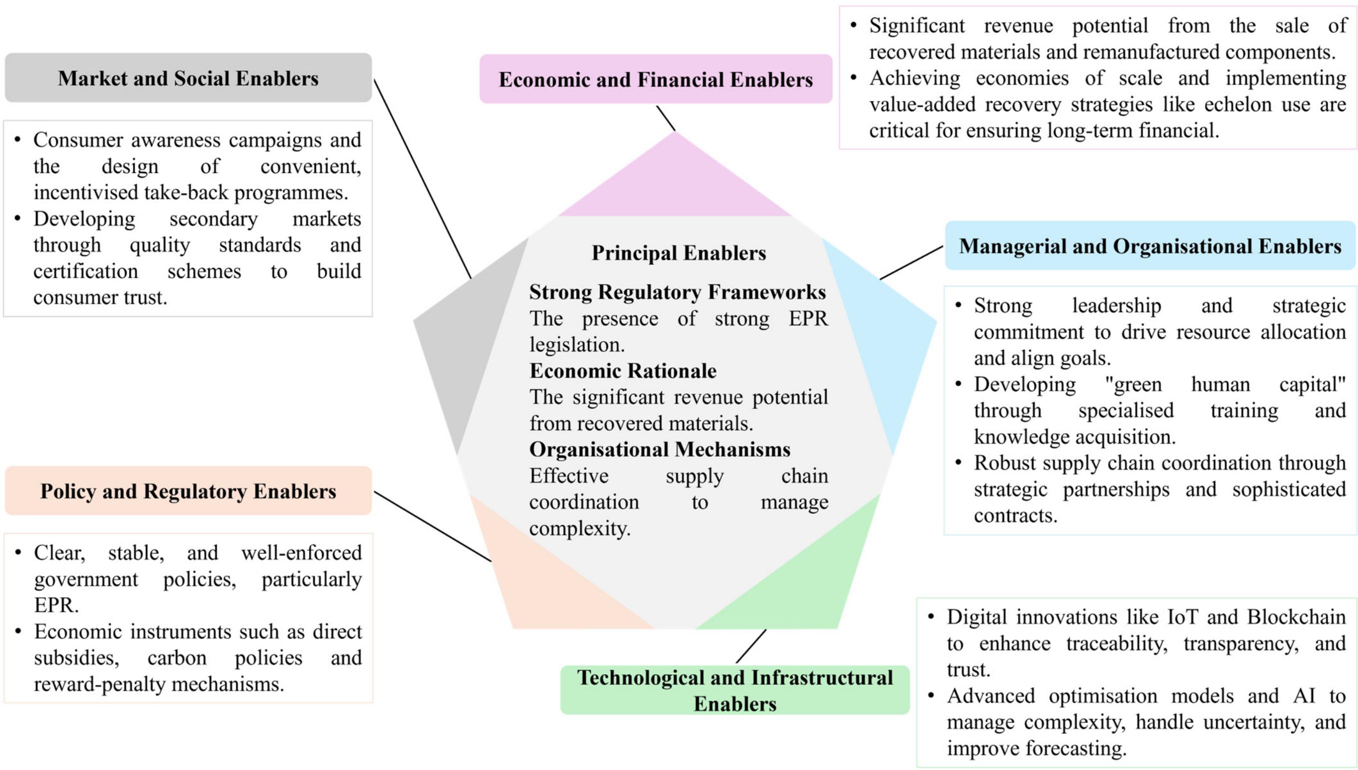

Figure 8. Visual synthesis of major enablers to RSC implementation. Source: Authors' synthesis based on literature analysis.

3.2.1. Economic and Financial Dimension

Barriers: The main obstacle to implementing waste collection systems stems from the high costs needed to establish collection infrastructure and acquire sorting technologies and processing facilities [27,44,51,53,56]. The unpredictable nature of material price fluctuations in the market sector makes recovery operations face unstable profit levels [67], and the operational costs exceed the value of recovered materials during the first stages of operation before achieving scale economies [68]. Moreover, the research by Zhu and Li [33] demonstrates that EV battery recovery networks operate at a loss when left to market forces, which creates a major obstacle for private sector investment. This financial instability does not emerge in isolation but is closely tied to the policy and regulatory dimension, where the lack of supportive fiscal instruments leaves firms exposed to market volatility with little institutional protection.

