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From Compliance Motives to Intelligent Reverse Supply Chains: Three Decades of Evolution and Future Research Directions

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Abstract
This paper provides a comprehensive synthesis of three decades of scholarly research on reverse supply chains by examining how the field has evolved and identifying promising directions for future research. Specifically, this study addresses two overarching research questions: (1) How has the reverse supply chain field evolved in terms of theoretical perspectives, technological adoption, and research focus over time? (2) What future research trajectories emerge from the literature regarding the role of digital technologies and artificial intelligence in reverse supply chains? To address these questions, a systematic literature review (SLR) is conducted to identify and select high-quality and relevant journal articles, followed by a rigorous content analysis to uncover dominant themes, conceptual shifts, and methodological trends. The analysis reveals six distinct evolutionary stages of reverse logistics research: the infancy stage, the golden age, the strategic stage, the multidisciplinary stage, industrial revolution stage, and artificial intelligence stage. Each stage is characterized by unique research foci, theoretical foundations, and operational challenges. In particular, the most recent stage highlights the growing integration of digital technologies, artificial intelligence, and sustainability considerations, reflecting a shift toward intelligent and system-oriented reverse logistics. Based on this evolutionary analysis, the paper develops a structured research agenda that outlines key theoretical, methodological, and technological opportunities for future investigations. This study contributes to the literature by offering a longitudinal and systematic perspective on the evolution of reverse logistics research and by providing an integrative framework that supports the advancement of future studies in an increasingly digital and sustainable context.

Keywords: Reverse supply chains; artificial intelligence; digitalization; sustainability; circular economy.

JEL Classification Code: M11, L62, L22

1. Introduction

Reverse supply chains is considered a relatively new field within operations management and has experienced significant growth over the past several decades (Dowlatshahi, 2000; Fleischmann et al., 1997; Govindan et al., 2019). Its importance is increasing in line with the emergence of new regulations, market pressures and threat from competitors who have already applied reverse logistics practices (Ilgin et al., 2015). As it is still a comparatively new topic, it is important to obtain an up to date knowledge regarding what research has already been conducted, and what methods have been used. To this end, a literature review of existing studies will be valuable in providing a map of existing studies. Consequently, existing research can be analysed to identify gaps and guide future research.

Some scholars use the terms ‘reverse supply chain’ and ‘reverse logistics’ interchangeably, yet others define them differently. For the purposes of this paper, the two terms have different definitions. Reverse logistics describes how to manage materials inside a company, whereas a supply chain involves additional activities with external parties, including coordination with suppliers, distributors, retailers and customers, to a certain extent. Broadly speaking, reverse logistics is just one part of the supply chain, and places greater emphasis on materials within an organisation, whereas reverse supply chains also involve external parties. In a reverse supply chain, products do not have to be sent to manufacturers because they can be returned to any recovery point to extract the value from end-of-life products. There are various drivers for adopting reverse supply chains, which can be categorised broadly according to three factors: the customers, who return the goods and recovered products to be priced lower than new ones; industries, who interested in reclaiming value; and governments, who aim to promote concern for the environment (Knemeyer et al., 2002). In some cases, various motivations for adopting reverse supply chains are intertwined (Fleischmann et al., 2000).

Although reverse supply chains have gained increased attention from both academics and practitioners, implementation problems still exist. On one hand, (Fleischmann et al. (2001) showed how the importance of reverse supply chain has increased over time. On the other hand, complexities in implementing a reverse supply chain means companies often experience difficulties in managing it. Some methods and techniques implemented in conventional manufacturing are not suitable for reverse supply chains, as there are critical differences between the two processes (Rogers & Rogers, 2002). A large variety of methods, techniques have been used to address emerging problems in reverse supply chains. After several decades of research on topics related to reverse supply chains such as reverse logistics, closed-loop supply chains, remanufacturing and so on), there is a need to accumulate what is known, what has been agreed and provide a roadmap for future investigations. Thus, the present study is timely and relevant.

As well as the rationales mentioned above, there are several other reasons why a literature review is relevant, timely and necessary at the present time. First, manufacturing companies are facing pressures from numerous parties to adopt green business practices, including reverse supply chain management. The ability to respond to these sensitive issues can determine the survival of businesses (Sarkis et al., 2010; Q. H. Zhu et al., 2005; Q. Zhu & Sarkis, 2007). Second, increasing attention is being paid to the topic, with a wide variety of studies and objects of investigation, but there has been a lack of effort to integrate these studies. This paper will attempt to assimilate and contributed to fragmented knowledge of reverse supply chains, derived from numerous small discussions, which are mostly unconnected. Specifically, the research questions that will be addressed in this study are:

1. How has the reverse supply chain field evolved in terms of theoretical perspectives, technological adoption, and research focus over time?
2. What future research trajectories emerge from the literature regarding the role of digital technologies and artificial intelligence in reverse supply chains?

The remainder of this paper will be organised into five sections. The next section will describe the Methodological Approach used to carry out the systematic literature review. This includes an explanation of the keywords used to search for articles, how articles from databases were selected and how the selected articles were analysed. Then, the Findings and Analysis section will present how knowledge of this topic has evolved chronologically, detailing the major issues of each period, the characteristics of publications in those eras, what problems arose and how these were solved. Then, any notable gaps in existing research will be identified, and some suggestions as to future research enquiries will be made; this last part represents the main contribution of the paper, and is discussed in the Future Research Avenues section. Lastly, the Conclusion will summarise the key points discussed in this paper.

