Reverse Logistics: A Mixed-Methods Analysis of Barriers, Strategies, and Key Determinants

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Resumo

A crescente preocupação com os impactos ambientais das atividades da cadeia de abastecimento tem impulsionado a adoção de modelos mais sustentáveis, destacando-se a transição de um paradigma linear para um modelo circular. Nesse contexto, a Logística Inversa (LI) surge como uma ferramenta estratégica fundamental, permitindo a recuperação, reuso e reciclagem de produtos e materiais no final do seu ciclo de vida, contribuindo para a sustentabilidade ambiental, social e económica. Apesar da importância reconhecida da LI como ferramenta estratégica para promover a sustentabilidade nas cadeias de abastecimento, muitas empresas, especialmente as Pequenas e Médias Empresas (PMEs) dos setores têxtil e do calçado em Portugal, enfrentam dificuldades na sua implementação efetiva. Assim, o presente estudo teve como objetivo identificar e analisar as principais barreiras que dificultam a adoção da LI nestas indústrias, bem como explorar estratégias para a implementação de redes de LI que sejam viáveis e eficazes.

Para alcançar o objetivo delineado de aprofundar o conhecimento sobre a implementação da LI em PMEs dos setores têxtil e do calçado, a investigação adotou uma abordagem metodológica mista, integrando métodos quantitativos e qualitativos nos cinco estudos desenvolvidos e que compõem a presente tese.

A investigação iniciou-se com uma Revisão Sistemática da Literatura (primeiro estudo), seguindo o protocolo de Denyer e Tranfield (2009), para mapear o conhecimento científico existente sobre LI e sustentabilidade. A pesquisa, realizada em maio de 2023 nas bases *Web of Science* e *Scopus*, utilizou as palavras-chave *"Reverse Logistics"* e *"Sustainability*.

O segundo estudo aplicou o Método Fuzzy Delphi para validar e categorizar em termos de relevância as barreiras à implementação da LI. O método permitiu validar um conjunto de barreiras que impactam negativamente na implementação de uma rede de fluxo inverso eficiente.

O terceiro estudo combinou o Interpretive Structural Modeling (ISM) e a análise "Matrices d'Impacts cross-multiplication appliqúe a classmate" MICMAC para mapear relações hierárquicas entre as barreiras. Um focus group com oito especialistas em LI, realizado via Zoom, desenvolveu um modelo gráfico de interdependências. A análise MICMAC classificou as barreiras em quatro quadrantes (autónomas, dependentes, de ligação e independentes), identificando aquelas que teriam maior impacto.

O quarto estudo focou-se nas PME dos setores têxtil e do calçado, utilizando entrevistas semiestruturadas com gestores da cadeia de abastecimento. A amostra intencional selecionou participantes com experiência prática em LI, permitindo aprofundar os temas abordados. As entrevistas, com duração média de 30 minutos, exploraram barreiras específicas do contexto das PMEs e estratégias de superação.

Por último, o quinto estudo integrou o *Fuzzy Analytic Hierarchy Process* (FAHP) e o *Fuzzy F-MARCOS* para priorizar estratégias de implementação da LI. O FAHP atribuiu pesos a critérios com base em avaliações linguísticas de especialistas, enquanto o F-MARCOS ordenou as alternativas estratégicas, tratando incertezas inerentes a decisões multicritério.

Nesta investigação foram identificadas as principais tendências de investigação nesta área, nomeadamente, o desenvolvimento de modelos de otimização, a avaliação do desempenho, a externalização de atividades e os desafios de implementação. Verificou-se, ainda, que as barreiras mais significativas para a implementação da LI estão categorizadas em sete grupos, destacando-se a incerteza na devolução de produtos, custos elevados e a falta de compromisso da gestão como os principais fatores que impedem a implementação eficaz. A análise das inter-relações das barreiras, usando métodos ISM e MICMAC, mostrou que a "falta de estrutura organizacional adequada" é a mais influente, afetando diretamente a responsabilidade social.

No setor têxtil e do calçado, as motivações para a adoção da LI incluem a sustentabilidade ambiental, os benefícios económicos e a responsabilidade social. Apesar disso, as empresas enfrentam desafios como os custos operacionais elevados e a falta de colaboração. Para superar esses obstáculos, neste estudo são propostas estratégias como externalização das atividades de LI e o desenvolvimento de parcerias estratégicas.

Palavras-chave

Logística inversa; Sustentabilidade; Cadeia de abastecimento; Têxtil; Calçado

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Abstract

Growing concern about the environmental impacts of supply chain activities have stimulated the adoption of more sustainable models, highlighting the transition from a linear paradigm to a circular model. In this context, Reverse Logistics (RL) emerges as a fundamental strategic tool, allowing the recovery, re-use and recycling of products and material at the end of their life-cycle, and contributing to environmental, social and economic sustainability. Despite the recognised importance of RL as a strategic tool to promote the sustainability of supply chains, many companies, especially Small and Medium-Sized Enterprises (SMEs) in the textile and footwear sectors in Portugal, find effective implementation difficult. Therefore, this study aimed to identify and analyse the main barriers hindering adoption of RL in these industries, as well as exploring strategies to implement viable and effective RL networks.

To do so, and to increase knowledge about the implementation of RL in textile and footwear SMEs, a mixed methodological approach was adopted, including quantitative and qualitative methods in the five studies making up this thesis.

The study began with a Systematic Literature Review (SLR) (first study), following the Denyer and Tranfield (2009) protocol, to map existing scientific knowledge about RL and sustainability. The search carried out in May 2023 on the *Web of Science* and *Scopus* databases used the key-words *"Reverse Logistics"* and *"Sustainability*.

The second study applied the Fuzzy Delphi method to validate and categorize in terms of relevance the barriers to implementing RL. This method allowed validation of a number of barriers with a negative impact on implementation of an efficient reverse flow network.

The third study combined Interpretive Structural Modeling (ISM) and Matrices d'Impacts Cross-Multiplication Appliqúe a Classmate (MICMAC) analysis to map hierarchical relations among the barriers. A focus group with eight RL specialists, carried out via Zoom, developed a graphic model of interdependences. The MICMAC analysis classified the barriers in four quadrants (autonomous, dependent, linking and independent), identifying those with the biggest impact.

The fourth study focused on SMEs in the textile and footwear sectors, using semi-structured interviews with supply chain managers. The intentional sample was formed of participants with practical experience of RL, meaning the themes addressed could be

dealt with in depth. The interviews lasted 30 minutes on average and explored specific barriers in the SME context and strategies to overcome them.

Finally, the fifth study included the Fuzzy Analytic Hierarchy Process (FAHP) and Fuzzy F-MARCOS to prioritize RL implementation strategies. FAHP attributed weights and criteria based on specialists' linguistic evaluations, while Fuzzy Measurement of Alternatives and Ranking according to Compromise Solution (F-MARCOS) ordered the strategic alternatives, handling uncertainties inherent to multi-criteria decisions.

The main research trends in this area were identified, namely, the development of optimization models, performance assessment, outsourcing activities and the challenges of implementation. The most significant barriers to implementation of RL were found to be categorized in seven groups, highlighting the uncertainty in returning products, high costs and the lack of management commitment as the main factors preventing effective implementation. Analysis of the inter-relations among barriers, using ISM and MICMAC methods, showed that the "lack of an appropriate organisational structure" has the greatest influence, with a direct effect on social responsibility.

In the textile and footwear sector, the reasons for adopting RL include environmental sustainability, economic benefits and social responsibility. Nevertheless, companies face challenges such as high operational costs and a lack of collaboration. To overcome these obstacles, this study proposes strategies such as the outsourcing of RL activities and developing strategic partnerships.

Key-words

Reverse logistics; Sustainability; Supply chain; Textile; Footwear

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List of Acronyms

AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
BWM	Best-Worst Method
COBRA	COmprehensive Distance Based Ranking
CSF	Critical Success Factors
DEMATEL	Decision Making Trial and Evaluation Laboratory
ERL	Externalized Reverse Logistics
FG	Focus Group
FAHP	Fuzzy Analytic Hierarchy Process
FDM	Fuzzy Delphi Method
F-MARCOS	Fuzzy Measurement of Alternatives and Ranking according to Compromise Solution
IRM	Initial Reachability Matrix
IRL	Internal Reverse Logistics
ISM	Interpretive Structural Modeling
JVRL	Joint Venture Reverse Logistics
KPI	Key Performance Indicators
MICMAC	Matrices d'Impacts Cross-Multiplication Appliqúe a Classmate
SMEs	Medium-Sized Enterprises
MILP	Mixed-Integer Linear Programming
MCDM	Multi-Criteria Decision-Making
RBT	Resource-Based Theory
RL	Reverse Logistics
SSIM	Structural Self-Interaction Matrix
SLR	Systematic Literature Review
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution

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Part I

Chapter 1

1.1. Importance of the topic

Supply chain activities have negatively impacted the environment, thus increasing concerns and debate about sustainability(dos Santos et al., 2023). These environmental (and economic) challenges show the need to move from a linear economic model to a circular one. However, this transition implies very significant transformations in companies' logistics networks (Vimpolsek & Lisec, 2022).

In this context, Reverse Logistics (RL) emerges as an essential configuration to achieve circularity in supply chains and thus maximize the value of products at the end of their useful life. RL is fundamental in supply chain management due to its environmental, social and economic impact. (Zhao & Osman, 2023).

The configuration of a RL network has been highlighted, among companies and researchers, due to the environmental challenges faced by society, the scarcity of resources, and the change in consumption patterns (Naseem et al., 2021). RL is a strategic tool that contributes to sustainability, through the reuse of materials and supporting for the development of new strategies (Pereira et al., 2023). In this sense, industries have implemented RL networks in order to maximize the value of products at the end of their life (Rajput & Singh, 2021).

RL has also become prominent among firms in the textile and footwear sector due to the urgent need for more sustainable practices (Sumo et al., 2023). The textile industry is fundamental for society, but the increasing speed with which fashion trends change and textile products' shorter useful life has caused a significant increase in consumption, and consequently, in concerns about managing textile waste and the sector's sustainability (John & Rahman, 2024).

The textile and footwear industries both put considerable pressure on the environment, contributing to air and water pollution, and to increased waste. In 2017, the European Union produced 7,4 kg per capita of textile products and final consumption was 25,9 kg per person, resulting in 654 kg of CO_2 emissions (Villoria Saez & Osmani, 2019). This level of production and consumption, together with dyeing and finishing processes, accounts for around 20% of global pollution of clean water. Furthermore, washing synthetic clothing accounts for 35% of the micro-plastic released into the environment (Commission European, 2023).

The situation in the footwear sector is no different. In 2022, global production was 23,9 thousand million pairs, an increase of 7,6% from the year before. This growth in footwear production meant a significant increase in the volume of waste, most of which ends up in landfill (APICCAPS, 2023).

Despite the environmental challenges, the textile and footwear sectors are fundamental for economies, stimulating job creation and economic growth. In 2024, the textile industry in the European Union was formed of more than 197.000 companies, with a turnover of 170 thousand million euros and around 1,3 million employees (Euratex, 2024).

Portugal stands out as one of the four biggest employers in the European textile and fashion industry, accounting for 10% of the sector's turnover in the EU (Euratex, 2024). The footwear sector, in turn, is one of the pillars of the Portuguese economy, being one of the ten biggest producers of leather footwear in the world. In 2023, Portuguese footwear exports reached 2 billion euros and employed 40,000 workers (APICCAPS, 2024).

In this context of strategic and sustainable of LR, academic research has played a fundamental role in advancing knowledge and supporting its implementation. Given the increasing environmental concerns, many academics have centred their studies on RL. Some researchers have developed mathematical optimization models and strategies to support implementation of RL networks, considering simultaneously economic, environmental and social objectives. These approaches can assess the *trade-offs* involved, determine the ideal number of installations for RL networks, their location, capacity and selection of products, by formulating programming models with carbon restrictions, aiming for a sustainable conception of RL faced with uncertainty (e.g., Ramos, Gomes, & Barbosa-Póvoa, 2014; Gao & Cao, 2020; Dutta, Mishra, Khandelwal, & Katthawala, 2020; Aljuneidi & Bulgak, 2020; Ayvaz, Kusakci, Aydin, & Ertas, 2021; Ali, Paksoy, Torğul, & Kaur, 2020; Bing, Groot, Bloemhof-Ruwaard, & van der Vorst, 2013; Noroña & Acot, 2020; Simsek, Ozdemir, & Satoglu, 2022).

Other authors have evaluated the sustainability of networks, developing metrics and performance indicators, namely KPIs (Key Performance Indicators), in order to measure and analyse the performance of RL activities, covering aspects of sustainability, customer satisfaction and operational performance (e.g., Olivo, Junqueira, Furlan, Justi, & de Morais Lima, 2020; Rabnawaz Ahmed & Zhang, 2021; Stević et al., 2021; Ahlström, Ferning, Cheniere, & Sorooshian, 2020;Kazancoglu, Ekinci, Mangla, Sezer, & Kayikci, 2020). Studies also explore the outsourcing of RL activities, analysing the performance of specialized service providers. This work has addressed tertiarization practices, criteria for selecting partners and strategic partnerships (Chen, Zhang, Govindan, Wang, & Chin, 2021; Mishra, Rani, & Pandey, 2022; Wang, Dang, & Nguyen, 2021; Abdel-Basset, Gamal, Elhoseny, Chakrabortty, & Ryan, 2021; Liu, Wang, Wang, & Liu, 2022; Mohammadkhani & Mousavi, 2022).

Others focus on the barriers and main reasons for implementing RL. These studies identify barriers, such as organisational resistance, lack of awareness, lack of an appropriate structure, limited resources, complex operations or a lack of environmental responsibility. Motivating factors identified include environmental regulations, stakeholder pressure and economic benefits (e.g., Sirisawat & Kiatcharoenpol, 2019; Bouzon et al., 2018; Waqas et al., 2018; Govindan & Bouzon, 2018; Kaviani et al., 2020; Mangla et al., 2018; Lamba et al., 2020).

Besides quantitative approaches and optimization models, research on RL has resorted to conceptual frameworks. The most commonly used approach is the Triple Bottom Line (TBL) model, covering the social, environmental and economic dimensions (Slaper & Hall, 2011). The approach is used to explore sustainable development, including measurement of social and environmental categories and companies' economic performance (Zhao & Osman, 2023).

Fuzzy set theory is also frequently used in research on RL. This is an approach that supports the decision process and considers multiple criteria, such as qualitative perceptions, data shortage and uncertainty in opinions (Zhao & Osman, 2023). Chen et al. (2021) and Mishra and Satapathy (2022) applied fuzzy set theory in RL supplier selection, including economic, environmental and social criteria. Wang et al. (2021) used the same approach to compare suppliers and establish the criteria for outsourcing RL activities. Pourjavad and Mayorga (2018) applied fuzzy set theory in the choice of logistics partners in uncertain situations. In turn, Noroña and Acot (2020) and Simsek et al. (2022) explored the relation between products' life-cycle and RL, through an MCDM analysis to assess different recycling and reconditioning strategies.

Resource-Based Theory (RBT) seeks to identify the strategic resources a company can exploit to gain a competitive advantage. Hove-Sibanda et al. (2025) used RBT to identify the barriers and the impact of RL on SMEs' competitiveness. Nag et al. (2021) applied the theory to identify and assess the factors motivating the implementation of RL.

Finally, Critical Success Factors (CSF) has also been applied in the study of RL activities (Zhao & Osman, 2023). It is fundamental to identify CSFs in order to support organisations in the implementation of RL (Julianelli et al., 2020).

Despite the importance of RL, small and medium-sized enterprises (SME) in particular, still find it very difficult to implement. RL has gained prominence, but still needs more investigation. While some studies deal with the barriers to its implementation, no recent research was found to use the Fuzzy Delphi Method (FDM) method and focus on SMEs in the textile and footwear sector. Moreover, no articles were found to study the interaction between the barriers in these specific sectors.

Therefore, this research proposes to identify and analyse the main barriers to implementation of RL in Portuguese SMEs in the textile and footwear sectors. The aim, based on the existing literature and the contributions of academic specialists, is to understand the most relevant obstacles that hinder or prevent effective adoption of RL in these industries.

1.2. Research objectives and questions

Given the growing relevance of RL in the context of business sustainability, this study aims to identify the main barriers to implementing RL in SMEs in the textile and footwear sectors, as well as developing strategies to mitigate them. The intention is therefore to contribute to improved understanding of the factors hindering the adoption of RL practices in these sectors, promoting their more effective integration in the respective business models.

With a view to achieving the general aim, the following specific objectives were defined: (1) map scientific production on RL and sustainability, so as to identify the main research trends, theoretical approaches, application contexts and existing gaps; (2) identify and validate barriers to implementing RL; (3) analyse the inter-relation between these barriers, exploring how they influence each other; (4) identify the barriers and the reasons for adopting RL in SMEs in the textile and footwear sectors in Portugal and (5) propose specific strategies that can contribute to overcoming the obstacles identified.