Enablers: The main enabler results from the profitable revenue streams of material recovery and component remanufacturing, which enables organisations to create profitable new business models [44,62–66,69]. The literature shows that financial sustainability requires companies to achieve scale economies and use value-added recovery techniques like echelon (or second-life) EV battery recycling to reduce their initial expenses [44,65,70–74]. This economic viability is systemically interconnected with the regulatory dimension, since government incentives (e.g., subsidies, etc.) often lower the risk of initial investment and allow these market forces to mature.

3.2.2. Managerial and Organisational Dimension

Barriers: Organisations face their main internal barrier because top management lacks sufficient support, which limits resource availability and concentration on RSC activities [27,50,53,56,75]. The implementation of RL systems faces challenges because organisations lack proper expertise in RL, and their departments, such as logistics, marketing, and finance, do not work well together [27,50]. The primary outside barrier that stops supply chain partners from collaboration and data sharing results in operational problems and unattainable value recovery [27,49,50,76].

Enablers: It is necessary for organisations to achieve effective leadership and strategic dedication to achieve RSC goals because these elements enable resource distribution and RSC target alignment with corporate strategy [27,50,75,77,78]. Additionally, organisations need to make this commitment before they can develop green human capital through specialised training programmes that teach employees how to handle reverse flows [27,75]. The literature also reveals that supply chain coordination mechanisms need solid bases to achieve successful implementation [79]. The Original Equipment Manufacturers (OEMs) and remanufacturers form strategic partnerships through the "reman-contract" model, which allows OEMs to maintain ongoing used component supply with remanufacturers [36,49,50,78]. The research by Xiao et al. [38] and Zhu and Yu [80] demonstrates that Shapley value-based profit allocation mechanism contracts enable different reverse chain participants to achieve alignment through incentive-based systems.

3.2.3. Technological and Infrastructural Dimension

Barriers: The management of unpredictable return flows becomes difficult because of inadequate IT systems [27,51,53,77,81]. The problem becomes more difficult since EV battery components lack standardised designs, which create challenges for disassembly, testing, and remanufacturing operations [59,81]. Then, the literature shows that physical infrastructure problems, including inadequate collection sites and insufficient central processing facilities, act as barriers to creating efficient large-scale RSC systems [27,28,52,54,82]. Importantly, these technological shortcomings generate chain effects within the managerial and organisational dimension, as limited data transparency constrains the cross-functional integration, apparently supporting effective decision making.

Enablers: Research today focuses heavily on enabling technologies that use digital solutions to break down information obstacles. The Internet of Things (IoT) and Blockchain technology function as fundamental elements that improve RSC traceability and transparency [30,71,77,81,83,84]. Additionally, the system requires advanced optimisation models and artificial intelligence to handle its natural complexity according to the research [85–93]. The literature reveals that advanced analytical tools help create resilient networks that respond to unexpected events [94–99,101–103] and enhance return flow prediction accuracy [58,100,103–106]. From a systemic perspective, these regulatory instruments act as the vital catalyst for the technical dimension, since such enforced recycling targets require manufacturers to place a greater importance to innovate and adopt advanced material recovery technologies.

3.2.4. Policy and Regulatory Dimension

Barriers: The implementation of RSC faces a major obstacle because of unstable or ambiguous regulatory frameworks. The literature demonstrates that regulatory gaps generate multiple issues since there are no complete take-back regulations and insufficient law enforcement, which hinders formal RL system development [27,46,50,51,54,61]. Additionally, the on-going regulatory systems lack proper economic incentives, which creates a major challenge. Businesses face challenges in obtaining necessary long-term capital to establish effective RSC infrastructure on account of a lack of suitable financial incentives and economic support systems [27,50,51,54]. The absence of effective regulation creates a negative feedback loop across the market and social dimension, whereby relatively weak enforcement allows the informal sector to expand, diverting volumes away from formal RSC and constraining their capacity to achieve economies of scale.

