Cleaner Logistics and Supply Chain 12 (2024) 100165

Contents lists available at ScienceDirect

Cleaner Logistics and Supply Chain

journal homepage: www.journals.elsevier.com/cleaner-logistics-and-supply-chain

Navigating barriers to reverse logistics adoption in circular economy: An integrated approach for sustainable development

Harshad Sonar [a], Bishal Dey Sarkar [a], Prasad Joshi [a], Nikhil Ghag [b], Vardhan Choubey [a], Sandeep Jagtap [c,d,*]

[a] Symbiosis Institute of Operations Management (SIOM), a Constituent of Symbiosis International (Deemed) University, Nasik 422008, India
[b] Indian Institute of Management (IIM), Vihar Lake, Powai, Mumbai 400087, India
[c] Division of Engineering Logistics, Faculty of Engineering, Lund University, Lund 22363, Sweden
[d] Sustainable Manufacturing Systems Centre, Cranfield University, Cranfield MK43 0AL, UK

ARTICLE INFO

Keywords:
Reverse logistics
Circular economy
Decision making
Sustainability
Supply chain management
Barriers to adoption

ABSTRACT

Achievement of sustainability goals is an epic task for developing economies that still strive to fulfil their basic needs. The availability of limited resources in the developing world vis-à-vis the ever-increasing demand poses further challenges to developing economies willing to transition into circular economies. Reverse logistics (RL) can facilitate this transition towards a circular economy (CE) by maximising resource utilisation and minimising waste, contributing to sustainability goals. This paper contributes to emerging literature by analysing the development and comprehensive potential of reverse logistics as a sustainability tool. It explores the significant barriers to the adoption of reverse logistics towards a circular economy, considering long-term sustainability. In the first phase, thirteen barriers have been identified from the past academic literature. Three barriers with a defuzzification number less than the threshold limit are excluded, and the final ten barriers are then prioritised using the decision-making trial and evaluation laboratory (DEMATEL) method. The findings suggest that a lack of strategic plans for returns is crucial for RL adoption towards a circular economy, followed by a lack of visibility for recycling/reuse. Organisations can increase customer satisfaction, promote environmental sustainability, and gain a competitive edge in the market by creating a strategic plan for reverse logistics. Organisations may lower costs and contribute to a more sustainable and ecologically responsible supply chain by improving visibility across the reverse logistics process. The results serve as a framework for decision-making in RL towards sustainable development. Managers and policymakers can formulate more robust and realistic decisions that align with "maximising profits," "saving the planet," "social concerns," and, most importantly, "consumer concerns" in the circular economy ecosystem. Several implications are derived, leading to increased competitiveness and resilient business strategies. The novelty of this work lies in the identification of barriers to reverse logistics adoption towards a circular economy using an integrated fuzzy Delphi-DEMATEL approach, considering long-term sustainability. This approach is studied for the first time in a developing economy context, proposing social, economic, and environmental effects and actions to be taken by organisations for sustainable development.

1. Introduction

The Circular Economy (CE) aims to reduce waste and maximise resource utilisation, making a significant contribution to the Sustainable Development Goals (SDGs) (Kumar et al., 2023). The CE is a strategic plan to address our unsustainable resource consumption and help businesses better understand the natural inputs that sustain them (Frei et al., 2020; Kandasamy et al., 2022). The idea of a circular economy has drawn increasing attention, particularly from scientists, consultants, lawyers, and lawmakers who approach the topic from a more sustainable society perspective (Sonar et al., 2024a). Key principles of the circular economy include closing the loop, resource efficiency, design for longevity and recyclability, and a shift to service-based models. According to Schultz et al. (2021) and Batista et al. (2018), involving various stakeholders in circular supply chains and business models requires a wider value chain view.

* Corresponding author at: Division of Engineering Logistics, Lund University, Lund 22363, Sweden.
E-mail address: sandeep.jagtap@tlog.lth.se (S. Jagtap).

https://doi.org/10.1016/j.clscn.2024.100165
Received 11 July 2024; Received in revised form 6 August 2024; Accepted 7 August 2024
Available online 17 August 2024

The circular economy, which promotes reducing the number of materials disposed of in landfills and incinerators and returning the residues to productive business cycles, is founded on the core idea that products must be given a longer shelf life (Sonar et al., 2024b). Primary actors like consulting firms, NGOs, and legislative and governmental bodies have initiated numerous measures for implementing the circular economy, such as the 4Rs (reduce, recycle, reuse, recover), waste reduction, eco-effectiveness and eco-efficiency, and stock optimisation (Kalmykova, Sadagopan, and Rosado 2018; Arena et al. 2021). Organisations frequently use various management techniques in the supply chain to enhance sustainability.

Reverse logistics, which streamlines a circular economy by taking, making, using, reusing, repairing, and recycling, has become central to discussions on gathering and distributing goods (Bernon et al., 2018; Julianelli et al., 2020; Kazancoglu et al., 2021). Reverse logistics is an important component of the circular economy as it allows for the sustainable management of product life cycles, ensuring that resources and products are properly recovered, reused, refurbished, or recycled (He et al., 2024). This process eliminates waste, reduces the demand for raw resources, and lowers the environmental impact of manufacturing and consumption. Reverse logistics promotes the principles of a circular economy by closing the loop in supply chains, ensuring that resources are used for as long as feasible and fostering sustainability. This helps to advance sustainable development by preserving natural resources, reducing greenhouse gas emissions, and stimulating economic growth through new business opportunities and green jobs, ultimately leading to a more resilient and environmentally friendly economy. However, little is understood about reverse logistics' role in the circular economy.

Literature highlights a few theoretical frameworks from the perspective of CE that support reverse logistics for the sustainable development of Closed-Loop Supply Chain (CLSC) Models, Sustainable Supply Chain Management (SSCM), and Industrial Ecology. CLSC models cycle materials and products within the system rather than discarding them after use (Mondal and Roy, 2021; Schneikart et al., 2024). SSCM underlines the integration of sustainability values into supply chain operations (Julianelli et al., 2020; Carissimi and Creazza, 2022). Industrial Ecology offers a comprehensive outlook on resource utilisation, waste generation, and environmental impact, providing guidance for enhancing resource efficiency and minimising environmental footprint (Wiprächtiger et al., 2023). Additionally, various business models have emerged to uphold circular economy principles, such as product-as-a-service, remanufacturing, and resource recovery (Hapuwatte and Jawahir, 2021; Sharma et al., 2021). These models frequently rely on reverse logistics to facilitate product return, refurbishment, and redistribution, enabling organisations to capture added value from products after their life cycle. Recycling and reuse through reverse logistics reduce the need for new manufacturing, thus lowering carbon emissions and energy usage. This mitigates environmental impact, contributing to climate action and achieving SDG-13. Encouraging product recycling and reuse aids in resource conservation, particularly energy and water, contributing to maintaining a clean and healthy environment (SDG-6) (Chen et al., 2024; Jayarathna et al., 2024).

Reverse logistics involves moving goods from their presumed destination to another location, adding value that would not otherwise be possible, or correctly discarding the goods (Guarnieri, Jorge A Cerqueira-Streit, & Batista, 2020; Mishra et al. 2022). In the circular economy, reverse logistics is the process of collecting and aggregating products, components, or materials at the end-of-life for reuse, recycling, and returns, leading to sustainable development (Vargas et al., 2024). There could be several causes for this product translocation (Sellitto and de Almeida, 2020). It might relate to providing good customer service (returning damaged goods, unsold goods, etc.), the environment, or the economy (Nanayakkara et al., 2022). The shared responsibility principle must strengthen the configuration and fulfilment of the reverse logistics system. Due to the recent emphasis on recycling and related challenges, some nations have passed waste management-specific legislation (Guarnieri, e Silva, and Levino, 2016; Arena et al. 2021). This issue is most prevalent in developing nations, where reverse logistics and waste management are still in their infancy. Most developing countries use the "take-make-dispose" loop model to manufacture and consume consumer items (Bhattacharyya et al., 2023; Esposito et al., 2017). While this model benefits the consumer market and plays an important role in the sector's economic development, it also has detrimental effects on the environment and society (Andrews, 2015). According to Schroeder et al. (2018), a paradigm that must be dismantled is based on the careless use of limited resources and inappropriate disposal (either as a source of energy or as raw materials). This linear pattern negatively impacts a corporate organisation's competitiveness.