Based on these objectives, the following research questions were defined: (1) What are the main research trends in RL? (2) What are the most significant barriers to implementing RL? (3) How are these barriers inter-related? (4) What are the main motivations and barriers to implementing RL in SMEs in the textile and footwear sectors? and (5) What strategies can be conceived to mitigate the barriers to implementing RL in these business contexts?

To carry out the studies, different units of analysis were defined. Regarding mapping of the scientific literature, the unit of analysis corresponded to scientific articles published in indexed academic journals, focused on the subject of RL and sustainability. Preliminary identification of the barriers was based on consulting academic specialists with consolidated production in this area. Subsequent validation of those barriers, identification of the relations between them and formulation of mitigation strategies was performed based on primary data gathered from the managers and directors of domestic SMEs belonging to the textile and footwear sectors

1.3. Methods

This study adopts a mixed methodological approach, including quantitative and qualitative methods in order to deepen knowledge about RL in SMEs, particularly in the textile and footwear sectors. To this end, five empirical studies were carried out to produce articles to publish in journals and present at conferences, each one with specific objectives, distinct data-collecting instruments and complementary analysis techniques. The first empirical study took the form of a systematic literature review (SLR), with the main aim of identifying, selecting and critically analysing the most relevant scientific contributions regarding implementation of RL in companies, from the sustainability viewpoint. This followed the methodological procedure proposed by Denyer and Tranfield (2009), who argue that an SLR must be understood as an autonomous research project, supported by a well-defined research question and directed towards a synthesis of existing knowledge. As suggested by Tranfield et al. (2003), the process was carried out in three phases: (i) planning the research, (ii) carrying out the review, and (iii) presenting and discussing the results, this last being addressed in another section of the work. As argued by Donato and Donato (2019), the clarity of the research question and rigorous definition of the analysis protocol are fundamental elements to ensure the robustness of the review. Based on this orientation, it was decided to make a search of the Web of Science and Scopus databases. This was done on 11 May 2023, using the key-words of "Reverse Logistics" and "Sustainability". Only peer-reviewed articles published in scientific journals were considered.

The first methodological step consisted of identifying the research gap through an exploratory analysis of the literature. To do so, a systematic search was made of the

Web of Science and Scopus databases, exclusively for peer-reviewed articles in English. This procedure followed the model proposed by Denyer and Tranfield (2009), who argue that the systematic literature review is a rigorous process of locating, assessing and summarising the relevant evidence to answer a clearly defined research question.

The second empirical study aimed to identify the main barriers to implementing RL and understand their importance from the organisational point of view. This involved following a methodological approach based on the FDM, to allow collecting, structuring and summarising specialists' opinions. Use of FDM is justified due to its advantages over the traditional Delphi method, particularly concerning the reduction of dispersed answers, elimination of inconsistencies and more robust results, as mentioned by Saffie et al. (2016) and Yusof et al. (2022).

Based on the literature analysed in the previous article, preliminary identification of the barriers to implementing RL served as the basis for the questionnaire used in the next stage of the study. Applying FDM meant preparing the collection instruments, defining the panel of specialists and using triangular fuzzy numbers for "fuzzification", aggregation and subsequent "defuzzification" of the data collected. According to Lim et al. (2021), FDM can reach a consensus more quickly and accurately, minimizing the need for multiple rounds.

The process followed the four phases suggested by Saffie et al. (2016): preparation, sorting, forecasting and final decision. Its application, via the structured opinions of the specialists, led to validating a critical number of barriers to implementing RL systems in organisations, that validation being fundamental for the subsequent developments of the study.

The third study followed a methodological approach structured in three distinct phases: (I) identification of the critical barriers to RL; (II) application of the Interpretive Structural Modeling (ISM) methodology; and (III) MICMAC analysis. Operationalizing phases II and III involved the fundamental support of the Focus Group (FG) technique, its methodological relevance being widely recognised in the literature.

According to Morgan (1996), the FG is an exploratory method of qualitative research that aims to gather data through participants' interaction around a previously defined and moderated topic. Marshall and Gretchen (2015) highlight that this technique can not only deepen existing information but also generate new perceptions by participants sharing opinions, beliefs and attitudes.

In this study, the focus group was formed of eight specialists with more than five years' experience in the area of RL, following the recommendations of Kitzinger (1995), who argues that the ideal composition of the group should be between four and twelve participants. The session was held remotely, via the Zoom platform, and moderated by one of the researchers, to ensure clarity in presenting the obstacles and a structured debate, gradually oriented from the general to the specific, as suggested by Larson et al. (2004). To settle possible differences of opinion among the participants, the principle of the majority decision was adopted (Shen et al., 2016).

The first phase of the study, selecting the critical barriers to implementing RL, was based on the results obtained in the previous study. With the specialists' support, this validated a set of 22 recurrent obstacles identified in the scientific literature.

The second phase involved application of ISM, a methodology that can identify and structure hierarchical relations among complex variables. In this case, it was possible to represent graphically the interdependences among the critical barriers to implementing RL, facilitating understanding of their mutual influence and relative position in the system.

Finally, the third methodological phase consisted of performing a MICMAC analysis, originally developed by Duperrin and Godet (1973), and based on the properties of matrix multiplication. This technique can classify the variables according to their driving force and level of dependence, distributing them over four quadrants: autonomous, dependent, linking and independent variables. This classification is essential to understand the barriers with the greatest capacity to influence and those most sensitive to the system, thereby guiding more effective mitigation strategies.

The fourth article aims to identify the main barriers faced by SMEs in the textile and footwear sectors to implementing RL, adopting the case study method for this purpose. This is considered appropriate to analyse complex phenomena in specific contexts, above all when attempting to understand "how" and "why" certain processes occur (Yin, 1994). The study followed a qualitative approach, recommended when the topics are little explored and the key variables are not yet well-defined (Creswell, 2009). Semi-structured interviews were held with supply chain managers, since this technique can go more deeply into the needs and perceptions of those involved (du Toit & Mouton, 2013). The sample was intentional (Bazeley, 2013), to ensure inclusion of particpants with practical, relevant knowledge about the subject analysed. Each interview lasted 30 minutes on average and followed a script divided in two parts. The first part characterised the sample and respective companies, including data such as the function performed, years of experience and involvement in RL processes. The second part focused on identifying the barriers to implementing RL and the strategies the companies adopted to overcome them. Being semi-structured meant that previously defined topics could be addressed, without compromising the flexibility necessary to explore emerging themes (Pozo et al., 2019).

The fifth article followed a hybrid approach to multi-criteria decision-making (MCDM), combining the FAHP and the Fuzzy F-MARCOS, in order to choose the most suitable strategy for implementation of RL in SMEs in the textile and footwear sectors. This made it possible to handle multiple, interdependent criteria, considering simultaneously economic, environmental and social factors, as argued by Stević et al. (2020) and Alpay and Feyzio (2021). FAHP was used to determine the weights of the criteria based on specialists' linguistic evaluations, while the F-MARCOS method ordered the strategic alternatives, dealing with the subjectivity and inexactness associated with human preferences, as proposed by Boral et al. (2020). Application of the model involved the contribution of specialists in the textile and footwear sector, thereby ensuring rigour and practical relevance in the decision-making process.

1.4. Structure

This thesis is divided in three main sections. The first corresponds to the introduction, with analysis of the relevant literature, definition of the research goals, the respective research questions, units of analysis and the methods adopted. The second section includes the articles completed, corresponding to five chapters, each one devoted to a different empirical study, i.e., a published article, one being reviewed or presented at a conference. The third section presents the conclusions of the research, together with the main theoretical and practical contributions made. The general structure of the thesis appears in Figure 1.

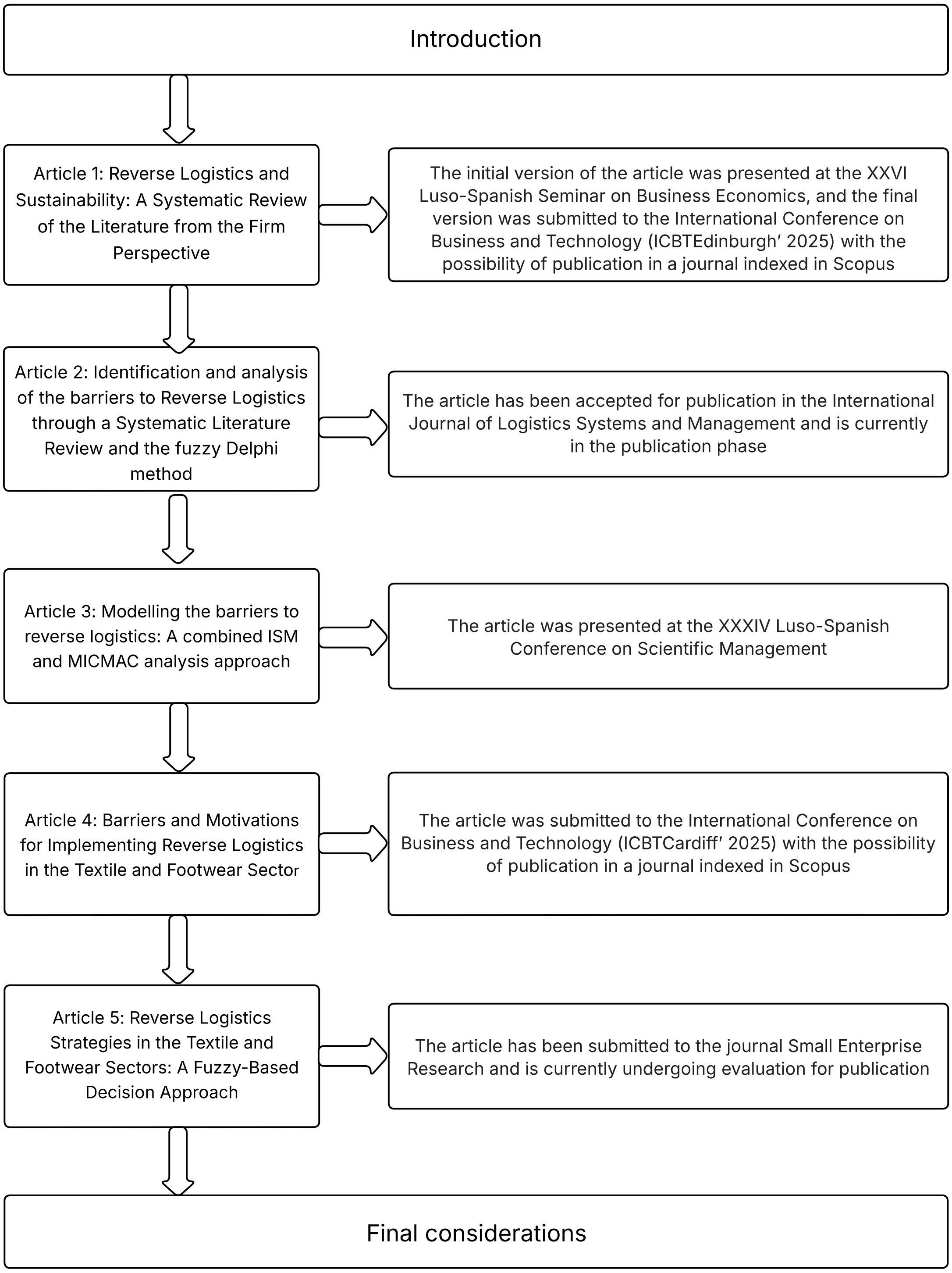

Figure 1 – Thesis structure

Part II

Chapter 2

Reverse Logistics and Sustainability – A Systematic Review of the Literature from the Firm Perspective[1]

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Abstract

Recent decades have seen growing consumption of natural resources, with worrying consequences for the environment. The environmental impacts arising from industrial activity have increased drastically and together with population growth the consumption of natural resources has become unsustainable. In this scenario, environmental awareness has received increasing attention in the literature and in society, leading to development of the concept of Reverse Logistics as a fundamental approach for companies to be able to improve their environmental performance.

In order to assess RL practices and increase knowledge about the subject, this study aims to present a Systematic Literature Review Using the Scopus and Web of Science databases, 203 articles were extracted for subsequent analysis. An exhaustive analysis of the articles selected resulted in identifying four major themes, namely: mathematical programming models of an Reverse Logistics network; externalization of Reverse Logistics activities; assessment of an Reverse Logistics network's performance and barriers to implementing an Reverse Logistics network.

The conclusions reveal that the main obstacles firms face are high costs, the lack of specialized human resources and the absence of government policies. As a response to the high costs of Reverse Logistics, most of the mathematical models analysed seek to balance the compromise between cost effectiveness and environmental performance.

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Similarly, the assessment of network performance focuses on the economic and environmental aspects.

Keywords: Systematic Literature Review; Reverse Logistics; Sustainability

1. Introduction

The effects of climate change are increasingly obvious with dramatic consequences. Extreme events such as storms, flooding and heatwaves are more and more frequent, with droughts and forest fires being major threats. Industry is one undeniable source of climate change, due to the consumption of energy and natural resources and the emission of polluting gases, but is also of central importance in our society (Garetti & Taisch, 2012;Shamsuddin, Ahmad, & Peng, 2020).

Most managers are focused on optimizing production and have neglected over-exploitation of natural resources, which will lead to exhausting some of these resources if there is no change in paradigm (George, Lin, & Chen, 2015).

One of the most active organisations contributing to arousing environmental concerns was the World Commission On Environment And Development (1987), a pioneering institution in the field, which underlines the need to change consumption and production. Eleven years later, Mebratu (1998) stated that the measures adopted over the years present positive results, but are clearly insufficient given the major environmental challenges. More recently, Landrigan et al. (2018) drew attention to the urgent need for behavioural changes to avoid jeopardizing the future of the coming generations. Indeed, there is an urgent need to move to more efficient and dynamic sustainable markets, in order to combat and minimize the collateral effects of large-scale production.

With population growth, companies realized that the recovery of used products would be a way to support sustainable development (Gao & Cao, 2020). Besides environmental concerns, the creation of environmental legislation and regulations has forced industry to consider the management of environmental operations with the help of RL (Kannan Govindan & Bouzon, 2018). According to Rogers and Tibben-Lembke (1998), RL is a process of planning, implementing and controlling the efficient and economic flow of raw material, stock management, finished goods and information from the point of consumption to the point of origin, aiming to recuperate the value of the product or channel the waste to elimination. Some authors (Agrawal & Singh, 2019; Safdar, Khalid, Ahmed & Imran, 2020) present RL as the sequence of activities necessary to recover the product used by customers, in order to repair, transform, recycle or even eliminate the waste. Others (Govindan, Soleimani & Kannan, 2015; Arruda, Carlos, Rosley & Simon, 2008) consider that RL may have a fundamental role for the environment, but will also be useful to support firms in complying with legislation and obligations with a view to sustainability. Traditionally, companies were not held responsible for the product after the consumer had used it, but with increasing stakeholder expectations in the area of social and business sustainability, firms have become more aware of the importance of managing social and environmental impacts.

Currently, companies are focused not only on economic but also on environmental impacts throughout their products' useful life. As consumers and other publics want firms to be more responsible regarding how the product is made, so as to minimize waste production, expectations have also changed towards recovery of products after their use, in order to reduce the costs and environmental impact of recycling (Rodrigues & Mathew, 2011). However, RL does not focus only on objectives related to sustainability, as RL systems are fundamental for companies to develop and improve their environmental and financial performance (Nikolaou, Evangelinos, & Allan, 2013; Kannan Govindan et al., 2015).

Based on the arguments presented, this study aims to systematize and present a review of the studies published, to give in-depth knowledge of the state-of-the-art of RL. The analysis is carried out from the perspective of sustainability, aiming to fill a gap in the literature, since no previous systematic reviews were found to address this topic specifically.

The aim of a literature review process is to (i) allow researchers to map and access the existing intellectual territory, and (ii) identify gaps and raise questions that can be answered by future studies (Tranfield, Denyer, & Smart, 2003). The literature review in management areas is fundamental to increase the diversity of existing knowledge on a given topic.

This SLR, specifically, aims to provide evidence confirming the need for more efficient and dynamic sustainable markets, in order to combat and minimize the collateral effects of large-scale production, and comply with environmental legislation.

2. Methods

This SLR followed the process proposed by Denyer and Tranfield (2009), who say that the methodology aims to identify and select existing studies, evaluate their contributions, analyse the data and describe the evidence in order to draw conclusions about knowledge of the subject. A systematic review should not be considered as a mere bibliographical review in the traditional sense, but rather an autonomous research project exploring a specific question, generally arising from a problem, and using existing studies. To fulfil this purpose, it was decided to apply the methodology suggested by Tranfield et al., (2003), a process in three phases: (i) Planning the Research (ii) Developing the Research and (iii) Presenting and Discussing the Results, with the last-named being dealt with in the next section.