2. Methodological approach

To analyse the research questions presented above, a systematic literature review as suggested in by scholars (Rousseaua et al., 2008; Tranfield et al., 2003) was conducted to survey existing literature in relevant topics. The purpose of the systematic literature review was to accumulate the findings of previous works, as a basis for developing a body of knowledge. This type of accumulation leads to more rapid development of the field, and also serves as a tool for formulating scientifically-based conclusion (Tranfield & Starkey, 1998).

As the first aim of this paper is to establish the chronological development of knowledge of reverse supply chains, this literature review will present the overall picture of what research has been carried out by scholars in the past, and how the pattern of this knowledge has developed. Through this review, this paper seeks to produce a chronological analysis from the early development of reverse supply chain just before 1990 up until February 2016. To this end, keywords searches were applied to identify articles published up to February 2016 via three business and management databases: Science Direct, ISI Web of Knowledge and Proquest. The methodological approach of this literature review is presented in Figure 1.

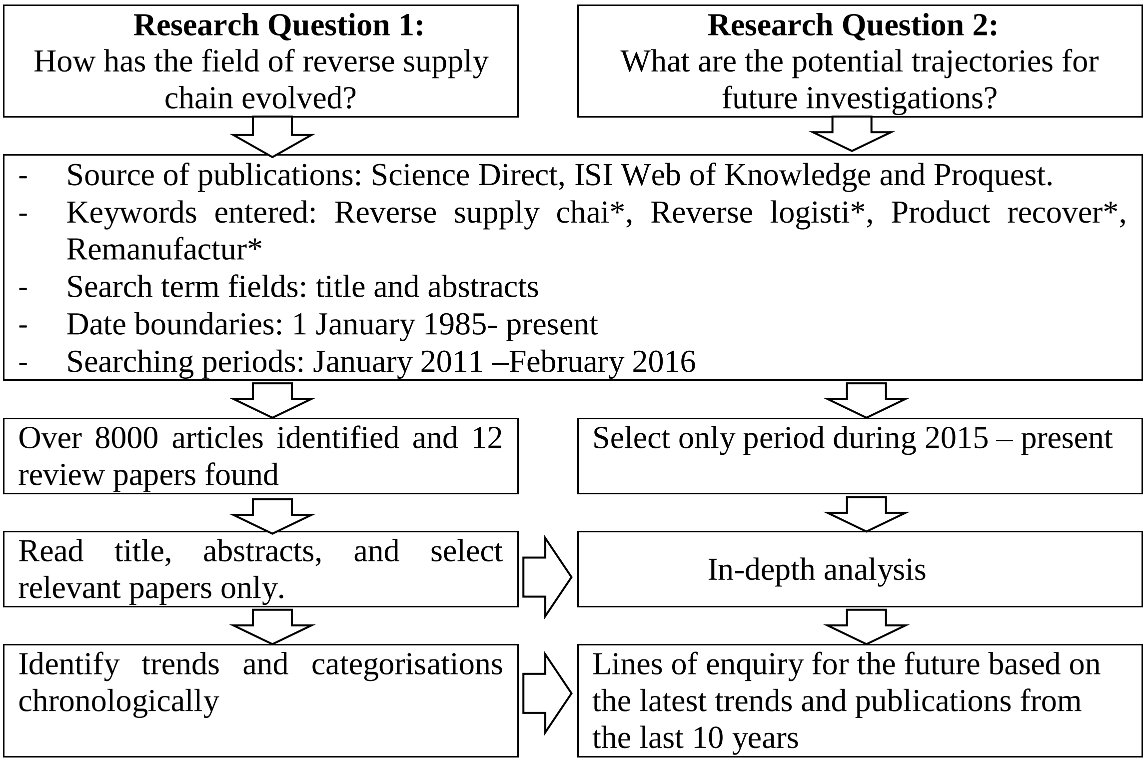


Figure 1. Methodological approach of the literature review

In addition to reverse supply chai*, reverse logisti* and remanufactur* were also included as keywords, as these terms are strongly related to the concept of reverse supply chain. The initial results of the search displayed more than 8,000 articles, which were then reduced using two techniques, the 'bird's eye' reading technique and then classifying based on the reputation of the journals in which the articles were published.