Enablers: The most effective factor under this dimension is stable government policies, which are both clear and strictly enforced. The EPR legislation, which makes manufacturers handle ELV waste, drives the creation of organised take-back systems [27,46,50,60,61,104]. The base policies receive support from various economic tools that work to enhance recycling financial stability. The reviewed studies also analyse the positive impact of direct subsidies [32,33,72,104–112], carbon cap-and-trade policies that penalise emissions [30,113,114], and reward–penalty mechanisms that provide targeted incentives [113,115], all of which serve to align the economic goals of firms with broader environmental targets, specifically sustainable goals [116]. Technically, these digital tools serve a cross-functional role by resolving information asymmetry, thereby reducing the economic costs, such as transaction costs, associated with obtaining and verifying used vehicle components.

3.2.5. Market and Social Dimension

Barriers: The main market challenges result from unstable product return volumes and quality, creating operational management difficulties and activity planning problems [49,50,59,64,117]. The consumer market faces two main barriers to the adoption of secondary goods because of a lack of environmental understanding and doubting the quality and operational effectiveness of remanufactured products [27,50,118–120]. Additionally, the informal recycling sector in developing economies operates outside regulatory frameworks, which causes valuable materials to move away from environmentally friendly RSCs and decreases the profitability of these facilities [27,38,121].

Enablers: Consumer awareness initiatives together with take-back programmes that provide incentives create the necessary foundation for reaching high collection rates and sustaining a continuous supply of quality returned materials [27,63,119,120,122–124]. The development of secondary markets depends on quality standards and certification schemes for remanufactured products, which serve as key enablers. The measures establish customer trust on account of revealing full information about recovered component quality, which leads customers to pay higher prices [40,49,51,60,118,125].

3.3. Systemic Patterns and Evolutionary Dynamics

The research in this section extends past thematic element identification to study both systematic patterns and developmental trends which appear in the field.

3.3.1. Overarching Systemic Dynamics

Technology–Policy Interdependence

The studies by Narang et al. [113], Tognetti et al. [126], Yin and Liu [114], and Zhang et al. [30] demonstrate that firms will adopt emission reduction technologies when governments establish challenging policy targets through carbon cap-and-trade schemes. Conversely, the availability of advanced technologies, particularly digital ones, enables more effective and granular policy design and enforcement (see Figure 9). To illustrate, the blockchain system provides transparent subsidy distribution, which results in improved outcomes through accurate payment delivery to eligible recipients while minimising fraud risks, thus uniting technology with policy [39,71,77,84].

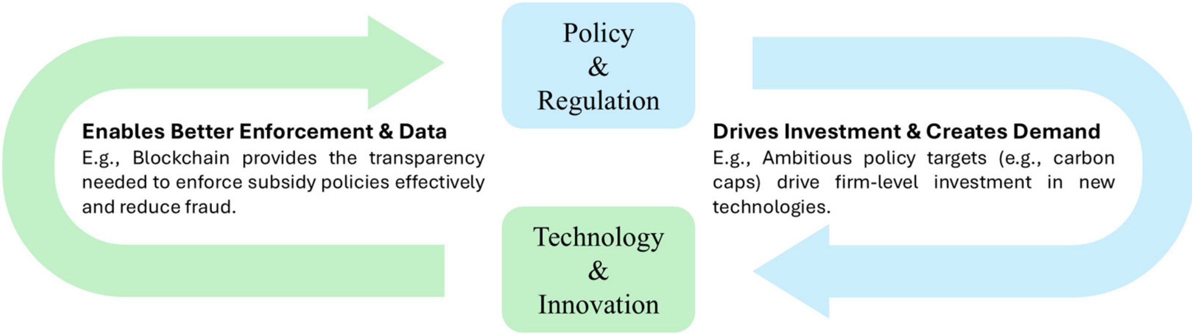

Figure 9. A system dynamics loop–technology–policy interdependence. Source: Authors' synthesis based on literature analysis.