Four interconnected marketing environment factors—customer expectations, corporate social responsibility, legal requirements, and economic ramifications—affect the growing need for reverse logistics systems (Dev et al., 2020; Kusumowardani et al., 2022). As businesses continue to look for competitive advantages, the economic ramifications of reverse logistics are becoming clearer. According to Guide & Wassenhove (2009), the total value of returned goods for a single store can reach hundreds of millions of dollars, most of which are not currently recovered. Reverse logistics can provide businesses with several financial advantages, including lower material input costs, decreased risks related to price volatility and supply disruption issues (Gaustad et al. 2018; Wilson and Goffnett 2022), and new revenue streams from remanufactured and recycled goods (Larsen and Jacobsen 2016; Münch, von der Gracht, and Hartmann 2023). Significant changes have occurred in industrialised nations, and reverse logistics are being promoted for these interconnected foci. However, reverse logistics practices are notably lacking in India (Dutta et al., 2021).

According to the literature, researchers have previously attempted to prioritise the barriers to reverse logistics (Badenhorst, 2016; Lamba et al., 2020); however, quantitative models that account for how the barriers are related and support the implementation of reverse logistics by outlining suitable strategies to lessen their impact are still in their infancy. More research is needed to evaluate the effectiveness of RL on sustainable development by understanding approaches like refurbishing, remanufacturing, and repurposing. The development of a standard framework assessing RL's contribution to the circular economy would benchmark reverse logistics systems that align with circular economy goals. To close this research gap, this study has created a taxonomy of reverse logistics barriers relevant to business and supply chains from the circular economy perspective in developing economies, particularly in sectors like consumer electronics, e-commerce, manufacturing, and retail. Additionally, the study outlines the connections between reverse logistics barriers towards a circular economy for developing countries. The following are the research questions that this study will address:

RQ1: What are the barriers to reverse logistics towards a circular economy?

RQ2: Which barriers must be prioritised for successfully implementing reverse logistics towards a circular economy? And how are these barriers related to each other?

Based on the research questions, the study develops the following research objectives:

RO1: To identify and prioritise the crucial barriers based on their influence on reverse logistics to attain circular economy goals.

RO2: To investigate and develop the interrelationship between these barriers for strategy formation.

The study uses an integrated approach of methodologies to accomplish the developed objectives. Existing literature has been reviewed from the Scopus database for the years 2000–2023 to identify the barriers to reverse logistics towards a circular economy. To select the appropriate barriers, the study uses the fuzzy-Delphi method. To rank and investigate the interrelationships among the barriers, it uses the DEMATEL technique. This article has six sections: the first is the introduction. The literature review is presented in Section 2, the study's methodology in Section 3, and the results and analysis in Section 4. The managerial implications of the study are presented in Section 5, followed by the conclusion and suggestions for further study in Section 6.

2. Literature review

A circular economy (CE) as a concept can only be advanced with the help of reverse logistics (RL). In a linear economy, goods are produced, used, and then thrown away, depleting resources and harming the environment. By extending the life of products and resources, a CE seeks to maximise resource utilisation while reducing waste. RL, which emphasises the return, recovery, and reuse of goods and commodities, is crucial to achieving this shift. Researching RL for the CE is essential for resolving societal, economic, and environmental issues. It encourages resource conservation, waste reduction, environmental sustainability, and economic rewards, while assisting businesses in adhering to rules and involving consumers in sustainability initiatives. RL is a crucial enabler of the shift to a more sustainable and circular future.

2.1. Reverse logistics (RL)

Reverse logistics involves handling the flow of goods, materials, and information in the reverse direction of the traditional supply chain (Ravi and Shankar, 2004). Where forward logistics focuses on the movement of goods from the manufacturers to the customers, RL includes recycling, refurbishment, repairs, product returns, and disposal. This process becomes essential when products need to be returned due to customer dissatisfaction, expiration, damages, or defects. RL aims to extract maximum value from returned products while minimising waste and environmental impact (Dutta et al., 2020). Increasing environmental concerns have created regulatory and social pressures on manufacturers globally, demanding the safe and eco-friendly disposal of products at the end of their life (Ren et al., 2023). Businesses are held responsible for their "take-make-dispose" linear economy, which leads to environmental and social issues such as climate change, wastage, toxicity, etc. (Mallick et al., 2023). Businesses are held accountable and are expected to take corrective actions and devise damage control mechanisms (Butt et al., 2023). These increasing expectations from producers pave the way for RL to emerge from an eco-friendly initiative to a strategic decision from an economic, regulatory, and social perspective (Dutta et al., 2021). RL is defined by Carter & Ellram, (1998) as the philosophy that businesses should emphasise the reuse, reduction, and recycling of end-of-life or end-of-use products. RL is the mechanism by which the original manufacturer arranges to collect the remains of previously distributed products with the intent to reuse, recycle, or dispose of them (Wilson and Goffnett 2022; Alarcón et al. 2021). Though RL can be costly (Julianelli et al., 2020), increasing customer expectations are compelling organisations to implement it. Wilson & Goffnett, (2022) have studied multiple companies that have successfully implemented RL systems. Based on the study, they offer multiple solutions for the successful implementation of RL that can be beneficial from environmental, social, and economic perspectives. Guarnieri et al., (2020) while understanding the implementation of RL in Brazil, claimed that though the term circular economy is not formally used in the nation's policy, the essence of the study is based on CE principles. Thus, RL and CE are cohesive elements for a sustainable economy.

2.2. Circular economy (CE)

A circular economy is a business approach that has a restorative and regenerative nature in all its processes, right from the design stage. While studying 114 definitions from varied perspectives of CE, Kirchherr et al., (2017) concluded that it is the systemic shift towards adapting reuse, reduction, recycling, and remanufacture. CE is about extracting the complete utility value of a product to its fullest extent for the betterment of the environment, society, and efficient use of resources. Zhang et al., (2021) claim that CE is different from sustainability in that it demands circularity and improved efficiency of resources, unlike sustainability which focuses only on people, the planet, and profit. To imbibe CE values in the supply chain and ensure the circularity of resources, RL plays a decisive role (Shahidzadeh and Shokouhyar, 2022) as closing the loop of traditional supply chains is not possible without RL. They have analysed and found a strong relationship between RL and the circularity of resources.

Julianelli et al. (2020) also studied the relationship between RL and CE, identifying five critical success factors of RL and claiming that RL is not only a regulatory requirement but has transformed into a value-creation tool for manufacturers. Along similar lines, Dutta et al., (2021) stated that RL is a value-creation tool for businesses and provided strategic solutions for enhancing the efficiency of RL. The real drive for CE comes from consumer-backed practices like reuse, recycling, refurbishing, repairing, etc., all of which are elements of RL. Thus, RL contributes towards CE (Mishra et al. 2022; Camilleri 2019). The RL support for CE can be established only if the design, inputs, processes, and motives are aligned and form a circular supply chain that fosters the growth of a circular flow of resources impacting social, environmental, and economic factors (Julianelli et al., 2020). Zhang et al., (2021) emphasised that remanufacturing or recycling is a critical process and if it goes wrong, it can cost the company in terms of money, customers, quality, and brand value. Thus, the success of RL is critical for businesses from socio-economic and environmental perspectives (Sudarto et al., 2016a, 2016b; Vijayan et al., 2014).

2.3. Success factors

There have been multiple studies suggesting the success factors of RL towards CE. RL is stated by Alarcón et al., (2021) as complex and uncertain, affecting supply chain efficiencies. To reduce inefficiencies and improve RL effectiveness, a well-structured and standard RL process establishment was suggested. According to De Oliveira et al., (2014), the success of RL largely depends on awareness among consumers and a well-structured collection network. As a solution, creating customer awareness, ensuring optimum logistics network utilisation and efficient warehousing were proposed by Dutta et al., (2021). In a study involving outsourcing decisions and RL, Agrawal & Singh, (2020) suggested that outsourcing RL is a better solution to ensure efficient RL to support CE. For the success of RL for CE, Münch et al., (2023) suggested a few measures including the use of recyclable raw materials, innovative packaging, returnable transport items, and zero waste shops. They claimed that if businesses and consumers collaborate, RL for promoting CE would be a success. The work of Dev et al. (2020) suggests that implementing Industry 4.0 in RL management would ensure better tracking of products and higher efficiency, resulting in a circular economy.