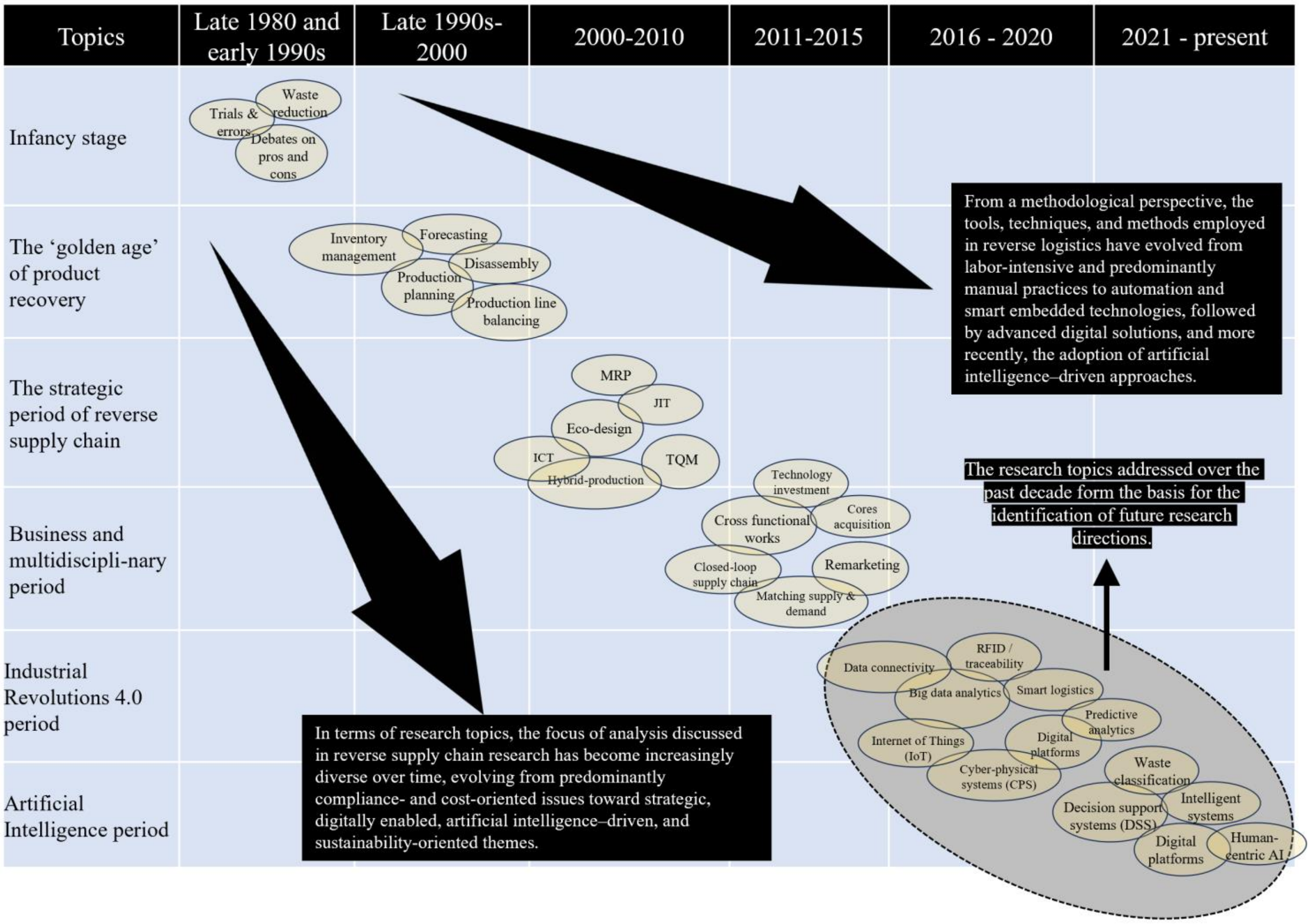
3. Findings and analysis

3.1. Chronological development of reverse supply chain

The chronological development of the concept of a reverse supply chain is presented graphically in Figure 2. The size of the circles in the figure indicates the amount of research undertaken during the corresponding period. In response to the most recent publications, located in the bottom right-hand corner of the figure, this paper will present several possible research avenues in the next section.

An interesting pattern can be observed within each stage of development. It is found that for each new topic, the investigation of a particular topic typically begins with operation research without any supporting empirical data. Then, after a number of studies using this method, researchers begin to use empirical data for analysis.

In terms of investigator expertise, the complexities of the problems that arise in this field have attracted scholars from various backgrounds, such as computer science, environmental engineering, mathematics and statistics, as their solution often requires a multidisciplinary approach.


Topics
Late 1980 and early 1990s
Late 1990s-2000
2000-2010
2011-2015
2016 - 2020
2021 - present
Infancy stage
The 'golden age' of product recovery
The strategic period of reverse supply chain
Business and multidiscipli-nary period
Industrial Revolutions 4.0 period
Artificial Intelligence period
Trials & errors
Waste reduction
Debates on pros and cons
Inventory management
Forecasting
Disassembly
Production planning
Production line balancing
MRP
JIT
Eco-design
ICT
TQM
Hybrid-production
Technology investment
Cross functional works
Cores acquisition
Closed-loop supply chain
Remarketing
Matching supply & demand
Data connectivity
RFID / traceability
Big data analytics
Smart logistics
Predictive analytics
Internet of Things (IoT)
Digital platforms
Cyber-physical systems (CPS)
Waste classification
Decision support systems (DSS)
Intelligent systems
Digital platforms
Human-centric AI
From a methodological perspective, the tools, techniques, and methods employed in reverse logistics have evolved from labor-intensive and predominantly manual practices to automation and smart embedded technologies, followed by advanced digital solutions, and more recently, the adoption of artificial intelligence–driven approaches.
The research topics addressed over the past decade form the basis for the identification of future research directions.
In terms of research topics, the focus of analysis discussed in reverse supply chain research has become increasingly diverse over time, evolving from predominantly compliance- and cost-oriented issues toward strategic, digitally enabled, artificial intelligence–driven, and sustainability-oriented themes.