In planning the research, it is crucial to define clearly the research question. According to Donato and Donato (2019), a well-defined research question and a well-grounded protocol increase the efficiency of the review. The research protocol addressed the following research question: What are the main aspects studied on implementation of RL in companies, from the perspective of sustainability?

After defining the research question to orient the study, the Web of Science and Scopus databases were chosen as the sources for the search. The search was made on 11 May 2023, using the terms of "Reverse Logistics" and "Sustainability". Only peer-reviewed articles in international journals were selected.

The table below shows the inclusion criteria used to form the sample.

Table 1 – Criteria for selection of articles

Criteria for selection and inclusion of articles	
Database	SCOPUS and Web of Science
Search field	Title, Abstract and Key-Words
Scopus	423
Web of Science	829
Date of Search	May 2023
Period of analysis	2001 - 2023
Type of document	Article
Language	English
Stage of publication	Final
Duplicated articles	279
Total identified article	973
Articles excluded after analysis	770 (79%)
Articles analysed	203 (21%)

The search identified 423 articles on Scopus and 829 on Web of Science. However, 279 of these were found to be duplicated. After more detailed analysis of the 973 articles considered initially, it was decided to exclude 770, due to not satisfying the criteria established for the study. The excluded articles were more focused on subjects such as the circular economy and the closed-loop supply chain, whereas the scope of analysis was directed to RL.

3. Analysis and discussion of the results

3.1Descriptive analysis

Figure 1 shows the evolution of the number of articles published over the period of analysis (2001 to 2023). In this period, there was a gradual increase in the number of publications, reaching a peak of 38 in 2022. A fall in publications is seen in 2023, as only the first five months of the year were included.

Figure 2- Number of publications per year

Table 2 presents the 10 most cited articles, among the 203 analysed, according to the research protocol. The 10 articles account for 35% of all 8.167 citations shown.

Table 2 - Top 10 most cited articles

Authors	Year	Journal	Title	Citations
Chaabane; Ramudhin; Paquet	2012	International Journal of Production Economics	Design of sustainable supply chains under the emission trading scheme	993
Presley; Meade; Sarkis	2007	International Journal of Production Research	A strategic sustainability justification methodology for organizational decisions a reverse logistics illustration	291
Sodhi; Reimer	2001	Quantitative Approaches in Management	Models for recycling electronics endoflife products	259
Ramos; Gomes; Narbosa-pvoa	2014	Omega	Planning a sustainable reverse logistics system balancing costs with environmental and social concerns	235
Gonzalez-torre; Alvarez; Sarkis	2010	British Journal of Management	Barriers to the implementation of environmentally oriented reverse logistics evidence from the automotive industry sector	221
Mavi ;Goh ;Zarbakhshnia	2017	The International Journal of Advanced Manufacturing Technology	Sustainable third party reverse logistic provider selection with fuzzy SWARA and fuzzy MOORA in plastic industry	215
Govindan; Paam; Abtahi	2016	Ecological Indicators	A fuzzy multiobjective optimization model for sustainable reverse logistics network design	180
Silva; Ren; Sevegnani; Sevegnani; Truzzi	2013	Journal of Cleaner Production	Comparison of disposable and returnable packaging a case study of reverse logistics in Brazil	173
Ferri ;Diniz;Ribeiro	2015	Waste Management	Reverse logistics network for municipal solid waste management the inclusion of waste pickers as a Brazilian legal requirement	159
Agrawal; Singh; Murtaza	2016	Resources, Conservation and Recycling	Outsourcing decisions in reverse logistics sustainable balanced scorecard and graph theoretic approach	145

Table 3 presents an analysis of the authors' geographical origin, considering both countries and continents. It is noted that some articles can originate in more than one country.

This geographical analysis shows a significant concentration of studies in Asian countries, representing 41% of the total. Within this region, India and China stand out, with a combined total of 72 studies. This is followed by 27% from North and South America, with Brazil (34 studies) and the United States of America (20 studies) producing most. Europe is in third position, with 21% of the studies analysed. Africa and Australasia have few studies in this area, only 5% and 4%, respectively.

Table 3 – Studies by country and by continent

Studies by country					
India	37	Australia	9	Turkey	5
China	35	Canada	8	Norway	5
Brazil	34	Denmark	7	Netherlands	5
United States of America	20	United Kingdom	6	Others	88
Iran	16	Italy	5		
Studies by continent					
Asia	41%	Europe	23%	Australasia	4%
America	27%	Africa	5%		

Analysis of the articles shows they have been published in a total of 115 journals. However, as can be seen in Figure 2, the greatest number of articles on the subject (36) have been published in "Sustainability", with "Journal of Cleaner Production" in second place with 25.

A hundred and seven articles were published in journals publishing 1 or 2 articles on the subject.

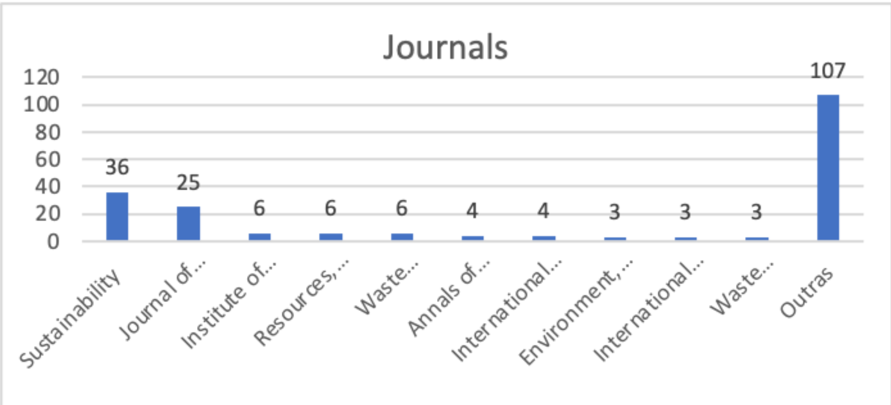

Figure 3 - Journals

3.2 Identification and analysis of predominant themes

Based on content analysis, and aiming to answer the research question, the articles can be grouped in four clusters, since most studies focus on the following research: i) mathematical programming models of an RL network (51% of articles, n=103); ii) assessment of an RL network's performance (20% of articles, n=41) ; iii) externalization of RL activities (15% of articles, n=30); iv) barriers to implementing RL (14% of articles, n=29).

3.2.1. Cluster 1: Mathematical programming models of an RL network (n=103)

Increased environmental concerns, together with legislation, forces industry to review the impact of its operations on the supply chain (Chaabane, Ramudhin, & Paquet, 2012; Kumar & Kumar, 2016). Aiming to respond to market needs, models have been elaborated to support the tactical and operational planning decisions of RL systems, considering simultaneously economic, environmental and social objectives (Ramos, Gomes, & Barbosa-Póvoa, 2014).

These models have been used to assess the trade-offs between economic and environmental goals, according to various cost and operating strategies, aiming to reduce the environmental impact and increase organisations' degree of social responsibility (Sodhi & Reimer, 2001; Yu & Solvang, 2016; X. Gao & Cao, 2020; Tavakkoli Moghaddam, Javadi, & Hadji Molana, 2019; Lagarda-Leyva, Morales-Mendoza, Ríos-Vázquez, Ayala-Espinoza, & Nieblas-Armenta, 2019).

The literature review also reveals real concern about studying mathematical models that can determine the number of installations necessary for the RL network, its location, capacities and product selection (Ferri, Diniz Chaves, & Ribeiro, 2015; Dutta, Mishra, Khandelwal, & Katthawala, 2020; Eskandarpour, Zegordi, & Nikbakhsh, 2013; Harraz & Galal, 2011; Reddy, Kumar, & Ballantyne, 2019; Li & Huang, 2018; Couto, Lange, Rosa, & Couto, 2017; Aljuneidi & Bulgak, 2020; Xuehong Gao, 2019; Ayvaz, Kusakci, Aydin, & Ertas, 2021; Cao et al., 2022). In turn, various studies focus on elaborating programming models with carbon restrictions for a sustainable conception of RL from the perspective of uncertainty (Yu & Solvang, 2017; Ali, Paksoy, Torğul, & Kaur, 2020; Xuehong Gao, 2019; Bing, Groot, Bloemhof-Ruwaard, & van der Vorst, 2013; Bennekrouf, Boudahri, & Sarib, 2011). Several authors (Noroña & Acot, 2020; Simsek, Ozdemir, & Satoglu, 2022; Ali Qureshi, 2011) have concentrated their research on studying and analysing products' life-cycle. The conception of recirculation systems based on assessing products' life-cycle seems to be an efficient process in reducing environmental impacts.

3.2.2. Cluster 2: RL performance assessment (n=41)

Different industries are seeking methods to measure and analyse the impacts of their RL activities from the economic, environmental and social point of view (Slomski, Slomski, Valim, & Vasconcelos, 2018; dos Santos, Loureiro, & de Oliveira, 2013). By evaluating the network's sustainability, various studies demonstrate how efficient RL can reduce costs, diminish the harmful effects on the environment, present a positive social performance and give firms competitive advantages (De Araujo, Matsuoka, Ung, De Castro Hilsdorf, & Sampaio, 2013; Ghisolfi, Diniz Chaves, Ribeiro Siman, & Xavier, 2017; Nikolaou, Evangelinos, & Allan, 2013; Bottani, Casella, Nobili, & Tebaldi, 2019; Slomski et al., 2018; Olivo, Junqueira, Furlan, Justi, & de Morais Lima, 2020). Aiming to assess RL performance, some researchers have developed performance measurement metrics, particularly Kpis (Key Performance Indicator), able to assess the network's sustainability (de Oliveira Neto & de Sousa, 2014; Rabnawaz Ahmed & Zhang, 2021; Stević et al., 2021; Ahlström, Ferning, Cheniere, & Sorooshian, 2020;Y. Kazancoglu, Ekinci, Mangla, Sezer, & Kayikci, 2020; Hazen, Overstreet, Hall, Huscroft, & Hanna, 2015).

The literature also contains studies that seek to compare and evaluate different network configurations, aiming to conceive a more efficient network (Yanikara & Kuhl, 2016; Junior, Dias, de Oliveira, & Forti, 2019).

3.2.3. Cluster 3: Externalization of the RL network (n=30)

Today, RL presents a fundamental role for most organisations, due to the increased flow of returned products and growing concern with the environment, legislation and companies' social responsibility. One of the important decisions to make concerns the possibility of total or partial sub-contracting of activities, or the absence of sub-contracting (Mavi, Goh, & Zarbakhshnia, 2017; . Agrawal, Singh, & Murtaza, 2016; Agrawal & Singh, 2020; Yan, Li, Chai, Qian, & Chen, 2018). However, as this is a complex procedure requiring a suitable system, the recent tendency is to externalize RL activities (Govindan, Kadziński, Ehling, & Miebs, 2019; Mishra et al., 2021).

Selecting RL suppliers is an important part of the operation and implementation of reverse supply chains. Economic partnerships based on costs are no longer acceptable for organisations seeking to introduce sustainable management in the supply chain. The recent emphasis on sustainability has made the assessment and selection of RL suppliers more complex. Currently, the search for RL suppliers has become an increasingly central issue for industries aiming for better customer service, cost reductions and more sustainable operations. However, evaluation and selection of RL suppliers is a complex problem of uncertain decision-making, due to the involvement of numerous items that are sometimes in conflict, and the lack of information (Bai & Sarkis, 2019). Aiming to overcome the problem, various studies attempt to develop a system to support decisions, to help firms select and assess different suppliers. The optimal selection of RL suppliers is fundamental in externalization practices, because it has the potential to improve firms' economic profitability (Chen, Zhang, Govindan, Wang, & Chin, 2021; Govindan, Agarwal, Darbari, & Jha, 2019; Mishra, Rani, & Pandey, 2022; Kafa, Hani, & El Mhamedi, 2015; Wang, Dang, & Nguyen, 2021; Nadine Kafa, Hani, & El Mhamedi, 2014; Pourjavad & Mayorga, 2018; Abdel-Basset, Gamal, Elhoseny, Chakrabortty, & Ryan, 2021; Liu, Wang, Wang, & Liu, 2022)

3.2.4. Cluster 4: Barriers to implementing an RL network (n=29)

RL has gained importance due to environmental issues, government policies, sustainability, globalization, returns under guarantee, components at the end of their life, etc. Nevertheless, companies face multiple difficulties in carrying out RL activities due to numerous barriers

The following table presents, in a systematized way, the barriers referred to in the literature.

Table 4 – Barriers to implementing a Reverse Logistic network

Barrier	Author
Lack of knowledge	Mangla, Govindan & Luthra (2016); Kazancoglu, Kazancoglu, Yarimoglu & Kahraman (2020); Vijayan, Kamarulzaman, Mohamed & Abdullah (2014)
High costs	Mangla et al., (2016); Couto et al. (2017); Kazancoglu, Kazancoglu, Yarimoglu & Kahraman (2020); Waqas et al. (2018)
Low expectations	Couto et al. (2017)
Lack of a specialized workforce	Kazancoglu, Kazancoglu, Yarimoglu & Kahraman (2020), Waqas et al. (2018), Laguir, Stekelorum & El Baz (2018)
Design challenges	Kazancoglu, Kazancoglu, Yarimoglu & Kahraman (2020)
Lack of integration	Kazancoglu, Kazancoglu, Yarimoglu & Kahraman (2020)
Technical infrastructure	Kazancoglu, Kazancoglu, Yarimoglu & Kahraman (2020)
Government policies/ Environmental legislation	Waqas et al. (2018); Laguir, Stekelorum & El Baz (2018)
Lack of community pressure	Waqas et al. (2018); Laguir, Stekelorum & El Baz (2018); Vijayan, Kamarulzaman, Mohamed, & Abdullah (2014);
Lack of stakeholder involvement	Laguir, Stekelorum & El Baz (2018)
Lack of coordination with third parties' logistics	Prakash & Barua (2016)
Uncertainty about quality	Prakash e Barua (2016); Vijayan, Kamarulzaman, Mohamed, & Abdullah (2014)
Long time for return	Prakash e Barua (2016); Vijayan, Kamarulzaman, Mohamed, & Abdullah (2014)
Little commitment from top management	Prajapati et al., (2019)
Lack of strategic planning to implement RL activities	Prajapati et al., (2019)
Lack of marketing strategy	Prajapati et al., (2019)

Analysis of articles focused on the barriers to implementing RL reveals the lack of knowledge, high costs, government policies and lack of a specialized workforce as the most frequently mentioned.

4. Conclusion

This study aimed to synthesize the literature on RL, analysing the key dimensions in research on the subject. The SLR focused on studies made over the years, from 2001 to 2023, their place of origin, the journals publishing them and the main topics present. The search identified 976 articles, of which 773 were excluded due to not coming within the scope of the research question, resulting in a total of 203 articles.

Analysis of these articles included in the study revealed four distinct clusters. Cluster 1, the biggest, is focused on developing mathematical optimization models and strategies to support implementation of RL networks. Cluster 2 addresses the theoretical aspect of assessing RL performance. The studies represented in this cluster aim to provide a conceptual framework to measure and analyse the performance of RL activities, considering aspects such as sustainability, customer satisfaction and key-indicators of performance. Cluster 3 is formed of articles exploring the externalization of RL activities, analysing specialized service providers, with research being focused on outsourcing practices, supplier selection and strategic partnerships in managing RL. In Cluster 4, the authors concentrate on the barriers to, and the main factors stimulating the implementation of reverse flow networks, examining the challenges faced by organizations when adopting RL, such as organisational resistance, lack of awareness and limited resources, besides identifying stimulating factors such as environmental regulations, stakeholder pressure and economic benefits.

The results provide a broad panorama of the dimensions addressed in the literature on RL and indicate directions for future research. The following table presents suggestions for future study based on analysis of the clusters.

Table 5: Suggested research

Cluster	Research Suggestions
Mathematical programming models for an RL network	Incorporate in the model the uncertainties of demand breakdown, supply breakdown and transport breakdown.
	Use the methodology of problem structuring, thinking focused on value, the methodology of flexible systems and the strategic choice approach
	Consider multiple orders in the model and integrate the concept of collaboration
Assessing RL performance	Studies using interviews and applying questionnaires
	Understanding how the behaviour of human agents influences the processing of returned products

	Introduce assessment of environmental and social performance in multi-criteria decision-making
Barriers to implementing an RL network	Investigate RL in different markets to determine solutions that depend on the context
	Analyse different industrial sectors and make comparative analyses between local and foreign industries
	Study the different perceptions of the barriers to implementing RL at the different levels, since each group may have different interpretations of what forms a barrier to implementation
	Compare the different supply chains and their RL activities in various emerging economies or even in developed ones

As for the limitations of this study, firstly, in the SLR, only the key-words of "reverse logistics" and "sustainability" were used, which this may have excluded relevant articles about the subject. Since RL is a complex subject, increasing the variety of key-words used, broadening the search to include phrases such as "closed-loop supply chain management" and/or "circular economy" could contribute to a more thorough and wide-ranging review of the literature.