Scale-Value Recovery Tension

The main conflict exists between two competing strategies, which focus on running large-scale operations versus maximising value extraction. Scrap metal bulk recycling requires centralised large facilities for processing low-value materials because these facilities operate at scale to deliver the most economical solution [28,35,46,61]. These systems, however, are commonly inappropriate for high-value, quality-sensitive recovery processes such as component remanufacturing or the echelon use of EV batteries. The activities require network structures which enable resource distribution for handling unpredictable return quality and complex component value management [9,49,61,65,70,127–129].

Formal–Informal System Dynamics

Particularly in the extensive literature on developing economies, formal and regulated RSCs are shown to co-exist and compete with a numerous informal sector, which often owns the properties of being highly efficient at collection due to its flexibility and low costs but typically lacking the technology for safe and environmentally friendly processing [26,48,104]. The combination of formal sector processing capabilities with informal sector collection efficiency through integrated strategies produces better results than attempting to eliminate the informal sector according to game-theoretical models [27,34,38,121,130].

Evolution from Operational to Strategic Focus

As illustrated in Figure 10, the research field shows a distinct chronological development of its main areas of study. The research papers from 2014 to 2018 concentrated on resolving operational problems through the identification of critical barriers [27,50,53,57,78]. Additionally, the studies by Ene and Öztürk [58] and Hao et al. [100] investigate return flow forecasting optimisation and focuses on return flow forecasting optimisation. The research direction moved towards strategic elements during the period from 2020 to 2024. This is revealed as a greater emphasis on business model innovation, the competitive dynamics between different recovery channels, multi-stakeholder coordination under government regulation [34,39,127,131–135], and RSC implementation as a strategic component for corporate innovation and sustainability initiatives, which illustrate that the field has become more advanced [83,126,127,136].

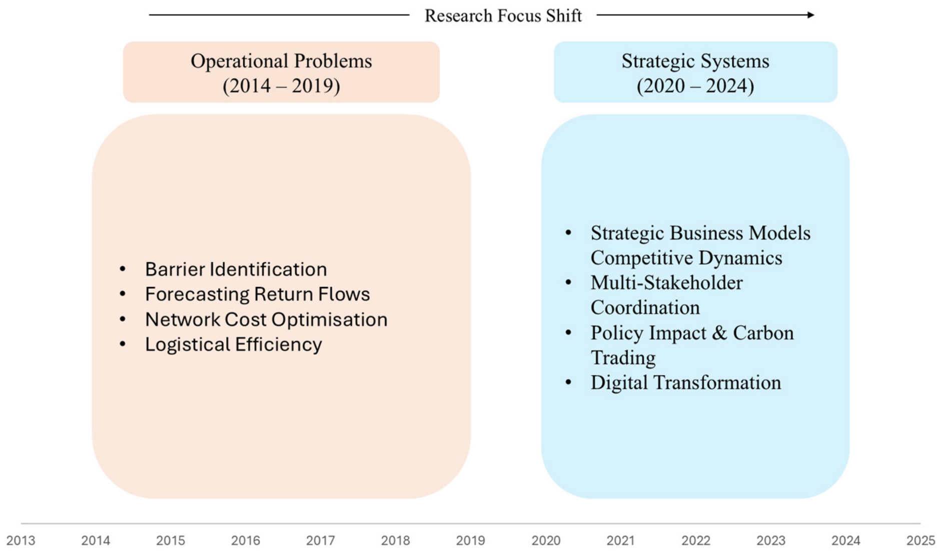

Figure 10. The evolution of research focus from 2014 to 2024. Source: Authors' synthesis based on literature analysis.

3.3.2. Component-Specific Dynamics: The Dominance of EV Batteries

As established in the descriptive analysis, the research landscape is dominated by studies concentrating on EV batteries. The results show a quantitative bias, which indicates that the recovery of traditional ELVs presents different and more complicated challenges than the recovery of modern ELVs. The highlighted technical, economic, and policy dynamics surrounding EV batteries have effectively created a specific and specialised sub-field within automotive RSC research (see Table 3).