With regard to specific subjects, most past studies have used automotive products as the subjects, followed by electronic and electrical products (Hatcher et al., 2011; Rubio et al., 2008). The short product life cycle characterising those two product categories, along with their high potential residual value, are the main reasons that researchers have taken these as subjects. Although there are various ways to recover value (including reuse, reconditioning, remanufacturing, refurbishing and recycling), remanufacturing is the most interesting to investigate, due to its economic potential (Ijomah et al., 2007; King et al., 2006; Mont & Tukker, 2006) and less negative environmental effects (Sutherland et al., 2002). This paper will analyse the development of product recovery in chronological order, as since its emergence as a concept there has been no review analysing its development over time.

3.2. Before 1990 and early 1990s: Infancy stage

Before the 1990 very few studies had been undertaken in the area of product recovery management, and reverse supply chain in particular. The first and most well-known study in this area was conducted by Lund (1984), who investigated the practice of remanufacturing in the United States and several developing countries. He demonstrated that reverse supply chain is a prerequisite for product recovery activity, of which remanufacturing is the most popular form. This work has been referred back to by many scholars in different countries up to the present time.

In addition to the study published by Lund (1984), another relevant piece of research in this field is the work of Kelle and Silver (1989), who developed a system for forecasting products that can be reused. In this period, the level of acceptance of product recovery as a concept was extremely low.

Three years on, Navin-Chandra (19910 highlighted the need to consider green design, in order to reduce waste. Other works related to sustainability include a study by Pohlen and Farris (1992), who used case studies to investigate reverse logistics. However, though these works address issues related to sustainability, none focus on reverse supply chains specifically.

Although new legislation was the main driver for companies to adopt reverse supply chain practices during the ‘infancy stage’, research has found that the effectiveness of policies promoting product take back is mixed, due to differences in local context (Giuntini & Gaudette 2003). Weak legislations and negative customer attitudes inhibit acceptance of recovered products (Corbett & Van Wassenhove, 1993). Webster and Mitra (Webster & Mitra, 2007) explains that where governments decide to offer a subsidy, this encourages companies to undertake remanufacturing. However, in emerging markets, the effects of such regulation are not significant. In addition, motivations are usually intertwined and are not mutually exclusive (Mcconocha & Speh, 1991).

A few years later, after academic debate had highlighted the importance of legislation as a key driver, higher acceptance rates and more positive attitudes were evident from companies. Later, the drivers shifted in response to customer demands for more environmentally friendly practices and the threat of competitors who had already implemented new practices. The last trigger discussed in the literature at this stage is corporate citizenships (Mcconocha & Speh, 1991) a discussion that continues to this day.

In this early period of introducing reverse supply, there are at least three important points to note. First, the main drivers for European companies were legislation whereas those in the US were pressured by market. Second, discussions regarding the motives behind adoption continue to the present day, examining objects in different geographical regions or different industries. Finally, there has been a notable shift in motivation from being legislation driven to more economic motives in later years.

3.3. Late 1990s-2000: The ‘golden age’ of product recovery

In this period, during the late 1990s, the number of publications in the field increased dramatically, and therefore this phase is termed the ‘golden age’ of product recovery (Guide & Van Wassenhove, 2009). In this ’golden age’ era, the number of studies investigating day-to-day operations that began to emerge in the previous period increased dramatically. According to a review carried out by Rubio et al. (Rubio et al., 2008), most investigators working in this period used various quantitative tools to investigate technical and operational problems (Guide & Van Wassenhove, 2009).

In a systematic literature review, Rubio et al. (2008) argue that despite the fact that multiple integer linear programming was dominant at that time, a variety of operations research tools were also employed in studies conducted during this period, indicating the array of issues in the field and the diversity of operations research tools used to tackle them. This is the key feature that distinguishes works of this period from those of the previous ‘infancy’ stage.

An example of day-to-day activities is provided in (Gungor & Gupta, 1999), who report that disassembly planning is an important phase, and one that affects profitability. This process determines to what extent products should be disassembled and the extent of environmental effects that will result from recovery activities. A comprehensive review of research on disassembly planning carried out during the 1990s is provided by Lambert (2003). Addressing scheduling issues, Guide et al. (1997) demonstrates how product structure complexity influences scheduling choices. Other research of this kind includes studies of inventory control in hybrid systems (van der Laan et al., 1999), production planning and control with remanufacturing and disposal (van der Laan & Salomon, 1997), the effect of inventory buffers on remanufacturing (Guide Jr. & Srivastava, 1998; Guide Jr., 1996) and scheduling policies in remanufacturing (Guide et al., 1997). Furthermore, they also develop a measure of product complexity, to serve as a guideline for a remanufacturing system.

At least three points can be raised with regards to the ‘golden age’. First, various characteristics that distinguish product recovery activities from conventional manufacturing systems were recognised (Fleischmann et al., 2001; Rogers & Rogers, 2002). Second, general characteristics of reverse supply chains were identified (Fleischmann et al., 2001); third, product recovery activities were found to be much more interesting than that had been predicted. More importantly, the realisation that the product recovery business, particularly remanufacturing, was a ’hidden giant’ (Lund, 1996) could be seen more clearly.