2.4. Barriers

There have been a few studies about identifying the barriers to RL. Multiple barriers to RL implementation were identified by Dutta et al., (2021) including the quality of circular goods, lack of responsibility, and initiation by top management. The same barrier of lack of responsibility by the management was identified (Frei et al., 2020) in the case of RL in the retail industry. The study by Sudarto et al., (2017) revealed that though socially responsible RL is essential, product life cycle uncertainties make RL costly and difficult to manage. Through their research, they suggest that efficient flexible capacity planning can be a solution to the aforementioned challenges of RL. Ambekar et al. (2021) studied the barriers to the success of RL in the construction and real estate sector and identified that lack of awareness and government policies along with the absence of a standard code for RL are the major macro barriers. Inadequate information systems, lack of organisational policies, and stakeholders' ignorance are the micro barriers affecting RL, preventing the establishment of a strong CE.

2.5. RL in multiple sectors

RL in retail is not necessarily at the end-of-life of the products, but because of product returns by consumers, and retailers consider it a cost of doing business without considering the impact on CE (Agrawal and Singh, 2020). Another study on the retail sector by Bernon et al. (2018) suggested a framework for embedding CE values among the stakeholders of the retail RL to ensure the successful implementation of RL supporting CE. Kazancoglu et al. (2021) measured the performance of RL and concluded that it contributes to improving green performance even in the food industry, supporting CE. Another study (Vijayan et al., 2014) of the food sector states that RL has to compete with the food wastage challenge and hence involves higher costs. Work in the automotive sector by Makarova et al., (2021) suggested that well-planned logistics processes can ensure efficient RL and transformation into CE.

Despite the boom of RL, past academic literature lacks important studies on RL from CE perspectives. The advantages of RL for the environment have been qualitatively described in numerous papers, but more thorough quantitative evaluations are required. The development of thorough life cycle assessments (LCAs) that evaluate the environmental impact of RL operations in circular supply chains should be the main focus of research. It is crucial to identify important barriers to RL towards CE from a strategy perspective. In this regard, the novelty of this work lies in the identification of important barriers to RL adoption and finalisation using the fuzzy Delphi method. The DEMATEL method has been used to rank and develop causal relationships between identified barriers. Several barriers were identified from Scopus and Web of Science databases, as highlighted in Table 1.

3. Research methodology

The purpose of this work is to identify and rank the barriers to reverse logistics towards a circular economy. Initially, 13 barriers were identified from past academic literature, and then 10 barriers were finalised using the fuzzy Delphi method. These barriers were then prioritised using the DEMATEL method. Many researchers (Ahmad et al., 2023; Chauhan et al., 2020; Kashyap and Shukla, 2022; Liang et al., 2022) have used this method in different contexts.

A few organisations were identified using the snowball sampling method. Experts from these firms were contacted via email and telephone. A few of the experts declined to take part in this study, but eleven experts ultimately agreed to participate. Seven experts are from the manufacturing domain, three are from consumer electronics, and one expert is from e-commerce. All the experts have a minimum of five years of experience in their respective domains and are located in Maharashtra state, western region of India. These experts are involved in reverse logistics processes in their respective organisations. The reasons for reverse logistics were also discussed in depth during semi-structured interviews. These experts provided their opinions to finalise the barriers and offer judgement on the DEMATEL method. The expert judgements were aggregated using the consensus method. The detailed steps followed for both the fuzzy Delphi and DEMATEL methods are discussed next.

3.1. Fuzzy Delphi method

Murray Thomas created the fuzzy Delphi method, which uses fuzzy set theory to achieve consensus by addressing the fuzziness and ambiguity of expert judgements. Addressing situations where respondents are unable to accurately define a judgement using fuzzy set theory also improves the effectiveness and quality of surveys utilising the conventional Delphi approach. Eleven expert responses were collected and analysed using the fuzzy Delphi method. A 9-point fuzzy scale was used

Table 1
Barriers to adopt reverse logistics towards a circular economy.

S. No	Barrier	Description	Source
1	Lack of top management initiation	Top management is satisfied with the current system. Refurbishment/recycling processes are not considered attractive.	(Liu and Bai, 2014; Prakash and Barua, 2016; Ravi and Shankar, 2004)
2	Lack of visibility for recycling/reuse	The company is not certain/informed about the system involved and the benefits of recycling/reuse.	(Prakash and Barua, 2016; S. K. Sharma *et al.*, 2011; Wijewickrama *et al.*, 2021)
3	Difficulty in deciding 3PL to partner with	The company is finding it difficult to design a supply chain network for reverse logistics. Considering that doing the same for a forward network is difficult.	(Bartl, 2015; Moktadir *et al.*, 2020; Piyathanavong *et al.*, 2019)
4	Lack of resources	Companies are not providing support in form of finance and technology for Recycle processes.	(Hosseini *et al.*, 2014; Prajapati *et al.*, 2019; Prakash and Barua, 2016)
5	Difficulty in segregating waste/returns at collection points	Difficulty in Setting up of collection points for waste at the customer's end with proper segregation of waste. Also, such collection points are not maintained properly.	(Brkljač *et al.*, 2017; Ghisellini *et al.*, 2016; Hosseini *et al.*, 2014; Prajapati *et al.*, 2019)
6	Less Return on investment	A high initial cost is required for setting Recycle processes in the form of collection points, and machinery. Also setting up existing logistics partners for RL consumes time and energy. This results in the company's disinterest in the entire process considering low returns in comparison to the investment required.	(Piyathanavong *et al.*, 2019; Prajapati *et al.*, 2019; Rahimifard *et al.*, 2009)
7	Lack of government policies on recycling	Little attention from the government towards recycling results in inadequate policies for recycling.	(De Man and Friege, 2016; Shah *et al.*, 2019; Su *et al.*, 2013)
8	Lack of KPIs to track the reverse logistics activities	The RL activities are not given importance and hence key performance indices are not deliberating RL activities.	(Meyer *et al.*, 2017; Su *et al.*, 2013; Tibben-Lembke and S., 2001)
9	Lack of regulatory compliances	Companies have not framed regulatory compliances for recycle/reuse processes.	(Jayasinghe *et al.*, 2019; Prajapati *et al.*, 2019; Spišáková *et al.*, 2021)
10	Demand uncertainty for return products	Forecasting Demand for recycled and refurbished products is difficult. This results in either excess or shortage of required products	(Brkljač *et al.*, 2017; Lau and Wang, 2009; Prajapati *et al.*, 2019)
11	Lack of strategic plans for returns	Companies are finding it difficult to devise proper strategies for selling returned products.	(Lewandowski, 2016; Scheinberg *et al.*, 2016)
12	Lack of information on RL for stakeholders	Customers, employees' owners, and the public are largely unaware of the benefits they can derive from RL.	(Piyathanavong *et al.*, 2019; Su *et al.*, 2013)
13	Lack of support from other supply chain members	Other supply chain members such as 3PL or customers or intermediaries are not very supportive for recycle/reuse processes.	(Prajapati *et al.*, 2019; Spišáková *et al.*, 2021; Wijewickrama *et al.*, 2021)(2005); Spisakova et al (2021)

Table 2
Aggregate Fuzzy Judgements.

Sr. No.	Barriers	Scores Min	Max	Geometric Mean	Aggregate Fuzzy number	Final (defuzzification)
1	Lack of top management initiation	3	9	6.758	3,9, 6.758	6.252
2	Lack of visibility for recycling/reuse	3	9	5.767	1,9, 5.767	5.922
3	Difficulty in deciding 3PL to partner with	3	9	6.544	1,9, 6.544	6.181
4	Lack of resources	3	9	4.435	3,9, 4.435	5.478
5	Difficulty in segregating waste/returns at collection points	3	9	6.213	3,9, 6.213	6.071
6	Less Return on investment	1	9	6.895	1,9, 6.895	5.631
7	Lack of government policies on recycling	3	9	5.256	3,9, 5.256	5.752
8	Lack of regulatory compliances	1	9	5.0001	1,9, 5.0001	5.000
9	Lack of KPI's to track the reverse logistics activities	3	9	6.256	3,9, 6.256	6.0853
10	Demand uncertainty for return products	1	9	7.412	1,9, 6.412	5.804
11	Lack of strategic plans for returns	3	9	6.569	1,9, 6.569	6.1896
12	Lack of information on RL for stakeholders	1	9	7.125	3,9, 7.125	5.708
13	Lack of support from other supply chain members	1	9	4.231	1,9, 4.231	4.743

Table 3
Direct relationship matrix.