It is also important to mention that the articles selected are limited to those in English. RL is influenced by geography, economic, social and regulatory conditions, and so some research perspectives may have been missed.

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Chapter 3

Identification and analysis of the barriers to Reverse Logistics through a Systematic Literature Review and the fuzzy Delphi method[2]

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Abstract

Increasing environmental awareness among consumers and the constant updating of legislation has led industries to re-assess their environmental management, through adopting Reverse Logistics (RL) practices. To establish effective RL systems, it is essential to analyse the barriers that hinder the reverse flow.

This article aims to compile the main barriers related to RL, identifying the most relevant barriers according to academic specialists in this scientific area. A Systematic Literature Review (SLR) was carried out, supported by the SCOPUS and WOS databases, and using the key-words of "Reverse Logistics" and "Barriers". This led to identifying 61 barriers which were then grouped in seven distinct categories. Subsequently, the Fuzzy Delphi Method (FDM) was used to obtain a critical list of barriers, involving the collaboration of 20 specialists in the area.

The category of "Economic related issues " obtained the greatest consensus among the specialists, while that of "Market and competitors related issues " was not validated. Barriers related to “Uncertain quality and quantity of returned products", “Uncertainty of economic benefits" and "High costs" emerged as the most relevant, and the barrier of “Financial constraints” obtained the greatest consensus among the specialists.

Key-words: Reverse logistics; barriers; fuzzy Delphi method; systematic literature review

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1. Introduction

Mass production and a shorer product life-cycle have contributed significantly to increased global production. As a result, more raw material is being used and landfill is reaching its maximum capacity (Bouzon, et al., 2015). Faced with this significant growth in production, customers and other agents along the supply chain are becoming increasingly aware of environmental issues and knowledgeable about sustainable management. (Sirisawat & Kiatcharoenpol, 2018; González-Torre, et al. , 2010; Naseem, et al. 2021).

Due to greater general awareness and the impacts of excessive consumption and environmental damage, interest in Reverse Logistics (RL) has grown, emerging as a crucial approach to sustainability and responsible management of resources (Abdulrahman, et al., 2014). Through RL, it will be possible to mitigate the environmental impacts resulting from inadequate elimination of waste, since it allows the valorisation of material through re-use and recycling (Gomes et al., 2019).

Although RL has existed for as long as conventional logistics, growing social concern about the environment has led to RL activities becoming a critical function for many organisations (González-Torre et al., 2010; Agrawal & Singh, 2019).

Management of RL is a fundamental aspect of supply chain management, as it can not only reduce costs but also create value for the firm. It consists of the set of operations designed to manage customers' returns to suppliers, generally involving recycling, repair, elimination or re-use, at the lowest possible cost (El Boudali et al., 2022).

Whereas conventional logistics is defined as the processing of moving goods from the point of origin to the point of consumption, RL establishes the opposite approach. Its growth worldwide has had an impact on all levels of the supply chains in various sectors of industry, since more efficient RL operations result in greater income and lower costs (Vieira, et al. , 2020; Darbari, et al. , 2021).

Despite the progress witnessed in recent years, RL is still a challenge for many developed, and especially developing, countries (Laribi & Dhouib, 2015). Recognised as a crucial component of supply chain management, the implementation of RL faces significant challenges due to various barriers (Waqas et al., 2018).

Overall, it seems that many companies face the same obstacles when they try to implement or manage RL activities. However, the context of the country (specific legislation, logistic infrastructure, social conditions, etc.) can influence the importance of each barrier, as well as creating specific barriers (Bouzon et al., 2016).

The literature review carried out revealed three research gaps regarding the implementation of RL:

- RL has gained prominence due to various factors, but still needs relevant studies;
- Although various studies show the importance of implementing RL, various obstacles jeopardize effective completion;
- Some studies focus on the barriers to implementing RL, but no recent studies using the FDM were found.

Given constant economic development and more competitive markets, companies need to find modern solutions to improve their commercial activities. RL emerges as a possible response in the search for better performance, but the decision to implement its processes in business practice is not easy. During this type of investment and in the subsequent maintenance stage, various barriers can arise, making effective RL complex (Starostka-Patyk et al., 2013).

To answer the research objective, i.e., identify the greatest barriers preventing full development of RL and study the importance of each barrier selected, a Systematic Literature Review "SLR" will be carried out with application of the Fuzzy Delphi Method "FDM". Section 2 presents a brief review of the literature on RL. The problem is described in Section 3 and the methodology and methods applied are described in Section 4. Section 5 presents and discusses the results of the research. The last section presents the final observations, conclusions and limitations, with suggestions for future research.

2. Literature Review

At present, most companies are interested in policies aiming to promote a sustainable environment. However, the great increase in industrial production and excessive consumption of natural resources result in environmental problems. It is therefore up to firms to reformulate their activities, in order to avoid these problems (Akdogan & Coskun, 2012).

At the same time, with economic and technological advances, the cycle of substituting products has speeded up, resulting in shorter life-cycles, with aggravates environmental problems considerably (Pimentel et al., 2022).

Due to the growing concern for the environment, integrated environmental management occupies a prominent place in the sustainability of companies, since this integration can contribute to the mitigation of some of the negative environmental impacts associated with their activity. In this context, the search for more sustainable practices and processes is essential to balance economic growth and environmental preservation. (Lyu et al., 2020).

Appropriate RL strategies not only help to create sources of profit, reduce manufacturing costs and increase customer satisfaction, but also help management to solve problems in good time and improve product quality (Liu & Cai, 2015).

RL is a process of planning, implementing and controlling the efficient and economic flow of raw material, stock management, finished goods and information from the point of consumption to the point of origin, aiming to recover the product's value or direct the waste to elimination. Agrawal and Singh (2019) and Safdar et al., (2020) present RL as the sequence of activities necessary to collect the product used by customers in order to repair, transform, recycle or even eliminate the waste. Despite the benefits associated with RL, its level of implementation in companies is still very low (Pimentel et al., 2022). Due to the lack of resources to implement solutions, RL has had a negative effect on costs and customer service in various supply chains, making it difficult to meet expectations in processing returns (Dabees et al., 2023).

According to Starostka-Patyk et al. (2013), it is challenging to implement RL processes in companies, and during that process obstacles that are difficult to overcome may arise.

3. Research methodology

To fulfil the aim of the article, i.e., identify the greatest barriers to developing RL and study the importance of each barrier, this research proposes to identify critical obstacles from an organisational point of view, using the FDM.

As shown by the research framework (Figure 1), the study was divided into various steps.

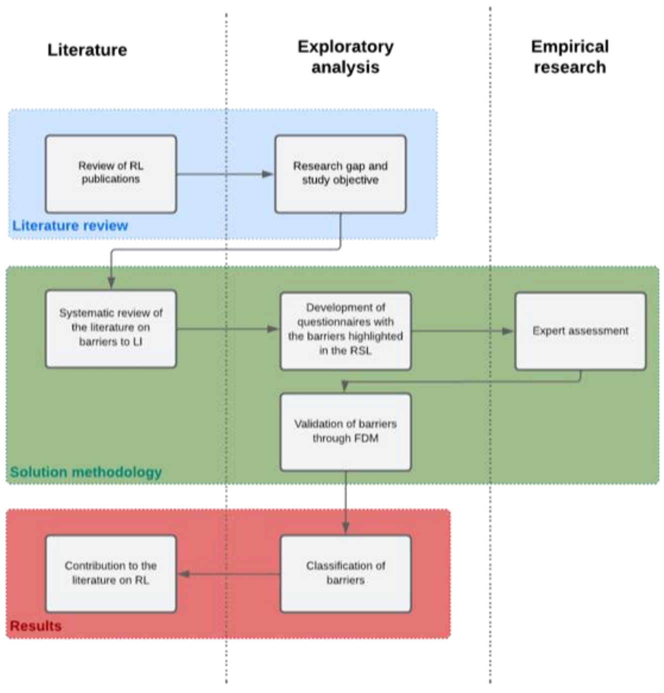

Figure 1 – Proposed research to identify barriers

First of all, a systematic search for articles on RL in English language journals was made on the Scopus and Web of Science databases, so as to circumscribe the research gap. The results of this analysis confirm the existence of only one study with a similar approach, arising in Brazil in 2014.

After identifying the research gap, the third step was to carry out an SLR of the barriers to implementing RL. Here, the key-words of "reverse logistics" and "barriers" were used, resulting in an initial selection of 385 articles, from which 55 were removed due to duplication. The articles were then sorted by analysing the titles and abstracts to ensure the main content fell within the scope of the research. A final set of 66 articles was chosen to identify the barriers to RL. Analysis of these articles identified 61 barriers which subsequently formed the survey sent to RL specialists for validation, in order to identify the main barriers to implementing an RL network.

3.1 Method of Analysing the Literature

This article followed the SLR process proposed by Denyer and Tranfield (2009), one which can locate existing studies, select, assess contributions, analyse data and describe the evidence so as to allow conclusions about knowledge of the topic.

Table 1 presents the databases where the search was made and the criteria for selecting articles.

Table 1 – Criteria for selection of articles

Criteria for selection and inclusion of articles	
Database	SCOPUS and Web of Science
Field of search	Title, Abstract and Key-Words
Scopus	264
Web of Science	121
Date of Search	October 2023
Type of Document	Article
Language	English
Stage of Publication	Final
Duplicate Articles	55
Total Articles Identified	330

Articles Excluded after analysis	264 (80%)
Articles Analysed	66 (20%)

Having defined the research question to guide the study, the Web of Science and Scopus databases were established as the source for the search.

The search of these databases was made on 6 October 2023 with the terms of "Reverse Logistics" and "Barriers". Only peer-reviewed articles in international journals were selected.

The search revealed 264 articles on Web of Science and 121 on Scopus, but 55 were repeated and 264 were excluded as they did not come within the study objective.

3.2 Fuzzy Delphi Method

The Delphi method was first developed by Dalkey and Helmer (1963), and since then has undergone some improvements and modifications. The Delphi technique aims to obtain the consensus of opinion in a group of specialists through a series of intensive questionnaires together with controlled feedback (Dalkey & Helmer, 1963).

The Delphi method, known as the method of surveying specialists, uses mainly questionnaires to obtain opinions from various specialists on the matter, and then compile and summarise the wide-ranging opinions. Next, the different opinions and questions are resent to the experts before asking for their opinion once again (Lim et al., 2021). However, the Delphi method has undergone improvements and modifications over time, giving way to the FDM.

The FDM is a modified, improved version of the classic Delphi technique. It was improved in order to rectify the imperfection of the Delphi method which leads to low convergence in obtaining results, the loss of important information and a long research process (Saffie et al., 2016).

The stages of the FDM (Figure 2) are as follows:

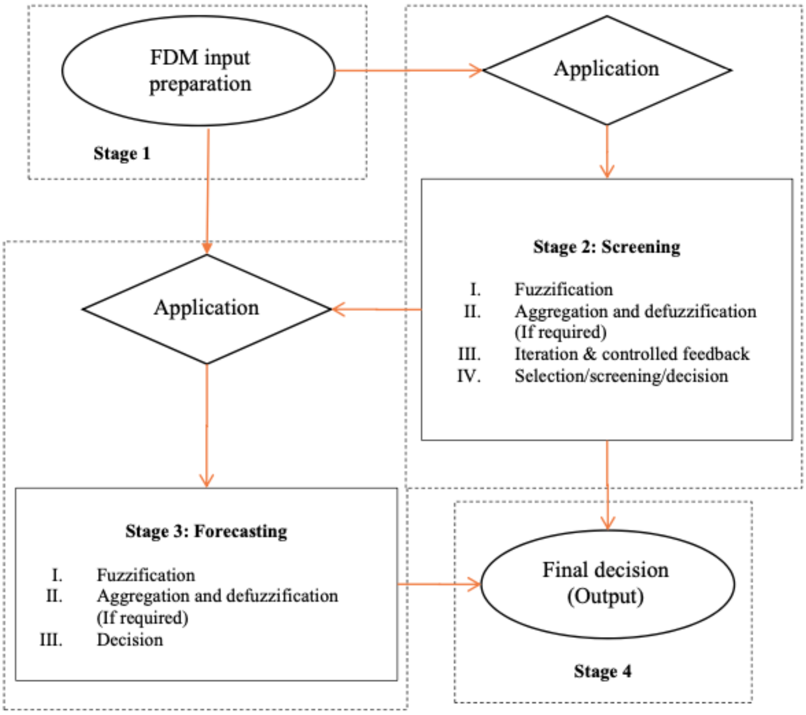

Figure 2 – Stages of the FDM (Saffie et al., 2016)

According to Saffie et al., (2016), the FDM process consists of four main phases: preparing the FDM, screening, forecasting and the final decision.

The first phase of the FDM begins by preparing the inputs, such as collecting information, preparing questionnaires and selecting the team members to include in the decision-making process.

In the second phase of the MFDM, screening, the first task is the fuzzification of values, using triangular fuzzy numbers. This is followed by aggregation and defuzzification, where the results of this process are used to indicate the need for an iteration processs in which controlled feedback is generated.

In the third phase, the fuzzified values calculated in the second phase are used for greater aggregation, with the results being used for forecasting or predicting. The FDM process is concluded with the final decision-making.

Recent studies demonstrate that the FDM can reach a reliable consensus among specialists in a single round, helping to produce rapid, precise results (Yusof et al., 2022).

This study has a quantitative design, applying the FDM to obtain consensus among specialists regarding the barriers to implementing RL. The SLR identified 61 barriers that were grouped in 7 categories according to Govindan and Bouzon (2018) , as shown in Table 2.

Table 2 – Category of barriers

	Category	Number of Items
Barriers to implementing RL	Technology and infrastructure related issues	10
	Governance and supply chain process related issues	5
	Economic related issues	9
	Knowledge related issues	5
	Policy related issues	9
	Market and competitors related issues	9
	Management related issues	14
	Total items	61

Fuzzy rules have essentially two main components: the triangular fuzzy number and the defuzzification process. The fuzzy number is used to create a measurement scale similar to the Likert scale, which translates the variables into fuzzy numbers (Figure 3). In this study, 7-point Likert scales were adopted, reflecting a diversity of responses ranging from "very low" (1) to "very high" (7) to represent levels of agreement and disagreement.

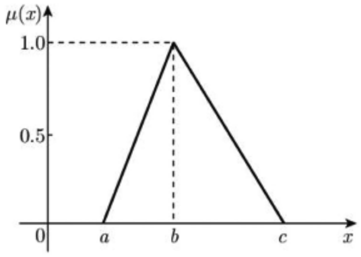

Figure 3 – Values of the Triangular Fuzzy Number

The FDM has a number of stages which must be followed. Initially, it is necessary to determine the number of specialists called on to evaluate the importance of the criteria, using linguistic variables. Next, after successfully obtaining all the data and information necessary from the specialists, the Likert-scale data must be converted into a diffuse scale, as shown in Table 3.

Table 3 - Triangular fuzzy number

Linguistic Scales	Likert Scale	Fuzzy Number
Very low	1	(0,0,0.1)
Low	2	(0,0.1,0.3)
Medium low	3	(0.1,0.3,0.5)
Medium	4	(0.3,0.5,0.7)
Medium high	5	(0.5,0.7,0.9)
High	6	(0.7,0.9,1.0)
Very high	7	(0.9,1.0,1.0)

Then the threshold is calculated, i.e., the (d) value based on the following formula. This process involves converting all the scales of linguistic variables to a diffuse triangular numbering. The values of m_1, m_2 e m_3 are used to represent the triangular fuzzy number. The value of m_1 is related to the minimum value, m_2 to the most appropriate value and m_3 to the maximum value.

$$d(\tilde{m},\tilde{n}) = \sqrt{\frac{1}{3}[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2]}$$

When the difference between the average and the specialists' assessment data is no greater than the limit value, (d) = 0,2, all the specialists are said to have reached an agreement (Cheng & Lin, 2002). To validate the barriers, it is still necessary for the percentage of the specialists' agreement to be at least 75,0% and the defuzzification value of each item on the questionnaire to be above 0,5 (Cheng & Lin, 2002; Chu & Hwang, 2008).

Finally, we can identify the diffuse score, position and priority of each item through the following formula (Yusof et al., 2022):

$$A = \frac{1}{3}(m_1 + m_2 + m_3)$$

Excel software was used to analyse all the statistical calculations.