3.4. 2000-2010: The strategic period of reverse supply chain

Identifying the boundary between the technical and strategic period is not an easy task, as some issues can be categorised as being characteristic of both eras. For example, eco-design had been viewed as a technical issue during ‘golden age’, as it deals with disassembly planning, but in this later period, product designs issues were discussed with a more integrated approach, encompassing various parties including designers, suppliers and distributors (Gehin et al., 2008; Zwolinski & Brissaud, 2008). These activities are not focused towards legislation compliance or minimising cost, but rather to maximise the value that can be reclaimed from returned products.

In order to maximise reclaimed value, various factors must be taken into consideration, including production cost structures, collection rate, product life cycle and component durability (Geyer & Jackson, 2004). In addition, Weeks et al. (2010) add that production mix and product route are also important, as these are variables that affect performance. A subject of interest for many researchers at this time was how to combine production systems for new and recovered products (Saadany & Jaber, 2011; Ferrer & Swaminathan, 2006). Shared facilities, human resources and capacity utilisation were among the frequently cited reasons to develop hybrid manufacturing systems (Kondoh & Salmi, 2011).

Another issue raised in this era was the closed-loop supply chain. The emergence of this topic indicated that product recovery activities were viewed as valued-added business structures (Wells & Seitz, 2005; Krikke et al., 2004); this was even more apparent in the inclusion of commercial returns in closed-loop chains (Blackburn et al., 2004; Guide Jr. et al., 2005). Despite their potential, designing a closed supply chain involves complex challenges. OEMs cannot develop reverse supply chain by simply ‘extending’ the networks of the forward one (Fleischmann et al., 2001). Further challenges that add to this complexity include the type of process choice (Ostlin, 2005; Seliger et al., 2002), length of product life cycle (Tibben-Lembke, 2002; Östlin et al., 2009), the need to balance demands with product returns (Östlin et al., 2009; Shi et al., 2011; Konstantaras et al., 2010), the need to disassemble products (Guide Jr et al., 2000; Guide Jr. et al., 1999), stochastic routing problems for materials and high variability of product recovery processing times (Guide Jr et al., 2000).

While product recovery activities were claimed to be an important and strategic element of business in the 1990s (Thierry et al., 1995), a more positive attitude was evident in the 2000s, seen in investments in product recovery technologies. This is an indication that manufacturers equated a reverse supply chain with a forward one. Information technology such as Radio Frequency Identification was introduced to streamline information for product returns (Condea et al., 2010; Langer et al., 2007; Visich et al., 2007; Gou et al., 2008), Just in Time (Chan et al., 2009) was developed to minimise the cost incurred by small product returns in various conditions.

Even though many companies decided to carry out product recovery in-house, others preferred to outsource this process. This phenomenon encouraged researchers to conduct studies examining how to outsource reverse supply chain activities to other parties by considering strategic factors and profitability (Jeung & Gerald, 2007; Meade & Sarkis, 2002). Cheng and Lee (2010) developed a method for selecting which activities should be outsourced and which should be carried out in-house. Another study conducted by Ordoobadi (2009) addressed outsourcing issues by proposing a conceptual framework for effective decision-making in outsourcing reverse logistics and remanufacturing function. While most studies examine how to select a third party logistics provider, Krumwiede and Sheu (2002) carried out research from a third party logistics perspective, in order to identify when they should enter the market and when they should not.

3.5. 2010-2015: Business and multidisciplinary period

Unlike the previous periods, in which discussions were mainly focused on production and operations perspectives, in the present era publications look to disciplines from other fields, such as accounting, finance, economics and marketing. For example, how to develop a marketing strategy for both new and remanufactured products has been extensively discussed in recent literature (Atasu et al., 2010; Guide Jr & Li, 2010; Wu, 2013). Another issue involving accounting and procurement functions is how to assess the value of returned and recovered products. More pessimistic perspectives recommend that returned products should be treated as a loss, whereas the optimistic view suggests that returns can be a source of profit (Guide & Van Wassenhove, 2009). The discussions in (Chung & Wee, 2010; Qiaolun et al., 2011; Wu, 2013; Wu, 2012) represent a good starting point for further investigation on accounting for product returns, though further study is still needed.

Product acquisition management, whose function is similar to procurement in conventional supply chain management, is a topic that has been investigated intensively in the more recent years of this period. This function must run alongside a finance function for gate keeping and return avoidance (Simolowo et al., 2011); these roles will also benefit the marketing function, as the decision to accept or reject cores can help to balance the number of incoming cores with the number demand for recovered products. In terms of the finance function, the decision to accept or reject cores ensures that these cores are of high quality, not costly to process and profitable (Loomba & Nakashima, 2012).

Unlike the technical and operational issues that characterised the ‘golden age’, which mainly related to how to carry out efficient product recovery activities, problems in this period mainly surround supporting product acquisition management, for instance through the buyer-supplier relationship as part of cores procurement (Martin et al., 2010), sorting process (Loomba & Nakashima, 2012), categorisation and valuation of cores (Simolowo et al., 2011). These technical issues can relate to remarketing issues, for instance how to manage new and remanufactured components (Wu, 2013) to avoid cannibalisation (Guide Jr & Li, 2010; Wu, 2013), and the pricing of remanufactured products (Wu, 2012; Qiaolun et al., 2011).