Barriers	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10
Lack of visibility for recycling/reuse (Ch1)	0	1	3	2	1	4	3	4	4	4
Difficulty in segregating waste/returns at collection points (Ch2)	1	0	2	2	1	2	2	3	4	4
Difficulty in deciding 3PL to partner with (Ch3)	4	2	0	2	1	2	1	4	4	4
Less return on investment (Ch4)	4	1	3	0	2	2	3	4	3	3
Lack of KPI's to track the reverse logistics activities (Ch5)	3	1	1	2	0	1	4	2	3	3
Lack of government policies on recycling (Ch6)	4	2	3	2	1	0	2	1	4	3
Lack of top management initiation (Ch7)	3	3	4	2	4	1	0	3	4	4
Demand uncertainty for return products (Ch8)	3	4	3	3	3	3	2	0	4	4
Lack of strategic plans for returns (Ch9)	4	4	4	4	3	3	3	2	0	4
Lack of information on RL for stakeholders (Ch10)	4	2	4	1	2	1	4	2	3	0

in this study with a threshold value of 5.6, as stated by Zhang, (2017). The aggregate fuzzy judgments for all barriers are highlighted in Table 2 below. Three barriers with a defuzzification score of less than 5.6 were deleted, and a final list of ten barriers was considered for further analysis.

3.2. Dematel method

One of the most widely used methods for establishing relationships between criteria is the DEMATEL method. Cause and effect serve as the foundation for DEMATEL's division of the factors into two quadrants (i.e., cause and effect). Each respondent's or expert's in-depth knowledge is incorporated into the DEMATEL model. It is very helpful for identifying and illustrating the causal connections between different criteria or elements in a decision dilemma. It can aid stakeholders in understanding how multiple aspects interact, which isn't always clear in other MCDM techniques. The approach can show interdependencies and feedback loops, which are crucial for understanding how modifications to one criterion can spread across the system and influence other criteria over time.

This technique was developed by the Battelle Memorial Institute through its Geneva research centre to determine the causal connections between various criteria in a challenging process (Bacudio et al., 2016; Wu and Lee, 2007). DEMATEL is a methodical structural modelling approach that employs a causal diagram to identify interference between system components. Lin, (2013) emphasised that the DEMATEL modelling technique produces a digraph and a cause-and-effect relationship that illustrates how each criterion is related to the others. By constructing a cause-and-effect diagram, DEMATEL helps decision-makers understand the direct and indirect interactions among factors. Factors with high cause values are identified as driving factors, meaning they significantly impact other factors. Conversely, factors with high effect values are those that are significantly influenced by other factors. The DEMATEL steps are discussed below:

Step 1: Instead of using a four-point scale to represent the input values, a five-point scale is used to increase the scale's range and the accuracy of the expert inputs that are gathered, which in turn improves the accuracy of the model that is developed. Very Low is equal to 0, Low is equal to 1, Medium is equal to 2, High is equal to 3, and Very High is equal to 4. The degree of direct influence matrix for each factor *'i'* on factor *'j'* is then to be filled out by the invited experts in the relevant field. For all invited experts, an average matrix D is produced by taking the mean of the same factor across all direct matrices. The direct relationship matrix is presented in Table 3.

X is a nonnegative matrix and is written as $X_m = \left[x_{ij}^m\right]$ where m is an expert in the procedure.

The average direct influence matrix B=x_{ij}.

$$x_{ij} = \frac{1}{m}\sum_{i=1}^{m} x_{ij}^m \tag{1}$$

Step 2: Equations (2) and (3) can be used to create the initial direct influence matrix X after normalising the average matrix (Refer Table 4).

$$C = \frac{A}{S} \tag{2}$$

$$S = max_{1\le i\le n}\sum_{j=1}^{n} aij \tag{3}$$

Step 3: Equation (4) can be used to create the total influence matrix (T), where J is a matrix with square identities. The matrix (refer Table 5) shows the overall influence between each pair of tasks, whereas the t_{ij}

Table 4
Normalized matrix.

Barriers	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10
Ch1	0.000	0.032	0.097	0.065	0.032	0.129	0.097	0.129	0.129	0.129
Ch2	0.032	0.000	0.065	0.065	0.032	0.065	0.065	0.097	0.129	0.129
Ch3	0.129	0.065	0.000	0.065	0.032	0.065	0.032	0.129	0.129	0.129
Ch4	0.129	0.032	0.097	0.000	0.065	0.065	0.097	0.129	0.097	0.097
Ch5	0.097	0.032	0.032	0.065	0.000	0.032	0.129	0.065	0.097	0.097
Ch6	0.129	0.065	0.097	0.065	0.032	0.000	0.065	0.032	0.129	0.097
Ch7	0.097	0.097	0.129	0.065	0.129	0.032	0.000	0.097	0.129	0.129
Ch8	0.097	0.129	0.097	0.097	0.097	0.097	0.065	0.000	0.129	0.129
Ch9	0.129	0.129	0.129	0.129	0.097	0.097	0.097	0.065	0.000	0.129
Ch10	0.129	0.065	0.129	0.032	0.065	0.032	0.129	0.065	0.097	0.000

Table 5
Total relation matrix.

Barriers	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	D
Ch1	0.4590	0.3546	0.5144	0.3738	0.3167	0.4195	0.4544	0.4940	0.6027	0.6081	4.5972
Ch2	0.4065	0.2647	0.4092	0.3174	0.2659	0.3070	0.3624	0.3982	0.5130	0.5190	3.7633
Ch3	0.5392	0.3586	0.3941	0.3522	0.2937	0.3468	0.3745	0.4704	0.5677	0.5742	4.2714
Ch4	0.5565	0.3402	0.4970	0.3017	0.3359	0.3552	0.4434	0.4861	0.5592	0.5651	4.4403
Ch5	0.4464	0.2826	0.3666	0.3060	0.2280	0.2680	0.4095	0.3614	0.4703	0.4763	3.6151
Ch6	0.5047	0.3305	0.4501	0.3268	0.2702	0.2602	0.3737	0.3591	0.5302	0.5089	3.9144
Ch7	0.5652	0.4224	0.5561	0.3887	0.4143	0.3480	0.3882	0.4903	0.6257	0.6338	4.8327
Ch8	0.5779	0.4577	0.5416	0.4247	0.3914	0.4139	0.4589	0.4104	0.6399	0.6465	4.9629
Ch9	0.6336	0.4736	0.5949	0.4692	0.4078	0.4321	0.5083	0.4997	0.5561	0.6773	5.2526
Ch10	0.5191	0.3442	0.4916	0.3096	0.3137	0.3016	0.4415	0.4042	0.5230	0.4411	4.0896
R	5.2081	3.6291	4.8156	3.5701	3.2376	3.4523	4.2148	4.3738	5.5878	5.6503	

element shows the indirect effect challenge i has on challenge j.

$$T = C(I - C)^{-1} \tag{4}$$

Step 4: The matrix in its entirety Each row and column's T was calculated separately. Let d_i represent the sum of the i^{th} row in the matrix (T). The value of d_i, r_j, $(d_i + r_j)$, and $(d_i\text{-}r_j)$ demonstrates how the barriers interact with one another. The $\mathrm{d_i}$ and $\mathrm{r_i}$ each stand for the sum of the j^{th} column and the i^{th} row, respectively. The outcome of $(d_i + r_j)$ reflects the overall effect of both the given and the results acquired by challenge i if $i = j$. The $(d_i + r_j)$ thus denotes a level of significance. In addition, barrier i will be the cause if $(d_i\text{-}r_j)$ is positive and the effect if $(d_i\text{-}r_j)$ is negative. Cause and effect matrix is presented in Table 6.

4. Result and discussion

This work employs a hybrid methodology that combines a qualitative method (Delphi) with a mathematical tool (fuzzy analysis) to confirm sustainable reverse logistics barriers. Furthermore, the DEMATEL technique has been used by the authors to group challenges into cause-and-effect categories in this section. A total of 10 barriers were selected through the fuzzy Delphi technique.

Based on the values of (D+R) in Table VI, the barriers are prioritised as Ch9 > Ch1 > Ch10 > Ch8 > Ch3 > Ch7 > Ch4 > Ch2 > Ch16 > Ch5. Based on the positive and negative signs of the components in Table 6, causal and effect factors can be distinguished. The causal factors can be sorted as Ch4 > Ch7 > Ch8 > Ch6 > Ch5 > Ch2, and the ranking of effect barriers is obtained as Ch10 > Ch1 > Ch3 > Ch9. Out of 10 barriers, six barriers—Less return on investment (Ch4), Lack of top management initiation (Ch7), Demand uncertainty for return products (Ch8), Lack of government policies on recycling (Ch6), Lack of KPIs to track reverse logistics activities (Ch5), and Difficulty in segregating waste/returns at collection points (Ch2)—fall under causal factors. Four factors are effect

Table 6
Cause-effect matrix.