3.3 Panel of specialists

Ocampo et al. (2018) state there is no need to include a high number of specialists in a study, as there is no direct relation between the number of specialists and the quality of the results arising from group discussions. Adding more specialists, especially less experienced ones, could even jeopardize the accuracy of the results (Saaty & Özdemir, 2014). Jones and Twiss (1978) proposed the participation of 10 to 50 specialists in this technique, while Adler and Ziglio (1996) suggested 10 to 15.

For this study, the survey was sent to the 200 researchers with most articles on the subject of RL, via e-mail and Linkedin, obtaining 20 responses.

4. Results: presentation and discussion

4.1 Barriers to implementing RL

Based on the articles included in the SLR, the 61 barriers (Table 4) revealed were grouped in 7 clusters: i)Technology and infrastructure related issues; ii) Governance and supply chain process related issues; iii) Economic related issues; iv) Knowledge related issues; v) Policy related issues; vi) Market and competitors related issues; vii) Management related issues; according to Govindan and Bouzon (2018):

- Technology and infrastructure related issues: including information technology barriers, matters of technical skills and barriers related to the lack of infrastructure to develop RL.
- Governance and supply chain process related issues: referring to barriers in the reverse supply chain, questions of cooperation and performance measurement.
- Economic related issues: including financial and economic barriers related to RL.
- Knowledge related issues: referring to information flows and awareness of RL in firms.
- Policy related issues: including matters about regulations and laws related to returning products and RL.
- Market and competitors related issues: including factors of competitive advantage and questions about recovery markets.
- Management related issues: including issues such as managers' position in relation to RL and the relative importance of RL compared to other activities.

Table 4 presents the barriers discussed in the literature, organised by categories, and the number of times each barrier was mentioned.

Table 4 – Barriers to implementing RL

Category	Barrier	Nº References
Technology and infrastructure related issues	Lack of information systems	21
	Lack of technological infrastructure	16
	Lack of storage and transport facilities	5
	Lack of technology transfers	1
	Complexity of the operation	5
	Capacity limitations	1
	Transport inefficiencies	1
	Lack of support infrastructure	5
	Lack of R&D to recover products	3
	Lack of marketing facilities	2
Governance and supply chain process related issues	Lack of coordination with reverse logistics suppliers	10
	Difficulty with members of the supply chain	6
	Uncertain quality and quantity of returned products	8
	Lack of support from supply chain players	10
	Lack of shared understanding of best practices	6
Economic related issues	Uncertain financial costs	6
	Financial constraints	20
	High costs	14
	High investments and low returns	3
	Lack of short-term economic benefits	2
	Expenses for collecting used products	4
	Uncertainty of economic benefits	3
	Lack of economy of scale	3
	Lack of financial support	3
Knowledge related issues	Lack of knowledge	12
	Lack of training	14
	Lack of corporate social responsibility	5
	Lack of qualified professionals in reverse logistics	8
	Lack of knowledge	9
Policy related issues	Lack of government policy and regulation	23
	Lack of supportive government policies	18
	Gaps in the law	4
	Lack of awareness of environmental legislation	5
	Lack of standards, codes and guidelines	7
	Regulatory restrictions on the use of recovered materials and components	1
	Poor supervision	3
	Change in regulations due to political changes	1
	Legal issues	1
Market and competitors related issues	Low demand	1
	Lack of customer awareness and participation	1
	Low product quality	9
	Informal market	1
	Lack of public focus on environmental issues	6
	Customer perception of a poorer quality product	4
	Lack of community pressure	1
	Lack of secondary markets for recovered materials	9
	Lack of human resources	9
Management related issues	Risk aversion	1
	Resistance to change	9
	Lack of implementation of certifications and environmental management systems	1
	Lack of strategic planning	15
	Limited forecasting and planning	6
	Lack of specific objectives	2
	Low importance of reverse logistics in relation to other issues	9
	Lack of commitment from top management	24
	Lack of performance management system	12
	Risk aversion	11
	Resistance to change	7
	Lack of implementation of certifications and environmental management systems	5
	Lack of strategic planning	1
	Limited forecasting and planning	5

As seen in Table 4, the most frequently mentioned barrier in the literature is the "Lack of commitment from top management" (24 references), followed by the "Lack of government policy and regulation" (23 references), "Lack of information systems" (21 references), "Financial constraints" (20 references), "Lack of supportive government policies" (18 references), "Lack of technological infrastructure" (16 references) and "Lack of strategic planning" (15 references). The least mentioned barriers (1 reference) were "Lack of technology transfers", "Capacity limitations", "Transport inefficiencies", "Regulatory restrictions on the use of recovered materials and components", "Change in regulations due to political changes", "Legal issues", "Low demand", "Lack of customer awareness and participation", "Lack of public focus on environmental issues", "Lack of community pressure", "Risk aversion", "Lack of implementation of certifications and environmental management systems" and "Lack of strategic planning".
We also find that the most frequently mentioned category in the literature is "Management related issues" and the least mentioned one is "Market and competitors related issues".

4.2 Data analysis using the fuzzy Delphi method

To complement this study, an FDM analysis was made of the specialists' opinions obtained through a survey in order to determine the level of consensus. The specialists' responses to the items on the questionnaire were classified on 7-point Likert scales and subsequently transformed into fuzzy sets.
Table 5 presents the FDM results of the category " Technology and infrastructure related issues"

Table 5 - DFM analysis" Technology and infrastructure related issues"

Category	Barriers	Threshold Value, d<0,2	Percentage of Experts Group Consensus, %	Fuzzy Score	Experts Consensus	Nº References	Position
Technology and infrastructure related issues	Lack of information systems	0,17	85%	0,693	Accept	21	15º
	Lack of technological infrastructure	0,22	65%	0,685	Rejected	16	-
	Lack of storage and transport facilities	0,25	75%	0,620	Rejected	5	-
	Lack of technology transfers	0,22	45%	0,588	Rejected	1	-
	Complexity of the operation	0,17	80%	0,723	Accept	5	10º
	Capacity limitations	0,24	45%	0,590	Rejected	1	-
	Transport inefficiencies	0,23	40%	0,583	Rejected	1	-
	Lack of support infrastructure	0,17	85%	0,720	Accept	5	13º
	Lack of R&D to recover products	0,22	50%	0,608	Rejected	3	-
	Lack of marketing facilities	0,28	55%	0,522	Rejected	2	-

As observed, “Lack of information systems” (Table 5) was the most frequently mentioned barrier in the literature and one of the most consensual among the specialists, but it occupied the lowest position in the category. According to Bernon et al., (2011), the lack or incompatibility of information technology systems for effective transfer of information on returning products between those involved acts as an important barrier to RL practices, since the quality of data and partners’ response capacity are jeopardized when returns have to be dealt with manually.

“Complexity of the operation” was the factor with the greatest impact in the group. According to Moktadir et al., the complexity of the RL operational process can create significant difficulties in recycling waste products. In this category, the barrier of “Complexity of the operation” was also validated. It is noted that “Lack of technological infrastructure”, although one of the most mentioned in the literature (e.g. Sirisawat & Kiatcharoenpol, 2019; Bouzon et al., 2018; Waqas et al., 2018; Kaviani et al., 2020), was not validated by the specialists on the subject.

Table 6 presents the FDM analysis of " Governance and supply chain process related issues”, a category where only one barrier was excluded.

Table 6 - FDM analysis " Governance and supply chain process related issues”

Category	Barriers	Threshold Value, d<0,2	Percentage of Experts Group Consensus, %	Fuzzy Score	Experts Consensus	Nº References	Position
Governance and supply chain process related issues	Lack of coordination with reverse logistics suppliers	0,22	60%	0,697	Rejected	10	-
	Difficulty with members of the supply chain	0,17	80%	0,655	Accept	6	18º
	Uncertain quality and quantity of returned products	0,16	80%	0,822	Accept	8	1º
	Lack of support from supply chain players	0,17	80%	0,705	Accept	10	13º
	Lack of shared understanding of best practices	0,16	80%	0,712	Accept	6	11º

Regarding the category of “Governance and supply chain process related issues ” (Table 6), only “Lack of coordination with reverse logistics suppliers” did not achieve consensus among the specialists, despite being one of the most mentioned in the category. It is also noted that all the other barriers in the category had 80% consensus. “Uncertain quality and quantity of returned products” presents the highest fuzzy score in the study, agreeing with the evidence in the studies by Lamba et al. (2020) and Prakash and Barua (2016).

Table 7 presents the result of "Economic related issues", the category with the highest percentage of barriers validated by the specialists.

Table 7 - FDM analysis "Economic related issues"

Category	Barriers	Threshold Value, d<0,2	Percentage of Experts Group Consensus, %	Fuzzy Score	Experts Consensus	Nº References	Position
Economic related issues	Uncertain financial costs	0,17	75%	0,752	Accept	6	5º
	Financial constraints	0,12	100%	0,738	Accept	20	7º
	High costs	0,17	80%	0,767	Accept	14	3º
	High investments and low returns	0,18	75%	0,725	Accept	3	9º
	Lack of short-term economic benefits	0,19	75%	0,635	Accept	2	19º
	Expenses for collecting used products	0,16	80%	0,708	Accept	4	12º
	Uncertainty of economic benefits	0,19	80%	0,778	Accept	3	2º
	Lack of economy of scale	0,14	90%	0,750	Accept	3	6º
	Lack of financial support	0,21	85%	0,742	Rejected	3	-

In this category, "Financial constraints" was most frequently mentioned, and the only barrier in this study with 100% consensus among the specialists answering the survey. In this connection, Tan and Hosie (2010) and Ravi (2014) conclude that financial restrictions are the main barrier to implementing reverse flows.

Analysis of the table shows that six economic barriers occupy the first ten positions in the study. This agrees with various studies (e.g. Govindan & Bouzon, 2018; Bouzon et al., 2016; Kaviani et al., 2020; Mangla et al.,2018; Lamba et al., 2020), but we also observe that in the work by Sirisawat and Kiatcharoenpol, (2018) and Prakash and Barua (2016) economic barriers are not mentioned as having an impact on implementing the chain.

In this category, only the barrier of "Lack of financial support" was not validated. However, this was considered the main obstacle in Chinese technological industry in the study by Lau and Wang (2009).

Table 8 shows the result of the analysis of the specialists' opinion on barriers in the category of "Knowledge related issues".

Table 8 - FDM analysis "Knowledge related issues"

Category	Barriers	Threshold Value, d<0,2	Percentage of Experts Group Consensus, %	Fuzzy Score	Experts Consensus	Nº References	Position
Knowledge related issues	Lack of knowledge	0,18	70%	0,688	Rejected	12	-
	Lack of training	0,19	65%	0,715	Rejected	14	-
	Lack of corporate social responsibility	0,19	80%	0,523	Accept	5	20º
	Lack of qualified professionals in reverse logistics	0,19	80%	0,660	Accept	8	14º
	Lack of awareness of reverse logistics in companies	0,19	65%	0,665	Rejected	9	-

In the category of "Knowledge related issues", we observe that the two least mentioned barriers in the literature, "Lack of corporate social responsibility" and "Lack of qualified professionals in reverse logistics", were validated by the specialists in our study, with 80% consensus. That of "Lack of training", widely mentioned in the literature and validated in the study by Nakiboglu (2019), only achieved 65% consensus among the specialists. Nor was "Lack of knowledge" validated by the group, unlike in the study by Vieira et al. (2020).

Table 9 (Market and competitors related issues) presents the only category where no barrier was validated by the specialists.

Table 9 -FDM analysis "Market and competitors related issues"

Category	Barriers	Threshold Value, d<0,2	Percentage of Experts Group Consensus, %	Fuzzy Score	Experts Consensus	Nº References	Position
Market and competitors related issues	Low demand	0,22	55%	0,572	Rejected	1	-
	Lack of customer awareness and participation	0,18	65%	0,595	Rejected	1	-
	Low product quality	0,21	50%	0,593	Rejected	9	-
	Informal market	0,18	70%	0,502	Rejected	1	-
	Lack of public focus on environmental issues	0,23	50%	0,448	Rejected	6	-
	Customer perception of a poorer quality product	0,23	40%	0,558	Rejected	4	-
	Lack of community pressure	0,23	75%	0,490	Rejected	1	-
	Lack of secondary markets for recovered materials	0,28	25%	0,595	Rejected	9	-
	Lack of human resources	0,20	70%	0,453	Rejected	9	-

Table 9 shows, albeit without consensus, that the barriers of "Lack of customer awareness and participation", "Lack of community pressure" and "Lack of human resources" are not considered obstacles to implementing RL. The evidence agrees with the study by Moktadir et al. (2020), who do not consider market and competition issues as barriers to implementing RL. However, in the study by Nakiboglu (2019), "Low product quality" is considered the main factor hindering the development of reverse flows. In Waqas et al., (2018), the "Lack of community pressure" is considered a major barrier, but only obtained 50% consensus among the specialists in this study.

“Lack of secondary markets for recovered materials” was where there was most disagreement among the specialists, agreeing with the result found by Prakash and Barua (2016), but contradicting that of Montoya et. al (2015) who found this to be the main external barrier.

Table 10 - FDM analysis "Policy related issues”

Category	Barriers	Threshold Value, d<0,2	Percentage of Experts Group Consensus, %	Fuzzy Score	Experts Consensus	Nº References	Position
Policy related issues	Lack of government policy and regulation	0,23	50%	0,533	Rejected	23	-
	Lack of supportive government policies	0,27	60%	0,625	Rejected	18	-
	Gaps in the law	0,23	25%	0,575	Rejected	4	-
	Lack of awareness of environmental legislation	0,20	55%	0,617	Rejected	5	-
	Lack of standards, codes and guidelines	0,16	80%	0,665	Accept	7	16º
	Regulatory restrictions on the use of recovered materials and components	0,23	45%	0,612	Rejected	1	-
	Poor supervision	0,26	55%	0,642	Rejected	3	-
	Change in regulations due to political changes	0,18	85%	0,503	Accept	1	21º
	Legal issues	0,15	75%	0,732	Accept	5	8º

Table 10 presents the results of applying the FDM to the category of “Policy related issues.

As seen in Table 10, the specialists validated the barriers of “Lack of standards, codes and guidelines”, “Legal issues” and “Change in regulations due to political changes”, although the barrier about changes in regulations was only mentioned in the study by Waqas et al.(2020).

The most frequently mentioned barrier, “Lack of government policy and regulation”, achieved only 50% consensus. In addition, that of “Gaps in the law” had only 25% consensus, being the barrier where there was least agreement among the specialists. The evidence here agrees with the results of Ambekar et al. (2022), Lamba et al., (2020) and Prakash and Barua (2016), where policy issues have little representation in the barriers to implementing RL, and within the category “Legal issues” are the main barrier. Also in the study by Nakiboglu (2019), “Legal issues” are found to be a major barrier to developing reverse flows.

Table 11 shows the result of “Management related issues” barriers, the category with the greatest number of obstacles but only two being validated by the specialists.

Table 11 - FDM analysis "Management related issues”

Category	Barriers	Threshold Value, d<0,2	Percentage of Experts Group Consensus, %	Fuzzy Score	Experts Consensus	Nº References	Position
Management related issues	Risk aversion	0,29	60%	0,458	Rejected	1	-
	Resistance to change	0,26	70%	0,515	Rejected	9	-
	Lack of implementation of certifications and environmental management systems	0,17	85%	0,498	Rejected	1	-
	Lack of strategic planning	0,30	30%	0,585	Rejected	15	-
	Limited forecasting and planning	0,27	45%	0,590	Rejected	6	-
	Lack of specific objectives	0,25	40%	0,567	Rejected	2	-
	Low importance of reverse logistics in relation to other issues	0,19	70%	0,703	Rejected	9	-
	Lack of commitment from top management	0,21	85%	0,742	Rejected	24	-
	Lack of performance management system	0,23	65%	0,653	Rejected	12	-
	Company policies	0,22	75%	0,647	Rejected	11	-
	Rigid structure	0,25	65%	0,635	Rejected	7	-
	Lack of recognition of competitive advantage	0,29	60%	0,547	Rejected	5	-
	Lack of investment in reverse logistics	0,17	85%	0,763	Accept	1	4º
	Lack of adequate organisational structure and support for Reverse Logistics practices	0,18	80%	0,700	Accept	5	14º

In the “Management related issues” category (Table 11), the specialists validated the barriers of “Lack of investment in reverse logistics” and “Lack of adequate organisational structure and support for Reverse Logistics practices”. It is noted that the most frequently mentioned barrier in the literature and the one that was the main factor in the studies by Thiyagarajan and Ali (2016) and González-Torre et al. (2010), “Lack of commitment from top management”, did not achieve consensus among the specialists participating in this study. That of “Lack of implementation of certifications and environmental management systems” achieved consensus, but the specialists considered it had little impact on implementing a logistics network. These results corroborate the study by Prakash and Barua (2015), except for the barrier of “Lack of commitment from top management” which the authors consider a central barrier to developing reverse flows.