Table 3. Differentiating EV battery and traditional ELV dynamics.

Feature Dimension	Traditional ELV Recovery	EV Battery Recovery (A Distinct Sub-Field)
Technical Uncertainty	• Primarily mechanical wear • Relatively predictable quality	• Complex electrochemical degradation • High uncertainty in state-of-health and remaining useful life
Economic Proposition	• Driven by recovery of bulk materials (steel, aluminium)	• Driven by recovery of volatile, critical materials (lithium, cobalt) • Often a net cost without government incentives
Stakeholder Ecosystem	• Established network of dismantlers and shredders	• Emerging ecosystems including specialised echelon utilisers (e.g., energy storage companies) creating multi-level value chains
Policy Instruments	• Governed by broad directives (e.g., recovery rate targets)	• Involves specialised and granular policies like digital battery passports, reward–penalty schemes, and carbon trading policies

Source: Authors' synthesis based on literature analysis.

Unique Technical and Quality Uncertainty

The electrochemical nature of battery degradation makes it different from mechanical components, which creates a major technical challenge for non-destructive testing and grading of battery state-of-health and remaining useful life [59,137,138]. The inherent quality uncertainty, which stems from consumer behaviour and technological advancements, serves as a main factor in numerous quantitative models that need advanced data analytics for proper management [59,137,139–141].

Divergent Economic and Value Propositions

The economic models for EV battery recovery are fundamentally different from those for traditional ELVs. While ELV recycling economics are majorly driven by the recovery of bulk materials like steel and aluminium, the profitability of battery recycling hinges on the recovery of high-value, price-fluctuated, and geopolitically sensitive critical materials, including lithium, cobalt, and nickel [65,134,142,143]. This creates a distinct set of economic risks and opportunities that are central to the game-theory models in the literature, concluding that recovery operations can be a net cost to the system without government incentives [33,144].

A More Complex Stakeholder Ecosystem

The EV battery RSC contains multiple new and developing specialised actors. This study investigates how manufacturers, recyclers, and dedicated gradient utilisers (e.g., energy storage companies) operate as a market for functional used batteries [30,39,40,70,72,123,145]. The resulting supply chain structure generates multiple gradients, which create special competitive and cooperative relationships that researchers in game theory and evolutionary game theory study as their main subject [39,70,104,109,145,146].

Specialised and Granular Policy Instruments

The literature about EV batteries examines specific policy instruments that differ from the general ELV recycling framework. The list contains digital battery passports that use blockchain technology for traceability purposes [30,31,71,84], reward–penalty systems for battery collection [113,147], and the application of carbon trading policies to the energy-intensive battery manufacturing and recycling processes [72,113,114,148]. The battery RSC's strategic decisions become directly influenced by these regulatory requirements.

4. Discussion

4.1. Synthesis of Principal Findings

The results of the studies present more than academic value because they establish essential directions for future automotive circularity research and practice development. The research environment uses a narrow approach to generate specific results, but it does not create a wide understanding of EV battery technology (e.g., [35,71]). The industry encounters difficulties during its transition because it needs better methods to handle its other significant material flows. Also, the literature presents policy recommendations and dominant strategies, which appear to be designed for state-led industrial contexts because it focuses mainly on China (e.g., [35]). It may not be readily transferable to other regions with different institutional frameworks. The interconnected nature of enablers and barriers in the system requires organisations to move beyond single-factor solutions because effective strategies need to address all three dimensions of the triple bottom line. Finally, the wide application of quantitative models based on rational actor assumptions reveals a critical difference between theoretical models and real-world applications because these models lack consideration of the complex non-economic behaviours of consumers and managers. Collectively, these implications suggest that the next phase of progress depends less on refining existing models and more on broadening the field's scope, integrating diverse perspectives, and closing the critical gap between theoretical optimisation and real-world implementation.