Sr. No.	Barriers	D	R	D-R	D+R	Ranking	Group
Ch1	Lack of visibility for recycling/reuse	4.5972	5.2081	−0.6109	9.8053	2	Effect
Ch2	Difficulty in segregating waste/returns at collection points	3.7633	3.6291	0.1342	7.3924	8	Cause
Ch3	Difficulty in deciding 3PL to partner with	4.2714	4.8156	−0.5442	9.087	5	Effect
Ch4	Less return on investment	4.4403	3.5701	0.8702	8.0104	7	Cause
Ch5	Lack of KPI's to track the reverse logistics activities	3.6151	3.2376	0.3775	6.8527	10	Cause
Ch6	Lack of government policies on recycling	3.9144	3.4523	0.4621	7.3667	9	Cause
Ch7	Lack of top management initiation	4.8327	4.2148	0.6179	9.0475	6	Cause
Ch8	Demand uncertainty for return products	4.9629	4.3738	0.5891	9.3367	4	Cause
Ch9	Lack of strategic plans for returns	5.2526	5.5878	−0.3352	10.8404	1	Effect
Ch10	Lack of information on RL for stakeholders	4.0896	5.6503	−1.5607	9.7399	3	Effect

Table 7
Effect of barriers on triple bottom line and their action plan.

Barriers		Affects	Action to be taken
Lack of strategic plans for returns	EC	Wastage of resources, decrease in revenue and increase in cost	• To formulate reverse logistics strategy Develop plan for returns handling Align return policy with business objectives Technology adoption to streamline returns process and reduce wastage Collaboration with 3PL having strong sustainability focus Transparency in returns policies and effective customer service
	SO	Lack of customer satisfaction, poor brand loyalty	
	EV	Increased wastage, inefficient return process	
Lack of visibility for recycling/ reuse	EC	Loss of revenue from reuse/recycle market, inefficient material handing leading to increased cost	• Collaboration and partnership to increase efficiency with suppliers Track and monitor recycled products Improve consumer trust by enhancing public reporting Training and awareness programs Establish targets aligning with sustainability strategy Implement circular economy practices
	SO	Poor brand loyalty, employee morale is less, unsustainable organization	
	EV	Increased waste within organization, high carbon footprints, resource depletion	
Lack of information on reverse logistics for stakeholders	EC	Lack of stakeholder's awareness and reduced cost savings, lack of communication and transparency among stakeholders	• Discuss the best practices of reverse logistics with stakeholders Use of centralized information system to track and monitor the progress and to increase transparency Understand and communicate the value of reverse logistics to internal and external stakeholders Develop environmental metrics and share progress with stakeholders Engagement with local communities to achieve sustainability efforts
	SO	Lack of transparency leads to less public trust; stakeholders are less inclined towards sustainable practices	
	EV	Huge waste generation, high environmental impact	
Demand uncertainty for return products	EC	Excess inventory and storage leading to increased cost, revenue forecasting is difficult, financial instability	• To adopt data analytics for better prediction of returned products To develop customer feedback mechanism Collaborate for recycling and refurbishing facilities Partnership with companies specialized in recycling or reselling products Train customer service team to handle queries effectively
	SO	Less customer satisfaction with recycled products, inefficient return process	
	EV	Inefficient recycled products lead to excessive resource utilization, Uncertain return demand have greater environmental impact	
Difficulty in deciding 3PL to partner with	EC	Additional overhead due to inefficient 3PL partnership, opportunity loss for cost saving	• Define criteria for selecting right 3PL Conduct cost-benefit analysis to evaluate 3PL performance Regular audit and feedbacks should be conducted on regular basis to meet customer service standards Select 3PL with strong certifications and environmental policies 3PL should commit sustainability goals to reduce emissions and waste Focus on customer service quality
	SO	Inconsistent or delayed return process decreases customer satisfaction, Decrease in brand reputation due to ineffective 3PL management	
	EV	Increased emission and waste due to lack of sustainability practices by 3PL, opportunity loss for eco-friendly RL processes	

*EC: Economic; SO: Social; EV: Environmental.

factors: Lack of information on RL for stakeholders (Ch10), Lack of visibility for recycling/reuse (Ch1), Difficulty in deciding 3PL to partner with (Ch3), and Lack of strategic plans for returns (Ch9).

The highest positive value in this study's findings is the lack of strategic plans for returns (Ch9) with a value of 10.8404 for sustainable supply chain and reverse logistics. Developing an effective strategy and plan for reverse logistics is essential for companies to minimise costs, reduce waste, and meet environmental regulations. This includes tracking the movement of returned products, providing customers with clear instructions for returning products, and communicating with retailers and distributors to ensure that returned products are properly processed. Companies should also consider implementing a reverse logistics information system (RLIS) to manage the flow of information and improve visibility into the reverse logistics process. On the other hand, the lack of KPIs to track reverse logistics activities (Ch5) has the least importance. Less return on investment (Ch4) is the main causal factor found in the results. Lower ROI in reverse logistics is due to the complexity of the process.

Reverse logistics often involves a wide range of activities, including product inspection, testing, and refurbishment, as well as transportation and storage of returned products. This complexity can lead to higher costs and longer processing times, which can reduce the overall profitability of the reverse logistics operation. Now that this has been established, it is clear that the significance of reverse logistics and sustainable supply chains is determined by the following three factors: i) their importance to the system (i.e., (D+R) values); ii) whether they are causal or effect factors; and iii) their relationships with others. From a research perspective, this method is useful for assessing the relative significance and potency of the various relationships in MCDM. The factors should be further analysed by being divided into different quadrants, with the elements above the X-axis being the most important causal factors and the factors below the X-axis being effectors because of their dependence on the causal factors.

4.1. Theoretical contribution

This study focuses on the hierarchical evaluation structure in a full model and proposes a novel method using fuzzy Delphi and DEMATEL to resolve the interrelationships and incomplete information to ascertain the degree and relationship of the barriers to reverse logistics and sustainable supply chains in developing economies for sectors like consumer electronics, e-commerce, manufacturing, and retail. The fuzzy Delphi technique, a qualitative method for gathering opinions from various participants, can capture the ambiguity and uncertainty in the data. From a research perspective, this method is useful for assessing the relative significance and potency of the various relationships in MCDM.

The goal of this paper was to provide a thorough framework for sustainability that takes reverse logistics into account. The elimination or reduction of barriers to any firm helps in balancing the sustainable supply chain and reverse logistics. In the present study, ten critical barriers to reverse logistics and sustainable supply chains were identified through literature and expert opinion surveys, and their cause-effect relationships were established. The result of the study highlighted that a lack of strategic plans for returns (Ch9) and a lack of visibility for recycling/reuse (Ch1) were the most significant barriers, which demand the maximum attention of decision-makers.

Furthermore, this is the first comprehensive study of the barriers to reverse logistics and sustainability for firms. The need for awareness programmes for firms to adopt reverse logistics should be a priority for the government and larger supply chain partners. Firms will become more competitive and resilient if timely initiatives are taken in this direction. For future directions in this context, academic experts and researchers from around the world should concentrate more on case studies and empirical research.

4.2. Managerial implications

Reverse logistics implementation aims to maintain the interest of supply chain participants, including customers, shareholders, the economy, society, and the government (Kazmi et al., 2021). Environmental concerns are thought to be a factor that encourages consumer participation in reverse logistics, especially in product take-back programmes, and the benefits to other stakeholders are directly related to the returned products (Govindan and Bouzon, 2018). This study proposed a model consistent with the sustainability concept, which analyses the barriers to reverse logistics specific to consumer electronics, e-commerce, manufacturing, and retail sectors.

The study helps the decision-makers in each of the sectors identify the sector-specific barriers and address them for successful RL implementation. The consumer electronics sector faces multiple barriers, namely, 'Lack of Resources', 'Lack of Strategic plans for returns', 'Difficulty in segregating waste/returns', and 'Less Return on Investment' that adds up to the cost due to the complex nature, size of the products, poor condition of returned products, refurbishment, recycling cost, etc. Thus, the managers should plan and deploy RL strategies considering the nature and size of the products to ensure optimal resources to execute RL, resulting in better ROI. The strategic plan should also ensure the availability of segregation facilities for harmful elements to reduce environmental hazards.

In the e-commerce sector, RL is a must-have activity for companies, not because of their environmental concerns, but to gain buyers' confidence. The e-commerce sector faces barriers like 'Lack of Strategic plans for returns,' 'Demand uncertainty for return products,' and 'Difficulty in deciding 3PL partners'. Awareness of these barriers can help managers devise an RL strategy plan partnering with the most efficient 3PL service providers. Also, the managers should work on forecasting RL patterns to optimise RL costs.