This study also contradicts the results of Ravi (2014), who mentions the lack of metrics to assess performance as one of the main barriers to implementing RL.

5. Final considerations, limitations and future research

RL has gained prominence worldwide, stimulated by the increase in the price of material, the shortage of resources, growing general conscientiousness and the impacts of climate change. Proactive companies in the manufacturing sector have adopted RL practices such as recycling, reuse and comprehensive waste management strategies. These initiatives are developed not only to gain competitive advantage but also to respond to demanding local and international environmental conservation needs. However, there are several obstacles to the implementation of these practices, making it crucial to identify and classify the barriers that impede effective implementation.

The barriers that have hindered the implementation of RLs present significant challenges for both managers and policy makers.

This study makes significant contributions to implementing RL in companies everywhere, since it includes barriers in a global context. It can help managers in industry to implement RL effectively, to develop strategies to overcome the barriers considering the classification of priorities, and support decision-makers to optimize the use of resources in the process of implementing RL.

The SLR identified 61 barriers that were divided into the following categories: i) Technology and infrastructure related issues; ii) Governance and supply chain process related issues; iii) Economic related issues; iv) Knowledge related issues; v) Policy related issues; vi) Market and competitors related issues; vii) Management related issue. The barriers most frequently mentioned in the literature were: “Lack of commitment from top management” and “Lack of government policy and regulation”, but the specialists participating in this study did not agree on their impact on implementing a RL network.

The study revealed that the most relevant barrier for RL is the “Uncertain quality and quantity of returned products” and that “Economics related issues” are the main obstacles to developing RL, above all the “Uncertainty of economic benefits” and “High costs”.

The research also found that the specialists do not agree with the impact of the barriers associated with “Market and competitors related issues”.

Similar to others in this area, this study has some limitations that should be considered. Despite analysing the barriers, no indications of how to overcome them were presented here. Therefore, we propose future directions for research, suggesting that subsequent studies should cover a variety of sectors and industries. Also highlighted is the possibility of examining the list of barriers with different MCDM tools, incorporating not only the organisational perspective, but also other relevant stakeholders’ points of view, such as customers or investors.

In this study, the barriers were validated exclusively by specialists in theory, which suggests including a validation group made up of professionals in companies, to give a consolidated practical perspective.

The list of 61 barriers selected can be subject to evaluation using an MCDM tool adopting a cause-effect approach. Such an analysis would identify the barriers with the greatest impact when implementing RL.

Considering managers' situation, it is essential to explore new options and opportunities in order to improve the best management practices for RL. From this practical viewpoint, it is relevant to consider the most critical barriers to RL that can be controlled and managed by companies.

Future research can also study how economic barriers influence the implementation of RL, since the literature contains studies with diverging results in this area. Such an analysis would contribute to broader, more contextualized understanding of the challenges faced when implementing RL initiatives.

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Chapter 4

Modelling the barriers to reverse logistics: A combined ISM and MICMAC analysis approach[3]

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Abstract

The aim of this article is to analyse the interaction between the barriers that difficult or prevent the implementation of RL in Small and medium-sized enterprises (SMEs). First, a literature review identified 22 barriers to developing Reverse Logistics (RL) in SMEs. Then, through experts opinions gathered in Focus Group (FG), an Interpretive Structural Modeling (ISM) model was used to understand the hierarchy relations between barriers, and a "Matrices d'Impacts cross-multiplication appliqúe a classmate" (MICMAC) analysis was carried out to aggregate the barriers in four categories according to their influencing power and dependence. Applying the methodology to the Portugal case resulted in an ISM model with seven hierarchical levels and a MICMAC diagram without dependent barriers. Moreover, six key barriers emerged, namely: Lack of adequate organizational structure and support for RL practices, Lack of corporate social responsibility, Complexity of the operation, Lack of shared understanding of best practices, Difficulty with members of the supply chain, and Lack of support from supply chain players.

Keywords: Reverse Logistics; Barriers; ISM; MICMAC; SME´s

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1. Introduction

Due to the growing demand for ecological products and the pressure exerted by customers and other stakeholders throughout the supply chain, emphasizing environmental awareness and sustainable management, many companies have come to recognize the importance of applying sustainable supply chain management concepts in their activities (Sirisawat & Kiatcharoenpol, 2018).

In response to market demands, a new logistics paradigm has emerged, focusing on the reuse, reconditioning and recycling of products, called Reverse Logistics (RL). While conventional logistics focuses on moving products from their origin to their points of consumption, RL introduces a paradigm shift by promoting reverse flows. This allows products to be returned for reuse, reconditioning, recycling or landfill, thus contributing to a more sustainable and circular economy(Calmon et al., 2021). The concept has gained prominence and has influenced all levels of supply chain operations in various industry sectors. Efficient RL strategies can increase revenues while significantly reducing costs (Sari et al., 2018).

However, despite the recognition of the advantages of these reverse flows, the implementation of RL is challenging due to several barriers. Although many efforts have been made to explore these barriers, research is still minimal.(Bouzon et al., 2015).

It is fundamentally important to analyze the interaction between these key barriers that difficult or prevent the application of RL (Waqas et al., 2018).

It is because these barriers inevitably interact with each other, and a particular barrier could be mitigated by removing other barriers that affect it (Xu and Zou, 2020). In addition, the interrelationships among barriers could influence the importance of each barrier because a particular barrier may become an important threat to the ISM through its interaction with other barriers, although this barrier cannot directly have a significant impact (Shen et al., 2016). However, few studies explored the interaction of these barriers, and their integrative effects

Some barriers influence others, so monitoring the system that can determine these key barriers and understanding how their influence spreads and impacts RL is essential. Identifying the key barriers and modelling how they affect others can support the design of appropriate decision-making to overcome those barriers and restrictions (Sari et al., 2018).

Aiming to understand the relations among the barriers hindering the implementation of RL, Interpretive Structural Modelling (ISM) can be a supporting tool to consider. It can identify and summarise relations between specific variables defining a problem or issue (Mandal & Deshmukh, 1993). ISM and Matrix Cross Impact Matrix Multiplication

(MICMAC) has been adopted in similar studies on adopting innovative technologies and practices. The literature review shows that ISM has been carefully used by researchers in various areas such as construction (Ribeiro et al., 2022a), RL suppliers (Govindan et al., 2012), the health system (Santosh & Roopali, 2018), the supply chain (Mor et al., 2018), entrepreneurship (Tripathi & Singh, 2018), education (Kinker et al., 2021), e-commerce (Rana et al., 2019), the lean system (Abu-Salim et al., 2023), six sigma (Kumar et al., 2016), and agriculture (Kumar et al., 2021).

However, few studies explored the interaction of these barriers, and their integrative effects (Wu et al., 2022).

The main objective of this article is to identify and analyse the key obstacles to the implementation of RL in SMEs. This study represents a new contribution to the literature, as the combined ISM-MICMAC analysis approach is not normally used to identify the barriers to RL implementation in SMEs, although the ISM-MICMAC approach has previously been used successfully to analyse the adoption of RL in large industries (Ravi & Shankar, 2005; Ravi & Shankar, 2017;M. Bouzon et al., 2015). This research focuses on the Portuguese context and offers a new insight by identifying the barriers to RL implementation in SMEs through a combined ISM-MICMAC approach, supported by focus groups.

Thus, this study aims to contribute by identifying barriers that can assist decision-makers in making informed decisions to mitigate the obstacles to the implementation of RL in SMEs.

The article is structured in six distinct parts. The first presents a general view of RL. The second reviews the literature, addressing the fundaments of RL and the methodology adopted in the research. The methodology is presented in great detail in the third part, being divided into three stages: a review of the literature referring to the barriers to implementation of RL; application of the ISM model; and the MICMAC analysis. The last part contains the conclusions, addresses the study's limitations and suggests future research paths.

2. Literature Review

2.1. Reverse Logistics

Companies have turned their attention to RL, using it as a strategic tool to satisfy customer needs and stimulate profit. An efficient reverse distribution structure can create significant return on investment and lead to a considerable increase in market competitiveness (Sharma et al., 2012). Due to economic development and growing competition in the market, companies are more motivated to find modern solutions to improve their commercial activity, and RL can be the path to higher performance.

RL consists of a number of operations to manage products returned by customers to suppliers, generally for recycling, repair, elimination or reuse, and always at the lowest possible cost (Starostka-Patyk et al., 2013).
Therefore, RL is recognized as a fundamental aspect of environmental protection, having been adopted by international companies as part of a strategy to improve economic and environmental performance (Qing & Yanyun, 2008).
According to El Boudali et al. (2022), RL management is a fundamental aspect of supply chain management, reducing costs and generating value for the firm. Appropriate RL implementation helps develop an ecological supply chain, increase customer satisfaction and gain a competitive advantage (Bajar et al., 2022).
As a central topic in academic debate in environmental performance and business sustainability, it has been recognized in various studies as an effective strategy for companies, the environment and sustainable development. RL is fundamental due to several factors, such as mitigating environmental problems, cost control and competitive advantage. However, despite its importance, the area of RL is not yet sufficiently explored and several questions remain to be studied (Sharma et al., 2021).
In spite of the progress made in recent years, RL is still a challenge for many developed countries, especially for developing ones (Laribi & Dhouib, 2015). Companies face several complications and challenges when carrying out RL activities due to the various barriers that hinder the process (Prajapati et al., 2019).

2.2. ISM and MICMAC

ISM is a computational method to develop graphic representations of the composition and structure of systems. It originated in the belief of Warfield (1974) about the need to establish a relation between science and politics. The author recognized the importance of communication tools that were scientifically robust and accessible to the general public. An advantage of this methodology is that it describes the order and direction of relations between a system's elements (Raci & Shankar, 2005).
The ISM model has been used by researchers in the last decade to analyze barriers. This methodology is widely used in ecological supply change management strategies to develop and analyze the variables hindering more sustainable supply chains (Mathiyazhagan & Haq, 2013).
The ISM approach is a technique that helps to understand and simplify complex problems. The model is particularly useful for interpreting rooted variables and transforming unclear models into visible, well-defined ones.
Kumar et al. (2018) state that ISM is a simplified way of solving complex problems by guiding the interpretation of deeply rooted objectives. The authors also mention that

the approach leads to a clearer and more structured analysis of problems, facilitating the identification of their interrelationships and providing a more comprehensive view. Furthermore, Jha et al. (2018) state that ISM helps in understanding the system, making it more tangible, facilitating the decision-making process and the implementation of effective solutions. However, for a deeper understanding of the barriers, the combination of ISM with the analysis of the Multiplication Cross Impact Matrix Applied to a Classification (MICMAC) is essential. The combination of MICMAC and ISM provides a holistic approach to the analysis of complex problems and, thus, a deeper understanding of the relationships between the variables involved and facilitating decision-making(Patel et al., 2021).

MICMAC analysis is based on the principle of matrix multiplication properties, and one of the main objectives of this analysis is to examine and categorize the variables of interest in terms of driving power and dependence power, classifying all variables into four specific groups(Agrawal, 2019).

The final hierarchical ISM model, associated with MICMAC analysis, considerably improves the understanding of the variables and increases methodological rigor(Ahmad & Qahmash, 2021; Bianco et al., 2023).

2.3. Justification of the methodology proposed for RL development

During constant economic development and increasing market competition, enterprises are compelled to seek modern solutions to enhance their business activities, with RL potentially providing an answer to these aspirations for improved performance. However, the decision to implement RL processes within a company is not an easy one. Such investments can encounter numerous barriers and obstacles that are difficult to overcome, effectively hindering the successful implementation of RL (Starostka-Patyk et al., 2013).

In this context, Laribi & Dhouib (2015) identified the barriers that prevente or complicate the implementation of RL in companies using multivariate descriptive and inferential statistics. Abdulrahman et al. (2014) proposed a theoretical model to empirically identify significant barriers to RL concerning management, finance, policies, and infrastructure in manufacturing industries.

Lamba et al., (2020) employed an analytic hierarchy process-based methodology to identify lack of investment in RL, lack of knowledge of best practices, and uncertainty regarding returns and demand as the three main obstacles to RL.

Sirisawat & Kiatcharoenpol, (2018) used a methodology based on the fuzzy analytic hierarchy process and the fuzzy technique for order preference by similarity to an ideal solution to classify the barriers.

Bouzon et al., (2018) used a Multi-Criteria Decision Making tool named grey-based Decision Making Trial and Evaluation Laboratory to extract perspectives from multiple company-customer-government associations on the barriers to implementing RL.

Over the years, many efforts have been made to explore these barriers, but investigations remain minimal. Quantitative research based on participants opinions, revealing the importance of each barrier, is still lacking (Xu & Zou, 2020). Furthermore, the interrelationships between obstacles systematically affect the importance of each one in implementing RL. It is crucial to classify them according to their dependency and driving powers. While previous studies have explored these barriers, few have analyzed their complex interrelationships (Shen et al., 2016; Sun et al., 2022)

Some variables, which in this study are referred to as barriers, affect the implementation of RL practices, so analysing the direct and indirect relationships between them can give a holistic view of the situation, rather than just considering the individual variable in isolation.

The effectiveness of the ISM model lies in its capacity to portray the structure of a complex problem using a carefully conceived standard combining graphs and words (Sharma et al., 2012).

The basic idea of ISM is to break down a complicated system into various sub-systems, using specialists' practical experience and knowledge to construct a multi-level structural model.

ISM can be used to identify and analyze the relations between specific variables defining a problem or issue (Warfield, 1974). Mishra et al., (2023) applied ISM methodology to identify and model the obstacles to the internationalization of SME´s in the automobile sector, in the context of emerging markets. Talib and Rahman (2017) used the methodology to identify the potential obstacles to telecommunication services and to develop relations between them. Dube and Gawande (2016) developed the model to identify the contextual relation between ecological supply chain management obstacles. Orji (2019) used the modelling technique to examine the barriers to organizational change towards sustainability and the factors supporting sustainable performance. Sarkar et al. (2021) used ISM to build a structured model of the factors leading to the adoption of green businesses in emerging economies.

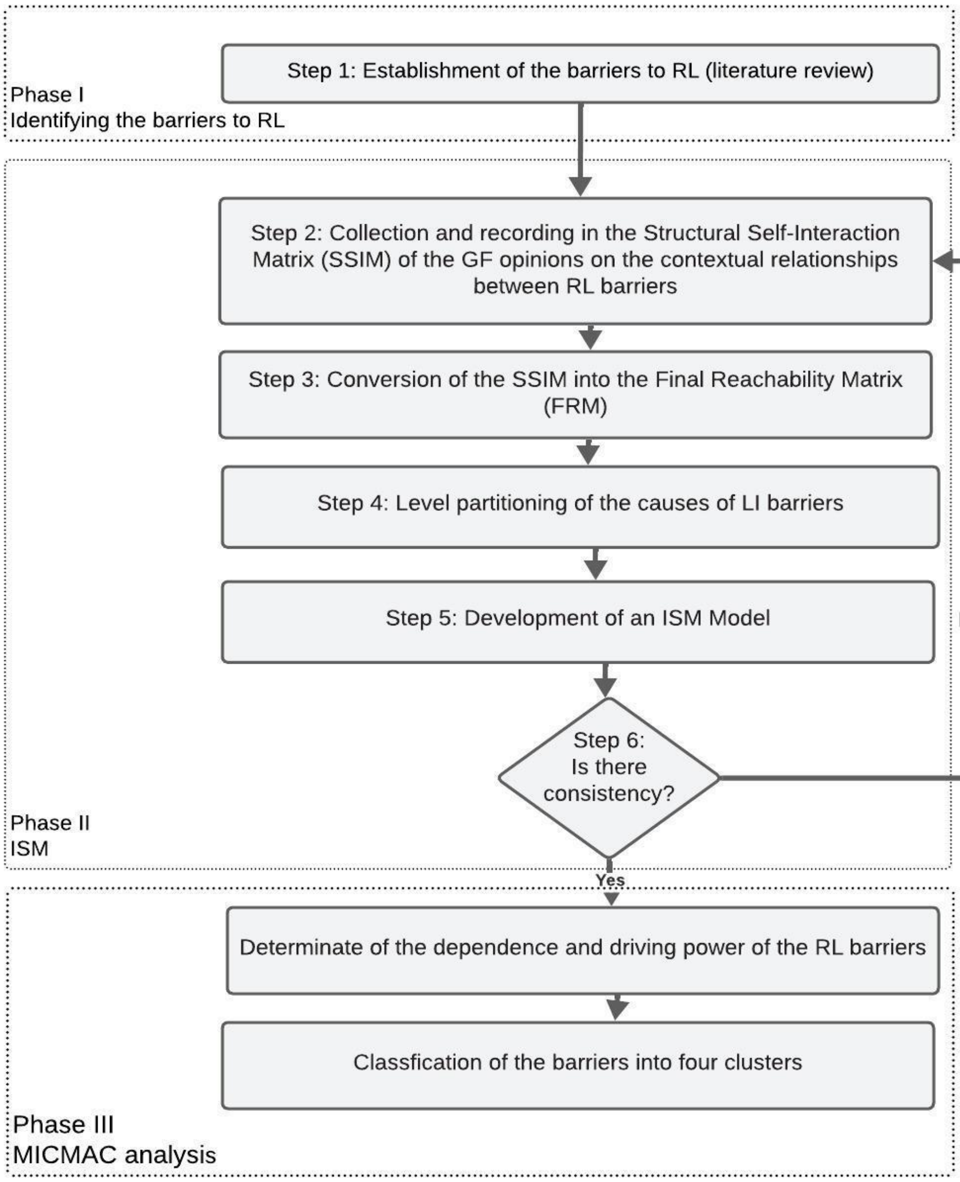

Figure 1- Research Methodology

Therefore, this research intends to apply the ISM methodology to understand the reciprocal influences among the barriers hindering or preventing RL implementation in SME´s, identify the stimulating barriers that can aggravate others, and the dependent barriers that are most affected by the stimulating barriers.