4.2. Interpretation and Contribution to Literature

Research studies produce multiple vital results, which increase existing academic knowledge. Our research shows EV batteries have become the primary focus, which demands more detailed component-level models. Li-ion batteries need unique recovery systems because their electrochemical breakdown and unpredictable state-of-health require frameworks that go beyond standard mechanical component frameworks [137] and their strategic value in echelon systems [139].

Also, the research findings present that regulatory and policy factors stand as the leading enablers that support the coercive isomorphism theory [156]. They also show that numerous businesses select RSC implementation during their first market development stage because they must meet external requirements and show EPR compliance (e.g., [60,61]), rather than by an internally generated, value-seeking strategy.

Additionally, this review demonstrates how the field has progressed through the Natural-Resource-Based View (NRBV) [157]. Organisations today focus on strategic management instead of operational compliance because of the observed advancements. The companies are building RSC as a strategic capability to create value and gain a competitive advantage, matching the NRBV Product Stewardship model [157]. Organisations that concentrate on sustainable resources achieve superior RL capabilities [136], which result in better financial outcomes and also direct their resources towards strategic investments for modular design and process innovation for these initiatives to help develop distinctive capabilities that produce financial advantages and environmental value [123,126,127,136].

Finally, this review performs a detailed assessment of geographical and component-based knowledge deficiencies through systematic mapping, which enables a thorough evaluation of analysed research findings that surpasses previous general reviews (e.g., [16]). Our research shows that the field made significant progress, but its research scope has become much more specific, e.g., neglected crucial areas and non-battery electronic components and advanced composite recovery, and further highlights a basic contradiction of the field's advancement by making its most advanced theories and models less applicable worldwide.

4.3. Managerial and Policy Implications

4.3.1. Managerial Implications

Organisations need to adopt strategic cross-functional methods for RSC implementation because the process involves multiple complex elements. Our findings suggest that organisations should treat the RSC as a strategic resource that generates business value instead of treating it as a cost centre for compliance, supported by Daaboul et al. [62,149]; Demirel et al. [63]; Fernando et al. [136]; Li et al. [65]; Tognetti et al. [126]; Wu et al. [78]. Additionally, our analysis shows that a single network design creates a "scale-value tension", which proves that such a design is not the best solution. Instead, firms must develop differentiated or hybrid network strategies that combine the efficiencies of centralised processing for low-value materials with the flexibility of specialised capabilities for high-value recovery (e.g., [9,61,65,70,127,150,151]). Furthermore, the deployment of advanced technologies such as IoT and blockchain functions as a strategic business approach to solve information asymmetry issues and improve product tracking systems [71,83].

4.3.2. Policy Implications

The strong connection between technology and policy requires governments to develop flexible governance systems that integrate these elements (e.g., [108]). The design of regulatory instruments needs to create stable market signals that provide long-term direction to enable innovation by minimising private investment risks (e.g., [27,109]). Research shows EPR schemes work functionally because producer responsibility-based policies operate successfully (e.g., [27,61]). However, the identified sectoral dynamics between formal and informal sectors require developing economies to create policies that unite informal sector collection capabilities with formal sector environmental and safety standards for building an improved national system.

4.4. Limitations and Future Research Agenda

The built-in restrictions that affect the SLR method need to be recognised by researchers. Our focus on an eleven-year period, though substantial, may have excluded some foundational work, and our reliance on major academic databases might have missed publications in regional journals. The research agenda for the future should consider three essential areas because of the major research gaps this review discovered.

4.4.1. Expanding Scope to Neglected Components and Geographies

This study demonstrates that studies about EV batteries exist in a concentrated pattern that focuses on both thematic content and Asian geographical locations. The EV battery sub-field demonstrates increasing growth, but its complicated nature and fast-paced development require an independent systematic review to analyse its distinctive characteristics. Research should shift attention to non-battery components, specifically automotive electronics (e.g., thermal management systems and sensors), plastics, composites, and other high-recycling-value components, to better understand the specific RSC behaviour patterns [152]. Given the geographic concentration (40.31%) of the reviewed papers originating from China, future work should expand to underrepresented regions such as the Middle East (e.g., Egypt, Jordan), Oceania (e.g., Australia, New Zealand), and the Americas (e.g., the U.S.), to improve regional and global relevance. Addressing these neglected but important geographies and high-potential-value components simultaneously can provide greater insights beyond China's context.