The retail sector is dynamic due to the unpredictability of demand, the large variety of products, varied shelf lives, and marginal per unit contribution. The barriers towards sustainable RL for this sector include 'Lack of visibility for recycling/reuse,' 'Lack of government policies on recycling,' 'Demand uncertainty for return products,' and 'Difficulty in deciding 3PL partners'. Primarily, the government should frame policies on the recycling and reuse of products. It is also important for managers to ensure the visibility and traceability of products being recycled and reused. Additionally, the application of forecasting models may help in gauging the demand for return products, and accordingly, RL can be optimised by partnering with the most efficient 3PL partners.

The barriers faced by the manufacturing sector include 'Lack of support from other supply chain members', 'Lack of Key Performance Indicators (KPI) to trace RL activities,' 'Lack of top management initiation,' 'Lack of resources', etc. The top management of manufacturing organisations should take the lead and inculcate the culture of circularity so that RL becomes an integral part of the supply chain and all stakeholders coordinate and contribute to its success. The organisation-wide culture of circularity will also ensure the availability of required resources. Managers should also align the performance of employees with RL-linked KPIs.

The absence of clear and comprehensive government policies creates a regulatory vacuum, leading to varied interpretations and enforcement of existing laws. These ambiguities can deter businesses from investing in reverse logistics due to the perceived risks and potential legal complications. Practical managerial implications include the need for organisations to actively engage with policymakers to advocate for clearer, more cohesive recycling regulations. Additionally, companies should invest in legal expertise to navigate the current legislative landscape effectively, ensuring compliance and minimising risks. By doing so, businesses can foster a more predictable and stable environment for implementing reverse logistics, ultimately contributing to sustainable development and a more robust circular economy. The adoption of reverse logistics practices, supported by clear policies and reduced legislative ambiguities, can lead to a significant reduction in waste and pollution. This contributes to a healthier environment and can raise public awareness about sustainable consumption and waste management practices.

Consumers will benefit from increased availability of refurbished and recycled products, potentially at lower costs, and can also participate more easily in recycling programmes, reducing their environmental footprint. Business owners will gain insights into overcoming barriers to implementing reverse logistics, such as understanding the impact of regulatory ambiguities. By effectively managing reverse logistics, companies can reduce waste disposal costs, recover value from returned products, and enhance their corporate social responsibility profiles. Public entities and governments can use this information to refine legislative frameworks, making them more supportive of reverse logistics. Clearer regulations can facilitate smoother operations for businesses, encourage investments in recycling infrastructure, and ultimately lead to a reduction in environmental pollution. By understanding the importance of reverse logistics, unions and employee groups can advocate for better training and working conditions in recycling and refurbishment sectors. This can lead to the creation of green jobs and enhance workers' skills, contributing to a more sustainable economy.

This study further provides decision-makers with the cause-and-effect relationships between the barriers to RL for each sector under consideration. Managers may work on these barriers and create a better ecosystem towards sustainability through improved RL, contributing towards circularity. This work has considered the top five barriers and their effect on social, economic, and environmental aspects, and the actions to be taken are discussed in Table 7.

5. Conclusion

The study was conducted to identify the barriers to reverse logistics in advancing a circular economy and to understand the interrelationship between these barriers. It also aimed to rank barriers based on their influence to suggest strategies for implementing reverse logistics towards a circular economy. The study began with a review of the existing literature on reverse logistics barriers. A total of 13 barriers were initially identified from past academic literature. In the current research work, an integrated approach of methodologies was adopted to accomplish the objectives. To select the appropriate barriers, the fuzzy Delphi method was used. Three barriers with lower defuzzification scores were excluded from further analysis. The DEMATEL method was used to prioritise the barriers and to develop causal relationships between them. These barriers were further categorised into cause-and-effect groups.

Lack of strategic plans for returns (Ch9) and lack of visibility for recycling/reuse (Ch1) emerged as the most significant barriers. The outcomes of the study can be used by decision-makers to align RL with a sustainable supply chain. The cause-and-effect groups of barriers, with systematically ranked barriers, will aid in managerial decisions. The study is the first of its kind to consider RL along with the circular economy and sustainability. The paper focuses on hierarchical evaluation structure and utilises a novel method combining fuzzy Delphi and DEMATEL to resolve the interrelationships.

It is essential to highlight that these barriers are not confined to any single industry. Across various sectors, organisations face universal challenges in implementing reverse logistics, including regulatory ambiguities, lack of comprehensive recycling policies, logistical complexities, and limited consumer awareness and participation. These barriers hinder the efficient recovery, reuse, and recycling of products, which are critical components of a circular economy. However, the principles of overcoming these challenges—such as advocating for clearer legislation, investing in advanced recycling technologies, improving supply chain coordination, and enhancing consumer education—are applicable across industries. By addressing these universal barriers with holistic strategies, businesses from diverse sectors can significantly advance their sustainability efforts, contributing to broader environmental and economic benefits. This cross-industry perspective underscores the importance of collaborative efforts and shared solutions in overcoming the obstacles to effective reverse logistics and fostering a sustainable circular economy.

6. Limitations and future scope

This study has some limitations. To increase the robustness of the model and to generalise the findings, a greater number of experts may be considered. Various other methods, such as AHP, WINGS, SCARA, SEM, etc., can be used to validate the findings to provide a different perspective on RL adoption. The case study method may also be used for further validation and analysis. Stakeholder theory and the triple bottom line approach theory can also be utilised in future research. A deeper investigation is required into sector-specific barriers in industries not covered in this study, the development of industry-specific reverse logistics frameworks, and the impact of emerging technologies such as blockchain and AI on reverse logistics. Additionally, future research could examine the role of consumer behaviour in greater detail, exploring how incentives and education can enhance participation in reverse logistics programmes. Finally, longitudinal studies tracking the long-term impact of improved reverse logistics practices on sustainability outcomes would provide valuable insights for policymakers and practitioners.

7. Funding sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CRediT authorship contribution statement

Harshad Sonar: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Bishal Dey Sarkar:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Prasad Joshi:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Nikhil Ghag:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Vardhan Choubey:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Sandeep Jagtap:** Writing – review & editing, Visualization, Investigation, Formal analysis, Resources, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

References

Agrawal, S., Singh, R.K., 2020. Outsourcing and reverse supply chain performance: a triple bottom line approach. BIJ 28 (4), 1146–1163. https://doi.org/10.1108/BIJ-09-2020-0498.

Ahmad, T., Rohit, S., Kunal, S., Samuel, K.G., Wamba, F., 2023. Enablers to the adoption of blockchain technology in logistics supply chains: evidence from an emerging economy. Ann. Operat. Res. 327, 251–291. https://doi.org/10.1007/s10479-022-04546-1.

Alarcón, F., Cortés-Pellicer, P., Pérez-Perales, D., Mengual-Recuerda, A., 2021. A reference model of reverse logistics process for improving sustainability in the supply chain. Sustainability (switzerland) 13 (18), 1–29. https://doi.org/10.3390/su131810383.

Ambekar, S., Roy, D., Hiray, A., Prakash, A., Patyal, V.S., 2021. Barriers to adoption of reverse logistics: a case of construction, real estate, infrastructure and project (CRIP) sectors. Eng. Constr. Archit. Manag. https://doi.org/10.1108/ECAM-02-2021-0112.

Andrews, D., 2015. The circular economy, design thinking and education for sustainability. *Local Econ.*, Sage Publications Sage UK: London, England 30 (3), 305–315. https://doi.org/10.1177/0269094215578226.

Arena, M., Azzone, G., Grecchi, M., Piantoni, G., 2021. How can the waste management sector contribute to overcoming barriers to the circular economy? Sustain. Dev. 29 (6), 1062–1071. https://doi.org/10.1002/sd.2202.

Bacudio, L.R., Benjamin, M.F.D., Eusebio, R.C.P., Holaysan, S.A.K., Promentilla, M.A.B., Yu, K.D.S. and Aviso, K.B. (2016), "Analyzing barriers to implementing industrial symbiosis networks using DEMATEL", *Sustainable Production and Consumption*, Elsevier B.V., Vol. 7 No. February, pp. 57–65, Doi: 10.1016/j.spc.2016.03.001.

Badenhorst, A., 2016. Prioritising the implementation of practices to overcome operational barriers in reverse logistics. J. Transport Supply Chain Manage., AOSIS 10 (1), 1–12. https://doi.org/10.4102/jtscm.v10i1.240.