3. Methodology

This research's methodological approach consists of three phases, as presented in Figure 1: I - Determining the critical barriers, II-ISM, III - MICMAC analysis.

The FG technique was fundamental to the operationalisation of stages II and VI of this study's methodology.

FG has a fundamental role in ISM, since the whole process and the result depend on its contribution. According to Morgan (1996), the FG is a research method of an exploratory nature that gathers qualitative data from the group's interaction in relation to a topic presented by the moderator. The group should represent all those involved in the scope of the problem, with special attention being paid to size, specialization and diversity. They should have solid experience in the area and specialized knowledge of the variables studied (Ahmad & Qahmash, 2021).

The FG stimulates discussion among specialists about their perceptions, opinions, attitudes and beliefs with regard to a product, service, theory or concept, extending and improving the existing information about a topic and creating new perceptions (Marshall & Gretchen, 2015).

According to Kitzinger (1995), FG should be formed of 4 to 12 participants.Therefore, the FG that built the SSIM (Structural Self-Interaction Matrix) for this study was made up of 8 experts with knowledge of RL and more than 5 years' experience.In the meeting, held using the Zoom video-conferencing application, the barriers to implementing RL were presented and explained, and the ISM-MICMAC logic was addressed.

The meeting was moderated by one of the researchers to ensure a clear understanding of the obstacles to implementing RL, stimulate debate, and ensure that the discussion transitioned from general to specific topics to promote sincerity and reduce biases (Larson et al., 2004).

The study used the principle of “majority rules” (Shen et al., 2016) when the specialists had diverging opinions.The meeting, held using the Zoom video-conferencing application, presented and explained the barriers to implementing RL and addressed the ISM-MICMAC logic.

3.1. Phase I – Identifying the barriers to RL

Step 1—Identification of the barriers

This study uses the barriers validated previously by Soares et al. (2024)(Table1). In that study, the literature review focused on the Scopus and Web of Science databases, using the terms of 'Reverse Logistics' and 'Barriers', analyzing 330 scientific articles published in international journals. That process identified 61 barriers that were subsequently grouped in seven categories. Then, the Fuzzy Delphi Method was used to obtain a critical list of barriers, with the collaboration of 20 specialists in the area. Of the 61 barriers identified, the specialists validated 22.

The study by Soares et al. (2024)serves as the basis for Phase I, wherein 22 barriers to the implementation of RL were identified and, subsequently, the authors determined both the fuzzy score and priority level associated with each of these barriers.

Table 1 – Barriers to implementation of RL

Code	Barriers	Concepts	Rank
		Category: Technology and infrastructure-related issues	
B1	Lack of information systems	The lack or incompatibility of information technology systems for effective transfer of information about product returns between those involved represents an important barrier to RL practices, since the data quality and partners' response capacity are jeopardized when returns have to be dealt with manually.	16
B2	Complexity of the operation	The complexity of the RL operational process can create significant difficulties in recycling waste	10
B3	Lack of support infrastructure	RL frequently faces problems with infrastructure, such as storage, collection, recycling facilities and selecting the most suitable form of transport	11
		Category: Governance and supply chain process related issues	
B4	Difficulty with members of the supply chain	An important obstacle to RL is the reluctant support from traders, distributors and retailers for activities.	19
B5	Uncertain quality and quantity of returned products	Companies cannot control the quality and quantity of returned products from the point of consumption. Product quality is not standard in RL compared to direct logistics	1
B6	Lack of support from supply chain players	Most RL processes are carried out by external logistics companies and the lack of coordination with these can have costs for the firm	14
B7	Lack of shared understanding of best practices	Many organizations do not yet follow the best practices adopted by their competitors and by developed countries.	12
		Category: Economic-related issues	
B8	Uncertain financial costs	Due to the uncertain quality of returned products, it is difficult to calculate the cost of operations.	5
B9	Financial constraints	Insufficiency or difficulty in attracting financial resources leads to postponing the implementation of RL practices.	8
B10	High costs	Organizations have a false perception that the costs of RL are higher than the costs related to eliminating waste.	3
B11	High investments and low returns	Organizations perceive RL as an operation involving high investment, but with little financial return.	9
B12	Lack of short-term economic benefits	Companies have the perception that the economic benefits of RL are only achieved in the long term.	20
B13	Expenses for collecting used products	For correct separation and segregation of the waste produced, it is necessary to use specific techniques for subsequent reuse or recycling of material, implying a greater effort.	13
B14	Uncertainty of economic benefits	The benefit of RL is uncertain for companies.	2
B15	Lack of economy of scale	A consumer-oriented market and competition from new products raise the question of price sensitivity. Consequently, the margin on returned products is very low, which leads to RL being unattractive.	6
		Category: Knowledge-related issues	
B16	Lack of corporate social responsibility	Business ethics implies that it is a company's responsibility to proceed in an approved way, and that it should necessarily reflect on the implications of its behaviour for the population.	21
B17	Lack of qualified professionals in RL	The lack of training and education is a major challenge for RL. These are the main requirements to achieve success.	18
		Category: Policy-related issues	
B18	Lack of standards, codes and guidelines	Companies say that the lack of a practical guide is a barrier to implementing RL.	17
B19	Change in regulations due to political changes	Changing political orientations are an obstacle to implementing an RL network	22
B20	Legal issues	Legal issues are an obstacle to developing reverse operations.	7
		Category: Management-related issues	
B21	Lack of investment in RL	The lack of investment in RL prevents the development of reverse flows	4
B22	Lack of adequate organizational structure and support for RL practices	The lack of basic conditions and functions in the organizational structure delimits practices in adopting RL.	15

3.2. Phase II – ISM

In the present study, ISM was employed to identify and evaluate the interactions between critical barriers to the implementation of RL. This approach allowed for a graphical and hierarchical representation of the connections between these barriers and facilitated the identification of the main barriers that need to be mitigated.

Step 2—Contextual relationships between the critical barriers

The 22 critical barriers to RL generated 22 × 21/2 = 231 different inter-relations. The FG specialists were asked to express the contextual inter-relations between a pair of barriers (Bi and Bj), obtaining four different types:

- V: Bi helps to achieve or influences Bj;
- A: Bj helps to achieve or influences Bi;
- X: Bi helps to achieve or influences Bj and vice-versa;
- O: There is no inter-relation between Bi and Bj.

The SSIM elaborated by the 8 specialists is presented in Table 2. As mentioned, the study used the principle of "majority rules" when the specialists had diverging opinions.

Table 2 - Structural self-intersection matrix

Bi[1]↓,Bj[2] →	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
1		O	O	O	O	O	O	A	O	O	O	O	O	V	O	O	O	O	O	O	A	A
2			O	V	O	V	O	O	O	V	V	O	O	O	O	O	O	O	O	O	O	O
3				O	O	O	O	A	A	A	O	O	A	A	O	O	O	O	O	O	A	A
4					O	X	X	V	O	O	O	V	O	V	O	A	O	O	O	O	O	A
5						O	O	V	O	O	O	V	O	V	O	O	O	O	O	O	V	O
6							X	V	O	V	O	V	O	V	O	A	O	O	O	O	O	A
7								V	O	O	O	V	O	V	O	A	O	O	O	O	O	A
8									V	O	O	O	O	V	O	O	O	O	O	O	V	O
9										A	A	A	A	A	O	O	O	O	O	O	V	O
10											X	V	O	O	O	O	O	O	O	O	V	O
11												V	O	V	O	O	O	O	O	O	V	O
12													A	X	O	O	O	O	O	O	V	O
13														V	O	O	O	O	O	O	O	O
14															O	O	O	O	O	O	V	O
15																O	O	O	O	O	O	O
16																	O	O	O	O	O	A
17																		A	O	O	A	A
18																			A	A	A	A
19																				V	V	O
20																					V	O
21																						A

[1] Bi—barrier in line i; [2] Bj—barrier in column j

Step 3—Converting the SSIM into the Final Reachability Matrix

Initially, the SSIM was transformed into the initial reachability matrix (IRM), a binarymatrix representing the direct relationships between the barriers, which was accomplishedby replacing the letters with 1 s and 0 s. If the (i,j) entry in the SSIM is:

- If the (i, j) entry is V in SSIM, (w, z) entry in the IRM becomes 1 and the (i, j) entry becomes 0.
- If the (i, j) entry is A in SSIM, (w, z) entry in the IRM becomes 0 and the (i, j) entry becomes 1.
- If the (i, j) entry is X in SSIM, (w, z) entry in the IRM becomes 1 and the (i, j) entry becomes 1.
- If the (i, j) entry is O in SSIM, (w, z) entry in the IRM becomes 0 and the (i, j) entry becomes 0.

$$IRM\_I \neq IRM\_I^{2} \neq \ldots \neq IRM\_I^{n-1} \neq IRM\_I^{n} = IRM\_I^{n+1} = FRM$$

Then, the IRM was checked for transitivity, giving way to the FRM. If barrier iinfluences barrier j and barrier j influences barrier k, then barrier i indirectly influences k through barrier j, and if the entry (i,k) in the IRM is 0, then it must be changed to a 1*. Before calculating the FRM, the matrix IRM_I was obtained by adding the IRM to identity matrix I. The FRM was then obtained through the Boolean operation, which involvedself-multiplication of IRM_I until it reached a stable state, as indicated in Equation(Ribeiro et al., 2022b):

Step 4—Level partitioning of the barriers

After completing the reachability matrix, the barriers are divided into levels. To establish the relevance of each barrier, they are divided into various levels, and three sets are created to divide the barriers efficiently. These are the sets of intersection, reachability and antecedents. The set of reachability includes the barrier in question and all the barriers that depend on it. The antecedent set includes the barrier and all those that affect or influence it. Finally, the intersection set combines the accessibility and antecedent sets, representing the barriers that depend on and affect the original variable. In the ISM hierarchy, barriers with the same accessibility and intersection are designated as Level I or higher-level barriers. The process of determining the remaining levels is iterative, with variables at the previous level being eliminated until all have been assigned to a level. Level I barriers are at the top of the ISM hierarchy and do not influence the others. At higher levels, barriers are at the bottom of the ISM hierarchy and have greater influence on the other variables (Ahmad & Qahmash, 2021; Pedrosa et al., 2023).

Step 5—Development of the ISM model

The ISM model was constructed by creating a diagram based on the FRM and the hierarchical level of each barrier. First, the conical matrix of the FRM was built, grouping barriers of the same hierarchical level in the rows and columns of the matrix to facilitate the creation of the ISM model. Second, a preliminary diagram was developed by placing the barriers vertically according to their level partitioning and connecting the barriers with arrows as per the conical matrix. Third, indirect links between the barriers were eliminated to obtain the ISM model.

Step 6—Consistency check

Finally, the GF experts were asked to verify the conceptual consistency of the hierarchical structure and the interrelations of barriers to the implementation of RL in the obtained ISM model. The experts were instructed to check for any ambiguities in the ISM model and to ensure that it accurately represented their mental model of the system of barriers affecting the implementation of RL.

3.3. Phase III – MICMAC

For a more thorough analysis of the main barriers to implementing RL, as defined in phase III of the methodology, we perform a MICMAC analysis, exploring these barriers' power of influence and dependence.

The MICMAC analysis was developed by Duperrin and Godet (1973) based on the matrices' multiplication properties. MICMAC is a technique to classify variables. The variables are mapped on a two-dimensional grid based on their values of dependence and stimulating strength, represented on the horizontal and vertical axes respectively. The interval of these values varies between 1 and the total number of variables, and the axis are bifurcated at the mid-points, resulting in four quadrants. These quadrants classify the variables in autonomous, dependent, connecting and independent categories. The autonomous variables are not linked to the rest of the system of variables, whereas the linking variables are sensitive and are strongly connected to the independent and dependent variables.

4. Results

4.1. Phase II: ISM

The ISM model was developed by following steps 3 to 6 of phase II of the methodology (Figure 1). In step 2, the SSIM was initially converted into the IRM (Table 3). Next, in step 3, the IRM was checked for transitivity, resulting in the FRM (Table 4) with the help of a VBA program in Microsoft Excel. The driving power and dependence of each barrier were also determined, with the former representing the sum of the respective row and the latter the sum of the respective column in the FRM.

Table 3 – Initial Reachability Matrix

Bi[1]↓,Bj[2]→	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
2	0	1	0	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	1	0	1	1	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0
5	0	0	0	0	1	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	1	0
6	0	0	0	1	0	1	1	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0
7	0	0	0	1	0	1	1	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	1	0
9	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
10	0	0	1	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	1	0
11	0	0	1	0	0	0	0	0	1	1	1	1	0	1	0	0	0	0	0	0	1	0
12	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	1	0
13	0	0	0	0	0	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0
14	0	0	1	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	1	0
15	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
16	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0
21	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0
22	1	0	1	1	0	1	1	0	0	0	0	0	0	0	0	1	0	1	0	0	1	1

[1] Bi—barrier in line i; [2] Bj—barrier in column j.

Table 4 - Final Reachability Matrix

Bi[1]↓,Bj[2]→	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**DVP[4]**
1	1	0	1*	0	0	0	0	0	1*	0	0	1*	0	1	0	0	1*	1*	0	0	1*	0	8
2	1*	1	1*	1	0	1	1*	1*	1*	1	1	1*	0	1*	0	0	1*	1*	0	0	1*	0	15
3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

4	1*	0	1*	1	0	1	1	1	1*	1*	1*	1	0	1	0	0	1*	1*	0	0	1*	0	14
5	1*	0	1*	0	1	0	0	1	1*	0	0	1	0	1	0	0	1*	1*	0	0	1	0	10
6	1*	0	1*	1	0	1	1	1	1*	1	1*	1	0	1	0	0	1*	1*	0	0	1*	0	14
7	1*	0	1*	1	0	1	1	1	1*	1*	1*	1	0	1	0	0	1*	1*	0	0	1*	0	14
8	1*	0	1*	0	0	0	0	1	1	0	0	1*	0	1	0	0	1*	1*	0	0	1	0	9
9	1	0	1	0	0	0	0	0	1	0	0	1*	0	1*	0	0	1*	1*	0	0	1	0	8
10	1*	0	1	0	0	0	0	0	1	1	1	1	0	1*	0	0	1*	1*	0	0	1	0	10
11	1*	0	1	0	0	0	0	0	1	1	1	1	0	1	0	0	1*	1*	0	0	1	0	10
12	1*	0	1*	0	0	0	0	0	1	0	0	1	0	1	0	0	1*	1*	0	0	1	0	8
13	1*	0	1*	0	0	0	0	0	1	0	0	1	1	1	0	0	1*	1*	0	0	1*	0	9
14	1*	0	1	0	0	0	0	0	1	0	0	1	0	1	0	0	1*	1*	0	0	1	0	8
15	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2
16	1*	0	1*	1	0	1	1	1*	1*	1*	1*	1*	0	1*	0	1	1*	1*	0	0	1*	0	15
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	2
19	1*	0	1*	0	0	0	0	0	1*	0	0	1*	0	1*	0	0	1*	1	1	1	1	0	10
20	1*	0	1*	0	0	0	0	0	1*	0	0	1*	0	1*	0	0	1*	1	0	1	1	0	9
21	1	0	1	0	0	0	0	0	1*	0	0	1*	0	1*	0	0	1	1	0	0	1	0	8
22	1	0	1	1	0	1	1	1*	1*	1*	1*	1*	0	1*	0	1	1*	1	0	0	1	1	16
DPP[3]	18	1	20	6	1	6	6	8	18	8	8	18	1	18	1	2	20	19	1	2	18	1	

[1] Bi—barrier in line i; [2] Bj—barrier in column j.