4.4.2. Investigating the Human and Social Dimension

Our findings show that quantitative optimisation models dominate in the literature while treating customers as rational decision-makers, which reveals a major deficiency in consumer perspective understanding. The studies of Gao et al. [39], Wang [119], Wang and He [120], and He et al. [153] demonstrate that numerous advanced models depend on basic consumer behaviour models. Future work should employ a mixed-methods approach, combining in-depth qualitative studies to explore the nuances of consumer motivations and barriers with large-scale quantitative surveys to validate these findings and develop more realistic behavioural models.

4.4.3. Bridging the Theory–Practice Gap

The number of research studies about theoretical optimisation and game-theory models has grown according to Govindan and Gholizadeh [95] and Yin and Liu [114], but few studies focus on actual deployment. Future research needs to concentrate on business aspects because it will help to connect theoretical concepts with actual managerial practices [154]. The research requires a mixed-methods design, which combines qualitative case studies to analyse real-world network design implementation obstacles with quantitative surveys to determine manager-identified essential barriers and enablers. The research confirms theoretical models by using real-world data, which produces practical findings that practitioners can use in their work.

4.4.4. Temporal and Journal Limitations

A temporal limitation should be noted on the scope of this review. The data collection protocol was strictly defined to cover the period from 2014 to the end of 2024 to ensure the analysis relied on complete annual datasets. Consequently, studies published during the subsequent process after manuscript completion for this review in 2025 were excluded to maintain statistical consistency in the longitudinal trend analysis. In addition, a journal limitation exists due to the exclusion of journals and conference proceedings/papers ranked below the Q2 quartile [24] or equivalent bibliometric thresholds. Although this ensures that the synthesised evidence meets rigorous standards for peer review and scholarly impact, it may inadvertently omit underdeveloped journals and their published papers or localised (non-English) studies. Future updates to this review should incorporate these emerging publications and broader journal types.

5. Conclusions

This study examined RSC and RL implementation in the automotive industry's CE transition through an SLR study from 2014 to 2024. By analysing 129 academic publications, this review presented a detailed understanding that RSC implementation is governed not only by isolated barriers but by complex systemic interdependencies as well. The transition is shaped by two critical dynamics: the feedback between technology and policy and the operational tension between large-scale bulk recycling and high-value component recovery. The analysis also revealed that the field is heavily concentrated on EV batteries within developing economies, particularly China.

From these systemic patterns, three vital insights emerge for practitioners. Firstly, managers should move beyond one-size-fits-all network designs and adopt hybrid models that separate high-volume bulk material flows from high-touch, high-value component recovery to resolve the tension between scale and value. Secondly, policymakers should leverage the technology policy interdependence by mandating digital tools, not merely as compliance mechanisms, but also as the foundational infrastructure for the allocation of subsidies to resist fraud. Thirdly, organisations need to transfer their strategic focus from viewing RL as a cost centre driven by regulatory compliance to treating it as a strategic asset for securing critical material supplies against geopolitical volatility.

Looking to the future, this review identifies several gaps that shape the research agenda. Although the literature has progressed from a concentration on operational optimisation to strategic value creation, geographical and component-specific deficiencies remain. Future research needs to expand beyond the EV battery dominance to engage with other aspects, such as the material streams of automotive electronics, plastics, and composites with high potential value. In addition, to bridge the gap between theoretical models and practical implementation, more academic attention needs to be directed to underrepresented regions like the Middle East, Oceania, and the Americas to ensure that circularity frameworks are globally relevant rather than regionally specific.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su18021129/s1, Table S1: PRISMA 2020 Checklist.