Further debates regarding strategic remanufacturing issues include how to position remanufactured products in the market; factors that are considered to determine market position include product life cycle contingencies (Östlin et al., 2009; Kumar et al., 2007), type of customers (for example industrial or individual customers) (Lee & Lam, 2012; Guide Jr & Li, 2010) and product durability (Geyer et al., 2007) whereas and research findings suggest that the position of recovered products could be as a cannibal of (Atasu et al., 2010; Ferrer & Swaminathan, 2006; Guide Jr & Li, 2010) or substitute (Guide Jr & Li, 2010) for existing products in the market.

Product recovery management is another issue currently being discussed by academics; this topic began to gain prevalence in 2000 initiated by Guide Jr. (2000), who analysed collaboration with external organisations in reverse supply chains with the support of information technology. Collaboration within a company involving different functions has been more or less ignored in academia; however, two recent studies by Jayaraman et al. (Jayaraman et al., 2008) and Olorunniwo and Li (2010) attempt to fill this gap.

In the current period, it is agreed by both academics and practitioners that product recovery is profitable (Sheu & Gao, 2014; Atasu et al., 2010). The next challenge is to determine how best to integrate product recovery activities into a holistic business model, a challenge highlighted by Guide et al. (2003), whose study concluded that companies cannot rely on products alone to satisfy customers any longer, and should also offer a product returns service. This shift has a positive impact for businesses, as companies not only attempt to obtain profit but also to create value, without ignoring industrial-ecology issues. At this point, the contradiction between environmental concerns and profitability are no longer questioned; all relevant parties believe that product recoveries can be profitable and offer a competitive edge. Consequently, there has been an increase in publications analysing how to incorporate product recovery activities into an integrated business model.

3.6. 2016-2020: Industrial Revolution 4.0 Period

This period is characterized by the widespread adoption of digital technologies in reverse logistics. Digital technologies, particularly those associated with Industry 4.0, have been identified as key enablers of business process transformation in reverse supply chains. Digital practices such as DIY logistics have been shown to enhance both environmental and operational performance (Upadhyay et al., 2021). Furthermore, the integration of lean production principles and Industry 4.0 technologies constitutes a foundational pathway for the transition toward a circular economy.

Nevertheless, the majority of the literature continues to conceptualize digital technologies primarily as tools for improving efficiency, rather than as strategic drivers of business process transformation or organizational change (Ciliberto et al., 2021). The application of Internet of Things (IoT) technologies and Low Power Wide Area Networks (LPWAN) has been demonstrated to improve visibility and effectiveness in managing end-of-life plastics (Plakas et al., 2020), while Radio Frequency Identification (RFID) contributes to reducing uncertainty and enhancing the performance of closed-loop supply chains (Usama & Ramish, 2020). Despite these significant contributions, most reverse supply chain studies still position reverse logistics as an operational or technical function, with an emphasis on process efficiency and environmental compliance, rather than as an integral component of organizational strategic design.

Another rapidly developing theme during this period relates to business model innovation. Business model approaches within the sustainability context emphasize the importance of transforming value creation logic, rather than merely improving process efficiency. (Romero et al., 2021)propose a meta-business model for complex organizations facing the combined challenges of digitalization, sustainability, and circularity. Bressanelli et al. (2018) further demonstrate that usage-focused (servitized) business models supported by digital technologies can effectively integrate reverse logistics activities into the value creation process. However, such studies remain relatively limited in number and have not yet become part of the mainstream literature.

3.7. 2021 - present: The rise of artificial intelligence

Overall, the seven most recent studies indicate that reverse logistics research in the era of artificial intelligence has advanced rapidly, yet continues to exhibit notable imbalances across major thematic areas. At the conceptual level, several studies emphasize the role of AI and digital technologies as key enablers of the transformation of reverse logistics toward more intelligent and sustainable systems, while also proposing future research agendas. However, these contributions remain predominantly normative and conceptual in nature, with limited empirical validation (Sun et al., 2022; Wilson et al., 2022).

At the methodological level, studies focusing on artificial intelligence and machine learning techniques demonstrate significant progress in forecasting, classification, and optimization of reverse logistics activities. Nevertheless, this stream of research tends to be fragmented around specific operational problems, highly dependent on data quality, and insufficiently connected to strategic implications and long-term sustainability outcomes (Chen et al., 2024; Silva et al., 2025).

Meanwhile, studies positioning AI as a decision-support and system optimization tool increasingly integrate AI with simulation, analytics, and digital frameworks to assess economic and environmental performance in a more comprehensive manner. Despite this advancement, these studies largely concentrate on system-level performance optimization and devote relatively limited attention to issues of organizational adoption, governance, and long-term value creation (Dabo & Hosseinian-Far, 2023; Oliveira Neto et al., 2023; Rodrigues et al., 2025).

Taken together, although the literature reflects a progression from conceptualization toward more sophisticated AI applications, reverse logistics research remains theoretically fragmented and methodologically siloed. This reinforces the need for integrative approaches that bridge conceptual frameworks, AI techniques, and decision-making mechanisms within a coherent empirical perspective.