Batista, L., Bourlakis, M., Smart, P., Maull, R., 2018. In search of a circular supply chain archetype–a content-analysis-based literature review. *Prod. Plan. Control*, Taylor & Francis 29 (6), 438–451. https://doi.org/10.1080/09537287.2017.1343502.

Bernon, M., Tjahjono, B., Ripanti, E.F., 2018. Aligning retail reverse logistics practice with circular economy values: an exploratory framework. *Prod. Plan. Control*, Taylor & Francis 29 (6), 483–497. https://doi.org/10.1080/09537287.2018.1449266.

Bhattacharyya, S., Sarkar, S., Sarkar, B.D., Manatkar, R., 2023. Risk Modeling Framework for Strategic and Operational Intervention to Enhance the Effectiveness of a Closed-Loop Supply Chain. *IEEE Trans. Eng. Manag.*, IEEE,. https://doi.org/10.1109/TEM.2023.3261323.

Butt, A.S., Ali, I. and Govindan, K. (2023), "The role of reverse logistics in a circular economy for achieving sustainable development goals: a multiple case study of retail firms", *Production Planning & Control*, Taylor & Francis, pp. 1–13, Doi: 10.1080/09537287.2023.2197851.

Camilleri, M.A., 2019. The circular economy's closed loop and product service systems for sustainable development: A review and appraisal. Sustain. Dev. 27 (3), 530–536. https://doi.org/10.1002/sd.1909.

Carissimi, M.C., Creazza, A., 2022. The role of the enabler in sharing economy service triads: A logistics perspective. Clean. Logist. Supply Chain 5, 100077. https://doi.org/10.1016/j.clscn.2022.100077.

Carter, C.R., Ellram, L.M., 1998. Reverse logistics: a review of the literature and framework for future investigation. J. Bus. Logist. 19 (1), 85–102.

Chauhan, A., Kaur, H., Yadav, S., Jakhar, S.K., 2020. A hybrid model for investigating and selecting a sustainable supply chain for agri-produce in India. *Ann. Operat. Res.*, Springer, US 290 (1–2), 621–642. https://doi.org/10.1007/s10479-019-03190-6.

Chen, W., Liu, Y. and Han, M. (2024), "Designing a sustainable reverse logistics network for used cell phones based on offline and online trading systems", *J. Environ. Manage.*, Vol. 354 No. 2014, available at: Doi: 10.1016/j.jenvman.2024.120417.

De Oliveira, R.B., Ruiz, M.S., Gabriel Dias Da Silva, M.L., Struffaldi, A. and Bocatto, E. (2014), "Environmental sustainability and reverse logistics: An analysis of the recycling networks of cooking oil waste in Sao Paulo, Brazil", *PICMET 2014 - Portland International Center for Management of Engineering and Technology, Proceedings: Infrastructure and Service Integration*, PICMET, pp. 2756–2763.

Dev, N.K., Shankar, R., Qaiser, F.H., 2020. Industry 4.0 and circular economy: Operational excellence for sustainable reverse supply chain performance. *Resour. Conserv. Recycl.*, Elsevier 153, 104583. https://doi.org/10.1016/j.resconrec.2019.104583.

Dutta, P., Mishra, A., Khandelwal, S., Katthawala, I., 2020. A multiobjective optimization model for sustainable reverse logistics in Indian E-commerce market. J. Clean. Prod. 249, 119348 https://doi.org/10.1016/j.jclepro.2019.119348.

Dutta, P., Talaulikar, S., Xavier, V., Kapoor, S., 2021. Fostering reverse logistics in India by prominent barrier identification and strategy implementation to promote circular economy. J. Clean. Prod., Elsevier 294, 126241. https://doi.org/10.1016/j.jclepro.2021.126241.

Esposito, M., Tse, T., Soufani, K., 2017. Is the circular economy a new fast-expanding market? Thunderbird Int. Bus. Rev., Wiley Online Library 59 (1), 9–14. https://doi.org/10.1002/tie.21764.

Frei, R., Jack, L., Krzyzaniak, S.A., 2020. Sustainable reverse supply chains and circular economy in multichannel retail returns. Bus. Strateg. Environ. 29 (5), 1925–1940. https://doi.org/10.1002/bse.2479.

Gaustad, G., Krystofik, M., Bustamante, M., Badami, K., 2018. Circular economy strategies for mitigating critical material supply issues. Resour. Conserv. Recycl., Elsevier 135, 24–33. https://doi.org/10.1016/j.resconrec.2017.08.002.

Govindan, K., Bouzon, M., 2018. From a literature review to a multi-perspective framework for reverse logistics barriers and drivers. J. Clean. Prod., Elsevier Ltd 187, 318–337. https://doi.org/10.1016/j.jclepro.2018.03.040.

Guarnieri, P., e Silva, L.C., Levino, N.A., 2016. Analysis of electronic waste reverse logistics decisions using Strategic Options Development Analysis methodology: A Brazilian case. *J. Clean. Prod.*, Elsevier 133, 1105–1117. https://doi.org/10.1016/j.jclepro.2016.06.025.

Guarnieri, P., Cerqueira-Streit, J.A., Batista, L.C., 2020. Reverse logistics and the sectoral agreement of packaging industry in Brazil towards a transition to circular economy. Resour. Conserv. Recycl., Elsevier 153, 104541. https://doi.org/10.1016/j.resconrec.2019.104541.

Hapuwatte, B.M., Jawahir, I.S., 2021. Closed-loop sustainable product design for circular economy. J. Indust. Ecol., John Wiley & Sons Ltd 25 (6), 1430–1446. https://doi.org/10.1111/jiec.13154.

He, M., Li, Q., Wu, X., Han, X., 2024. A novel multi-level reverse logistics network design optimization model for waste batteries considering facility technology types. J. Clean. Prod. 467, 142966 https://doi.org/10.1016/j.jclepro.2024.142966.

Jayarathna, C.P., Agdas, D., Dawes, L., 2024. Viability of sustainable logistics practices enabling circular economy: A system dynamics approach. Bus. Strateg. Environ. 33 (4), 3422–3439. https://doi.org/10.1002/bse.3655.

Julianelli, V., Caiado, R.G.G., Scavarda, L.F., Cruz, S.P., de, M.F., 2020. Interplay between reverse logistics and circular economy: Critical success factors-based taxonomy and framework. *Resour. Conserv. Recycl.*, Elsevier Vol. 158 No. March, 104784. https://doi.org/10.1016/j.resconrec.2020.104784.

Kalmykova, Y., Sadagopan, M., Rosado, L., 2018. Circular economy–From review of theories and practices to development of implementation tools. *Resour. Conserv. Recycl.*, Elsevier 135, 190–201. https://doi.org/10.1016/j.resconrec.2017.10.034.

Kandasamy, J., Kinare, Y.P., Pawar, M.T., Majumdar, A., K.E.K., V. and Agrawal, R. (2022), "Circular economy adoption challenges in medical waste management for sustainable development: An empirical study", *Sustainable Development*, Vol. 30 No. 5, pp. 958–975, Doi: 10.1002/sd.2293.

Kashyap, A., Shukla, O.J., 2022. Analysis of critical barriers in the sustainable supply chain of MSMEs: a case of Makhana (Foxnut) industry. Benchmarking. https://doi.org/10.1108/BIJ-11-2021-0696.

Kazancoglu, Y., Ekinci, E., Mangla, S.K., Sezer, M.D., Kayikci, Y., 2021. Performance evaluation of reverse logistics in food supply chains in a circular economy using system dynamics. Bus. Strateg. Environ. 30 (1), 71–91. https://doi.org/10.1002/bse.2610.

Kazmi, S.H.A., Shahbaz, M.S., Mubarik, M.S., Ahmed, J., 2021. Switching behaviors toward green brands: evidence from emerging economy. Environ. Dev. Sustain., Springer, Netherlands 23 (8), 11357–11381. https://doi.org/10.1007/s10668-020-01116-y.

Kirchherr, J., Reike, D., Hekkert, M., 2017. Conceptualizing the circular economy: An analysis of 114 definitions. Resour. Conserv. Recycl., Elsevier 127, 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005.

Kumar, M., Raut, R.D., Jagtap, S., Choubey, V.K., 2023. Circular economy adoption challenges in the food supply chain for sustainable development. Bus. Strateg. Environ. 32 (4), 1334–1356. https://doi.org/10.1002/bse.3191.