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Abbreviations

The following abbreviations are used in this manuscript:

CE	Circular economy
ELV	End-of-life vehicle
RSC	Reverse supply chain
RL	Reverse logistics
CLSC	Closed-loop supply chains
SLR	Systematic literature review
RQ	Research question
SSC	Sustainable supply chain
MRD	Maximum Relative Deviation
EV	Electric vehicle
SDGs	Sustainable development goals
EPR	Extended producer responsibility
OEMs	Original equipment manufacturers
IoT	Internet of Things
NRBV	Natural-Resource-Based View

Appendix A

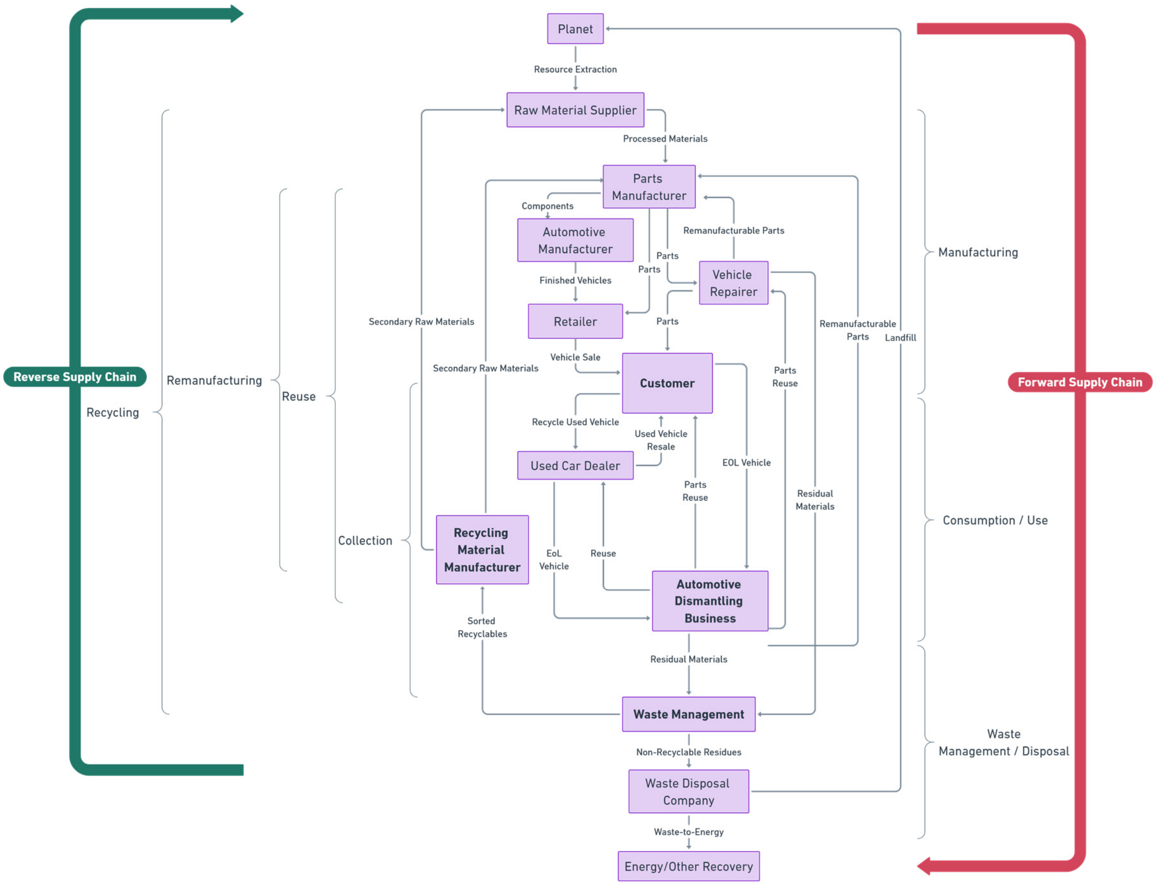

Figure A1. Lifecycle map of designed whole supply chain of automotive industry.

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