4. Future research avenues

The identification of future research avenues is grounded in the intersection between the 2016–2020 period, which emphasizes digital technologies, and the period from 2021 onward. The rapid expansion of artificial intelligence applications observed since 2021 remains closely linked to the utilization of digital technologies developed and adopted in earlier periods. In this context, the adoption of digital technologies constitutes a foundational prerequisite for the effective implementation of artificial intelligence in reverse logistics and supply chain management.

4.1. Meta-Business Model Validation

Recent developments in the reverse logistics and circular economy literature indicate a significant shift from predominantly conceptual approaches toward frameworks increasingly integrated with advanced digital technologies. Recent systematic studies confirm that the adoption of Industry 4.0 and Industry 5.0 technologies—such as the Internet of Things (IoT), artificial intelligence (AI), machine learning (ML), and digital twins—has fundamentally reshaped the structure and operations of reverse logistics systems. However, their integration into business model logic remains partial and fragmented (Rodrigues et al., 2025; Sun et al., 2022).

AI- and ML-based research in reverse logistics further demonstrates enhanced predictive and optimization capabilities, yet most studies continue to focus on process-level or network-level applications rather than on the holistic validation of business model structures (Chen et al., 2024; Silva et al., 2025). Even advanced quantitative approaches associated with Industry 5.0 primarily emphasize flow optimization and decision-making efficiency, while largely overlooking how such configurations validate or transform open and circular business model designs (Dabo & Hosseinian-Far, 2023).

Consequently, there remains a pressing need to apply and empirically validate meta-business models within the context of highly digitalized circular businesses. In line with this gap, the present research is guided by the following question: *How can meta-business models be applied and validated in empirical contexts of digital and circular business systems?*

4.2. Reverse Logistics and Value Creation

Recent literature increasingly emphasizes that reverse logistics can no longer be understood merely as an operational function, but rather as a strategic value-creation mechanism within the circular economy. Recent studies demonstrate that the integration of artificial intelligence (AI), machine learning (ML), and advanced analytics significantly enhances visibility, efficiency, and decision quality in reverse logistics, particularly in the contexts of return prediction, waste classification, and network optimization (Chen et al., 2024; Silva et al., 2025). Simulation-based approaches and AI-driven optimization have further shown their capacity to simultaneously generate economic and environmental benefits in urban- and regional-scale reverse logistics systems (Oliveira Neto et al., 2023).

Nevertheless, despite the increasingly measurable contribution of reverse logistics to sustainability outcomes, most studies remain focused on performance evaluation or efficiency improvement, without explicitly linking these outcomes to the logic of value creation and value capture within business models (Sun et al., 2022; Wilson et al., 2022). As a result, the mechanisms through which digitally enabled reverse logistics interact with sustainability dimensions to shape strategic value within complex business models remain insufficiently theorized and empirically explored. Based on this gap, the present study addresses the following research question: *How do the interactions between reverse logistics and sustainability shape value creation within complex business model structures?*

4.3. Open Business Model Dynamics

As circular and digital business systems become increasingly complex, recent literature highlights the limitations of static approaches in analyzing business models. Contemporary studies emphasize the need for dynamic, simulation-based approaches—such as system dynamics, agent-based modeling, and AI-driven methods—to capture the evolution, feedback loops, and inherent uncertainties associated with reverse logistics and the circular economy (Dabo & Hosseinian-Far, 2023; Oliveira Neto et al., 2023). In addition, the Reverse Logistics 4.0 and 5.0 research agenda explicitly calls for the development of quantitative models and digital twins to better understand the systemic transformations driven by intelligent technologies and human-centric innovation (Sun et al., 2022).

Despite these advances, the integration of quantitative and simulation-based approaches into the analysis of open business models remains highly limited, particularly with respect to linking the operational dynamics of reverse logistics to changes in business model structures and value creation logic (Rodrigues et al., 2025; Wilson et al., 2022). Consequently, to bridge this methodological and conceptual gap, this research is guided by the following question: How can the dynamics of open business models be quantitatively modeled or assessed through simulation-based approaches?

4.4. Conceptualizing Artificial Intelligence in Reverse Logistics

The literature on reverse logistics and the circular economy consistently positions digital technologies—including artificial intelligence (AI) – as key enablers of systemic transformation. Early conceptual studies emphasize that reverse logistics constitutes a critical component in achieving circular economy objectives, while simultaneously facing high levels of complexity due to return flow uncertainty and multi-actor coordination challenges (Ciliberto et al., 2021; Moreno et al., 2019).

Subsequent research increasingly frames AI as a strategic technology capable of enhancing visibility, predictability, and effectiveness in reverse logistics within circular economy contexts (Wilson et al., 2022). This conceptualization is further advanced through the notion of Reverse Logistics 4.0, which emphasizes the integration of AI, the Internet of Things (IoT), and advanced analytics to enable intelligent and sustainable transformations across reverse logistics systems (Sun et al., 2022).