Kusumowardani, N., Tjahjono, B., Lazell, J., Bek, D., Theodorakopoulos, N., Andrikopoulos, P., Priadi, C.R., 2022. A circular capability framework to address food waste and losses in the agri-food supply chain: The antecedents, principles and outcomes of circular economy. *J. Bus. Res.*, Elsevier 142, 17–31. https://doi.org/10.1016/j.jbusres.2021.12.020.

Lamba, D., Yadav, D.K., Barve, A., Panda, G., 2020. Prioritizing barriers in reverse logistics of E-commerce supply chain using fuzzy-analytic hierarchy process. Electron. Commer. Res., Springer 20, 381–403. https://doi.org/10.1007/s10660-019-09333-y.

Larsen, S.B., Jacobsen, P., 2016. Revenue in reverse? An examination of reverse supply chain enabled revenue streams. Int. J. Phys. Distrib. Logist. Manag., Emerald Group Publishing Limited. https://doi.org/10.1108/IJPDLM-03-2015-0054.

Liang, Y., Wang, H., Zhao, X., 2022. Analysis of factors affecting economic operation of electric vehicle charging station based on DEMATEL-ISM. Comput. Ind. Eng., Elsevier Ltd 163, 107818. https://doi.org/10.1016/j.cie.2021.107818.

Lin, R.J., 2013. Using fuzzy DEMATEL to evaluate the green supply chain management practices. J. Clean. Prod., Elsevier Ltd 40, 32–39. https://doi.org/10.1016/j.jclepro.2011.06.010.

Makarova, I., Shubenkova, K., Buyvol, P., Shepelev, V., Gritsenko, A., 2021. The role of reverse logistics in the transition to a circular economy: case study of automotive spare parts logistics. FME Transactions 49 (1), 173–185. https://doi.org/10.5937/FME2101173M.

Mallick, P.K., Salling, K.B., Pigosso, D.C.A., McAloone, T.C., 2023. Closing the loop: Establishing reverse logistics for a circular economy, a systematic review. *J. Environ. Manage.*, Elsevier 328, 117017. https://doi.org/10.1016/j.jenvman.2022.117017.

Mishra, A., Dutta, P., Jayasankar, S., Jain, P., Mathiyazhagan, K., 2022. A review of reverse logistics and closed-loop supply chains in the perspective of circular economy. Benchmarking. https://doi.org/10.1108/BIJ-11-2021-0669.

Mondal, A., Roy, S.K., 2021. Multi-objective sustainable opened-and closed-loop supply chain under mixed uncertainty during COVID-19 pandemic situation. Comput. Ind. Eng. 159, 107453 https://doi.org/10.1016/j.cie.2021.107453.

Münch, C., von der Gracht, H.A., Hartmann, E., 2023. The future role of reverse logistics as a tool for sustainability in food supply chains: a Delphi-based scenario study. Supply Chain Manag. 28 (2), 262–283. https://doi.org/10.1108/SCM-06-2021-0291.

Nanayakkara, P.R., Jayalath, M.M., Thibbotuwawa, A., Perera, H.N., 2022. A circular reverse logistics framework for handling e-commerce returns. Clean. Logist. Supply Chain 5, 100080. https://doi.org/10.1016/j.clscn.2022.100080.

Ravi, V., Shankar, R., 2004. Analysis of interactions among the barriers of reverse logistics. Social Change No. April. https://doi.org/10.1016/j.techfore.2004.07.002.

Ren, Y., Lu, X., Guo, H., Xie, Z., Zhang, H. and Zhang, C. (2023), "A Review of Combinatorial Optimization Problems in Reverse Logistics and Remanufacturing for End-of-Life Products", *Mathematics*, Multidisciplinary Digital Publishing Institute, Vol. 11 No. 2, p. 298, Doi: 10.3390/math11020298..

Schneikart, G., Mayrhofer, W., Löffler, C., Frysak, J., 2024. A roadmap towards circular economies in pharma logistics based on returnable transport items enhanced with Industry 4.0 technologies. Resour. Conserv. Recycl. 206 https://doi.org/10.1016/j.resconrec.2024.107615.

Schroeder, P., Dewick, P., Kusi-Sarpong, S., Hofstetter, J.S., 2018. Circular economy and power relations in global value chains: tensions and trade-offs for lower income countries. *Resour. Conserv. Recycl.*, Elsevier 136, 77–78. https://doi.org/10.1016/j.resconrec.2018.04.003.

Schultz, F.C., Everding, S., Pies, I., 2021. Circular supply chain governance: A qualitative-empirical study of the European polyurethane industry to facilitate functional circular supply chain management. *J. Clean. Prod.*, Elsevier 317, 128445. https://doi.org/10.1016/j.jclepro.2021.128445.

Sellitto, M.A., de Almeida, F.A., 2020. Strategies for value recovery from industrial waste: case studies of six industries from Brazil. BIJ 27 (2), 867–885. https://doi.org/10.1108/BIJ-03-2019-0138.

Shahidzadeh, M.H., Shokouhyar, S., 2022. Toward the closed-loop sustainability development model: a reverse logistics multi-criteria decision-making analysis. *Environ. Dev. Sustain.*, Springer, Netherlands,. https://doi.org/10.1007/s10668-022-02216-7.

Sharma, N.K., Kumar, V., Verma, P., Luthra, S., 2021. Sustainable reverse logistics practices and performance evaluation with fuzzy TOPSIS: A study on Indian retailers. Clean. Logist. Supply Chain 1, 100007. https://doi.org/10.1016/j.clscn.2021.100007.

Sonar, H., Sharma, I., Ghag, N., Raje, B., 2024a. Harvesting sustainability: assessing Industry 4.0 in agri-food supply chains. Int. J. Logist. Manag. available at:https://doi.org/10.1108/IJLM-10-2023-0443.

Sonar, H., Sharma, I., Ghag, N., Singh, R.K., 2024b. Barriers for achieving sustainable agri supply chain: study in context to Indian MSMEs. Int J Log Res Appl 1–20. https://doi.org/10.1080/13675567.2024.2345359.

Sudarto, S., Takahashi, K., Morikawa, K., 2016a. (2017), "Efficient flexible long-term capacity planning for optimal sustainability dimensions performance of reverse logistics social responsibility: A system dynamics approach". *Int. J. Prod. Econ.*, Elsevier 184 (January), 179–192. https://doi.org/10.1016/j.ijpe.2016.12.013.

Sudarto, S., Takahashi, K., Morikawa, K., Nagasawa, K., 2016b. The impact of capacity planning on product lifecycle for performance on sustainability dimensions in Reverse Logistics Social Responsibility. *J. Clean. Prod.*, Elsevier Ltd 133, 28–42. https://doi.org/10.1016/j.jclepro.2016.05.095.

Vargas, D.B., Campos, L.M., de, S., Luna, M.M.M., 2024. Brazil's formal E-waste recycling system: from disposal to reverse manufacturing. Sustainability 16 (1), 1–16. https://doi.org/10.3390/su16010066.

Vijayan, G., Kamarulzaman, N.H., Mohamed, Z.A., Abdullah, A.M., 2014. Sustainability in food retail industry through reverse logistics. Int. J. Supply Chain Manage. 3 (2), 11–23. https://doi.org/10.59160/ijscm.v3i2.921.

Wilson, M., Goffnett, S., 2022. Reverse logistics: Understanding end-of-life product management. *Bus. Horiz.*, Kelley School of Business, Indiana University 65 (5), 643–655. https://doi.org/10.1016/j.bushor.2021.10.005.

Wiprächtiger, M., Haupt, M., Froemelt, A., Klotz, M., Beretta, C., Osterwalder, D., Burg, V., et al., 2023. Combining industrial ecology tools to assess potential greenhouse gas reductions of a circular economy: method development and application to Switzerland. J. Indust. Ecol., John Wiley & Sons Ltd 27 (1), 254–271. https://doi.org/10.1111/jiec.13364.

Wu, W.W., Lee, Y.T., 2007. Developing global managers' competencies using the fuzzy DEMATEL method. Expert Syst. Appl. 32 (2), 499–507. https://doi.org/10.1016/j.eswa.2005.12.005.

Zhang, J., 2017. Evaluating regional low-carbon tourism strategies using the fuzzy Delphi- analytic network process approach. *J. Clean. Prod.*, Elsevier Ltd 141, 409–419. https://doi.org/10.1016/j.jclepro.2016.09.122.

Zhang, X., Li, Z., Wang, Y., Yan, W., 2021. An integrated multicriteria decision-making approach for collection modes selection in remanufacturing reverse logistics. Processes 9 (4). https://doi.org/10.3390/pr9040631.