Despite the development of well-articulated research agendas and conceptual frameworks, much of the existing literature remains predominantly normative and conceptual in nature. In particular, limited attention has been devoted to explaining how AI is operationalized and institutionalized in reverse logistics practices across different industries. Based on this gap, this study addresses the following question: *How are artificial intelligence and digital technologies conceptualized as enablers of reverse logistics and circular economy transformation in the recent literature?*

4.5. Machine Learning and AI for Reverse Logistics Forecasting

As conceptual agendas have matured, empirical research has increasingly explored the application of artificial intelligence and machine learning (ML) techniques in reverse logistics. Existing studies indicate that AI and ML are employed to support product return forecasting, waste classification, route optimization, and operational decision-making in reverse logistics systems (Chen et al., 2024; Plakas et al., 2020). A recent systematic review by Silva et al. (2025) confirms that supervised learning, unsupervised learning, and hybrid AI techniques dominate reverse logistics applications, particularly in waste management and end-of-life product contexts.

In addition, concepts such as digital intelligence and redistributed manufacturing have been introduced as important mechanisms for enhancing system flexibility and circularity in reverse logistics (Moreno et al., 2019). Nevertheless, several limitations remain prominent in the literature, including strong dependence on data quality, limited explainability of AI models, and insufficient assessment of long-term sustainability impacts (Chen et al., 2024; Silva et al., 2025) These limitations suggest that, despite increasing methodological sophistication, understanding of the effectiveness and boundaries of AI and ML applications in complex reverse logistics systems remains incomplete. Accordingly, this research is guided by the following question: *Which artificial intelligence and machine learning techniques are applied in reverse logistics, and how do their contributions and limitations affect system performance and sustainability?*

4.6. Artificial Intelligence for Decision Support and System Optimization

The last stream of literature highlights a shift from process-level AI applications toward the use of AI as a decision-support mechanism and system-wide optimization tool in reverse logistics. Digital frameworks proposed by (Rodrigues et al., 2025)Rodrigues et al. (2025) illustrate how AI, IoT, Big Data, and related digital technologies can be integrated with reverse logistics activities to enhance both performance and sustainability outcomes. Quantitative and simulation-based approaches have also been employed to evaluate the economic and environmental impacts of reverse logistics systems, particularly in large-scale circular networks and electronic waste management contexts (Oliveira Neto et al., 2023).

Other studies emphasize the critical role of AI and analytical methods within Industry 4.0 and Industry 5.0 frameworks in improving the quality of strategic decision-making in reverse logistics (Dabo & Hosseinian-Far, 2023; Sun et al., 2022). However, the majority of this research continues to focus on optimizing specific systems or networks, with limited integration of AI into broader discussions on business model innovation, servitization, and long-term value creation in reverse logistics (Bressanelli et al., 2018; Romero et al., 2021). Consequently, there remains a need for integrative approaches that connect AI-based decision support with systemic reverse logistics transformation and value creation logic. In response to this gap, this study addresses the following question: *How is artificial intelligence utilized as a decision-support mechanism to holistically optimize reverse logistics systems while supporting sustainability and value innovation?*

5. Conclusion

This systematic literature review provides a comprehensive synthesis of the evolution of reverse supply chain research, with particular emphasis on the growing role of digital technologies and artificial intelligence. The findings indicate a clear shift in the literature from viewing reverse logistics primarily as an operational support function toward recognizing it as a strategic mechanism for value creation within circular economy systems. Over time, the field has progressed from early conceptual discussions toward increasingly sophisticated technological applications, particularly those associated with Industry 4.0 and Industry 5.0 paradigms.

Having discussed and analysed the trends in reverse supply chain management research and practices, it can be concluded that the field of reverse supply chain management has undergone a substantial transformation. In the early stages, from the early 1990s to the early 2000s, research predominantly focused on operational and technical issues, a period often described as the “golden age” of reverse supply chain research. Subsequently, during the 2000–2010 period, the literature increasingly adopted a multidisciplinary perspective, integrating insights from accounting, operations, and marketing management. More recently, particularly throughout the 2010s and onward, reverse supply chain research has been characterized by a cross-functional orientation and a growing recognition of organizations as holistic and interconnected systems.

Within this contemporary phase, digital technologies—such as the Internet of Things, artificial intelligence, machine learning, advanced analytics, and digital twins—have fundamentally reshaped reverse logistics operations by enhancing visibility, predictability, and decision quality. Empirical studies document significant advances in return forecasting, waste classification, network optimization, and system-level performance assessment. However, these technological developments remain unevenly distributed across research streams. While methodological contributions related to AI and machine learning are rapidly expanding, they are often fragmented, problem-specific, and only weakly connected to broader strategic, organizational, and business model considerations.

At the conceptual level, the literature has developed robust normative frameworks positioning AI as a key enabler of intelligent and sustainable reverse logistics systems. Nevertheless, many conceptual contributions lack empirical validation and provide limited insight into how AI is operationalized and institutionalized across industries. Similarly, quantitative, simulation-based, and decision-support studies tend to prioritize system optimization and efficiency gains, with insufficient attention to business model dynamics, value creation mechanisms, and long-term sustainability outcomes.

Overall, this review highlights persistent theoretical fragmentation and methodological siloing within reverse supply chain research, despite substantial technological progress. The integration of conceptual frameworks, AI-based analytical techniques, and business model perspectives remains limited, underscoring the need for more integrative and empirically grounded research approaches. Conducting research along the identified trajectories – bridging operational dynamics, strategic decision-making, and sustainability-oriented value creation—will not only advance scholarly understanding but also contribute to the development of sustainable and economically viable business models in increasingly digital and circular economies.

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