In stage 3, the process of partitioning the levels of barriers to implementing IL resulted in seven iterations and the corresponding seven hierarchical levels, as shown in Table 5.

Table 5 - Level partitioning

Barrier	Reachability Set	Antecedent Set	Intersection Set	Level
3	B3	B:1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,19,20,21,22	B3	I
17	B17	B:1,2,4,5,6,7,8,9,10,11,12,13,14,16,17,18,19,20,21,22	B17	I
15	B15	B15	B15	II
18	B18	B:1,2,4,5,6,7,8,9,10,11,12,13,14,16,18,19,20,21,22	B18	II
1	B:1,9,12,14,21	B:1,2,4,5,6,7,8,9,10,11,12,13,14,16,19,20,21,22	B:1,9,12,14,21	III
9	B:1,9,12,14,21	B:1,2,4,5,6,7,8,9,10,11,12,13,14,16,19,20,21,22	B:1,9,12,14,21	III
12	B:1,9,12,14,21	B:1,2,4,5,6,7,8,9,10,11,12,13,14,16,19,20,21,22	B:1,9,12,14,21	III
14	B:1,9,12,14,21	B:1,2,4,5,6,7,8,9,10,11,12,13,14,16,19,20,21,22	B:1,9,12,14,21	III
21	B:1, 9, 12, 14, 21	B:1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16, 19, 20, 21, 22	B:1, 9, 12, 14, 21	III
8	B8	B.2, 4, 5, 6, 7, 8, 16, 22	B8	IV
10	B:10, 11	B:2, 4, 6, 7, 10, 11, 16, 22	B:10, 11	IV
11	B:10, 11	B:2, 4, 6, 7, 10, 11, 16, 22	B:10, 11	IV
13	B13	B13	B13	IV
20	B20	B:19, 20	B20	IV
4	B:4, 6, 7	B:2, 4, 6, 7, 16, 22	B:4, 6, 7	V
5	B5	B5	B5	V
6	B:4, 6, 7	B:2, B, 6, 7, 16, 22	B:4, 6, 7	V
7	B:4,6,7	B:2, 4, 6, 7, 16, 22	B:4, 6, 7	V
19	B19	B19	B19	V

2	B2	B2	B2	VI
16	B16	B:16,22	B16	VI
22	B22	B22	B22	VII

In stage 5, the ISM model was established using the conical matrix of the FRM and is presented in Figure 2. Finally, in stage 6, this model was discussed in the GF, where experts were asked to verify any potential inconsistencies. The experts agreed on the consistency of the ISM model. Thus, the model was deemed appropriate, highlighting both the hierarchical structure and the interrelationships of the barriers to implementing RL.

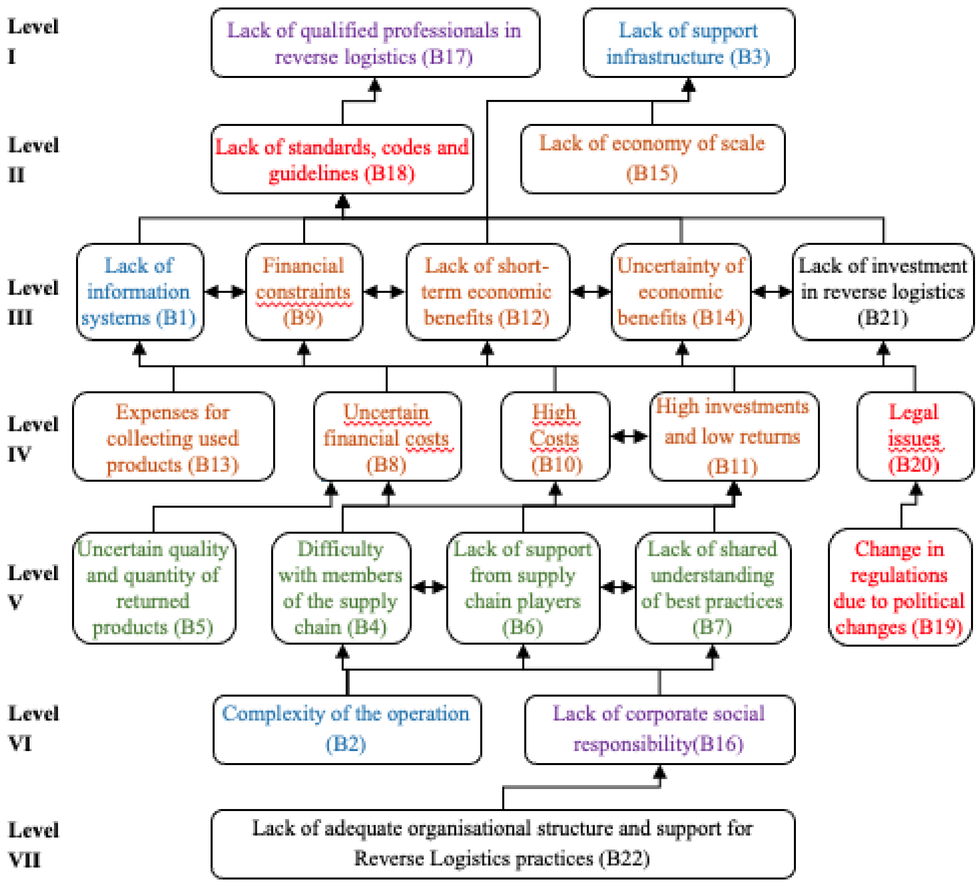

Figure 2 - ISM model of the barriers to RL in Portugal

Analysis of Figure 2, shows that Lack of support infrastructure (B17) and Lack of qualified professionals in RL (B3) are at the top of the table, since they were considered Level I barriers. These barriers do not exert an influence on the others but are strongly influenced by other barriers.

Levels II to V are considered intermediate levels in the model. Level II includes Lack of economy of scale (B15) and Lack of standards, codes and guidelines (B18). Level III includes Lack of information systems (B1), Financial constraints (B9), Lack of short-term economic benefits (B12), Uncertainty of economic benefits (B14) and Lack of investment in RL (B21). Level IV includes High costs (B10), Uncertain financial costs (B8), Legal issues (B20, High investments and low returns (B11) and Expenses for collecting used products (B13). Level V includes Uncertain quality and quantity of returned products (B5), Difficulty with members of the supply chain (B6), Lack of support from supply chain players (B7), Lack of shared understanding of best practices (B8) and Change in regulations due to political changes (B19).
Figure 2 also reveals that barriers in the category of Economic related issues are concentrated in Levels III and IV, and those in the category of Governance and supply chain process related issues in Level V.
The barriers attributed to the intermediate levels influence the barriers of the lower hierarchical levels and are also influenced by the barriers of the higher hierarchical levels.
Finally, the barriers at the highest level are positioned in the lower part of the ISM model and are considered the main barriers to implementing RL in Portugal. Level VI includes Complexity of the operation (B2) and Lack of corporate social responsibility (B17) and Level VII, the highest level, includes Lack of adequate organizational structure and support for RL practices (B22).

4.3. Phase III: MICMAC Analysis

As observed in Figure 3, the barriers to RL are classified in four groups. The first is formed of autonomous variables that have a weak power of influence and weak dependence. These variables are disconnected from the system, with which they have only a few, but strong, links. The second group is formed of the dependent variables that have a weak power of influence but strong dependence. The third cluster contains the linking variables that have a strong power of influence and also strong dependence. These variables are unstable in as much as any action on them will have an effect on the others and also a feedback effect on themselves. The fourth group includes the independent variables that have a strong power of influence but weak dependence. It is noted that the variables with a very strong power of influence, called key variables, belong to the category of independent variables.

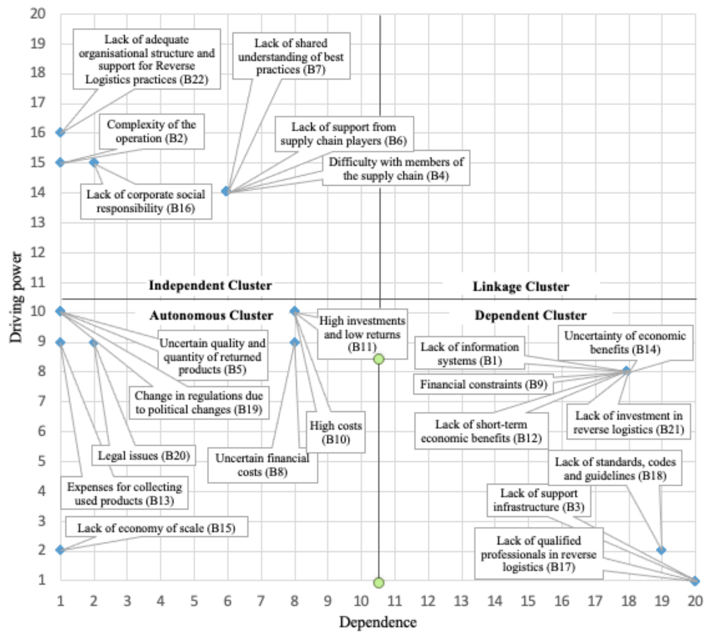

Figure 3 - MICMAC diagram of the barriers to implementing RL

5. Discussion

The model based on ISM proposed to identify the obstacles to RL can give decision-makers a realistic representation of the problems involved in implementing RL. This can help them decide on priorities for taking proactive measures to overcome these barriers.

Lack of adequate organizational structure and support for RL practices (B22), at the highest hierarchical level of the ISM model, is the barrier with greatest influence on the system. A lack of conditions and basic functions in the organizational structure limits the adoption of RL practices (Kiatcharoenpol & Sirisawat, 2020).

According to the results, Lack of adequate organizational structure and support for RL practices directly influences Lack of corporate social responsibility (B21). An appropriate structure could improve the company's social responsibility (B16), Lack of shared understanding of best practices (B7), Lack of support from supply chain players (B6) and Difficulty with members of the supply chain (B4).

Regarding the MICMAC analysis, we can observe that B5, B8, B10, B11, B13, B15, B19, and B20 are in the autonomous cluster. This means these barriers have low influence and low dependence, indicating no significant relationship with the system due to their weak connection with other barriers. These barriers are outside the barrier system, they need to be dealt with autonomously.

The analysis also shows that B2, B4, B6, B7, B16, and B22 are classified as independent barriers, as they have a high influence. This implies that these are fundamental barriers for the effective implementation of RL in the supply chain.
Integrating the hierarchical structure and the interrelationships of the barriers (ISM model) with their influence and dependence (MICMAC analysis) contributes to the discussion about the importance of barriers to the implementation of RL in SMEs and their relationships.
The main barriers from the MICMAC analysis (independent cluster) and the main barriers from the ISM model (level VII barriers) are now classified as key barriers to RL in Portugal (specifically barriers B2, B4, B6, B7, B16, and B22).
Compared to other critical barriers, the key barriers have a relatively low ranking in terms of perceived importance by the respondents in Soares et al. (2024) study. This result confirms the need to go beyond merely classifying the barriers when the goal is to adapt mitigation measures to reduce their impact and promote the implementation of RL.
We also note that B14, classified as the second most important barrier in the rank of Soares et al. (2024) study, is situated in the dependent cluster. This analysis indicates that B14 significantly depends on the mitigation of other barriers, which are considered less important by the experts. Therefore, key-cause mitigation measures are more effective than those based solely on importance.

6. Conclusion

A duly planned and well-managed RL network is crucial to increase the company's income and customer satisfaction. To concentrate on the business's main operations and achieve good cost effectiveness, companies need to organize their RL activities correctly. Consequently, identifying barriers is a challenge for both decision-makers and managers.
In this study, the barriers to implementing RL activities were identified through a review of the literature and introduced in the ISM model to develop a contextual relation between the selected barriers, and to establish the hierarchical structure of the barriers, identifying those with the greatest influence and their dependence.
The ISM converted the perception of 8 RL specialists, in the Portuguese context, into a clear, structured map deciphering the contextual relations among the barriers to implementing reverse flows.
Besides the ISM model, a MICMAC analysis was performed to determine the dependence and strength of influence of the variables identified. This analysis helped to

determine the factors that can be worked on immediately, those requiring most attention.

Application of the ISM and MICMAC analysis revealed that *Lack of adequate organizational structure and support for RL practices* stimulates *Lack of corporate social responsibility*, which in turn and jointly with *Complexity of the operation*, influences the barriers of the *Governance and supply chain process related issues* category. The barriers of the *Economic related issues* category are at the intermediate levels, meaning that they influence the lower levels, but these barriers are also greatly influenced by the higher levels. This analysis reveals that these barriers depend significantly on mitigation of the higher-level barriers.

The research also showed that *Lack of adequate organizational structure and support for RL practices*, *Lack of corporate social responsibility*, *Complexity of the operation, Lack of shared understanding of best practices*, *Difficulty with members of the supply chain* and *Lack of support from supply chain players* are the key barriers to implementing RL. This observation suggests it is crucial to mitigate these barriers, as they exert a significant influence on the others.

Lack of support infrastructure and *Lack of qualified professionals in RL* were found to be lower level barriers, which indicates they are influenced by most of the other barriers.

The results of the study show the importance of mitigating barriers related to management, corporate social responsibility and complexity of operations. By prioritizing these barriers and taking appropriate measures, stakeholders may be able to overcome them and thus promote the effective adoption of RL practices. This research contributes to existing academic knowledge and provides important guidance for practitioners and policy makers to strengthen sustainability. Future research could focus on developing strategies and interventions to address the identified barriers and assess their effectiveness in implementing RL. There should also be a focus on mitigating the main barriers found in the study and determining the impact on different industrial sectors. Although this study makes a significant contribution, it is important to acknowledge some limitations. First, the sample used was relatively small, which may limit the generalizability of the results beyond the group studied. Furthermore, the results refer only to the Portuguese context, and caution should be exercised when extrapolating them to other European markets with different characteristics. Finally, it is essential to consider that different sectors may present unique interactions between the various barriers identified, which may influence the interpretation and application of the results.

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Chapter 5

Barriers and Motivations for Implementing Reverse Logistics in the Textile and Footwear Sector [4]

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Abstract

This study aims to analyse the barriers and propose solutions for implementation of Reverse Logistics (RL) in small and medium-sized enterprises (SME) in the textile and footwear sectors, marked by their high environmental impact and intensive use of resources.

Although RL contributes significantly to mitigating environmental problems and promoting the circular economy, its implementation faces various challenges, especially in companies with limited resources, such as SMEs.

This study adopts a qualitative approach based on interviews with eight people involved in the supply chain of Portuguese SMEs in the textile and footwear sectors. The data gathered were subject to content analysis, using NVIVO 15.0 software for coding.

Standing out among the barriers identified are high costs, the complexity of operations, uncertainty as to the number of products returned, the lack of a suitable organisational structure, absence of scale economies, absence of effective information systems, lack of support from partners and stakeholders, absence of social responsibility and the lack of standardized procedures.

To mitigate the obstacles, various solutions are suggested. These aim to develop strategic partnerships, highlighting the share of information and costs, sensitizing top management, investment in technology, creating standard processes and using outsourcing for product collection and infrastructure.

The intention is to contribute to deeper understanding of RL, showing the specific barriers faced by SMEs in the textile and footwear sector, and proposing solutions that can not only overcome those challenges but also improve these companies' sustainability and competitiveness.

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Keywords: Reverse Logistics; SME; Textile Sector; Footwear Sector; Qualitative Analysis

1. Introduction

Rapid population growth, spreading industrialization and increased consumption are contributing to significantly greater waste production, with the resulting environmental impacts such as air, soil and water pollution and substantial losses of valuable resources (Ribeiro et al., 2017). In response to these environmental challenges, businesses are faced with the need to adapt to mitigate the negative effects of excessive and unsustainable use of natural resources. RL thus emerges as an essential approach to promoting sustainability and, in this context, the circular economy, providing new opportunities to reduce waste, reuse resources and recycle materials in highly polluting industrial sectors (Jordao et al., 2018; Waqas et al., 2020).

RL has been much studied in developed countries due to the increase in strict environmental legislation, pressure from stakeholders and greater awareness among producers and consumers.

However, the implementation of RL faces obstacles, especially in industrial sectors such as textiles and footwear, sectors with resource-intensive production practices and consequently a very high environmental impact (Virgens et al., 2023).

The footwear industry also has a significant environmental impact. As one of Europe's main producers, Portugal faces unique challenges in waste management, due to the complex nature of the materials used and the lack of appropriate infrastructure for recycling and recovery of products (Marques et al., 2017; Rensburg et al., 2020). Despite their economic importance, SMEs in these sectors lack the financial resources, technical knowledge and institutional support necessary to implement effective RL practices (Goncalves & Silva, 2016). Consequently, great quantities of waste continue to be eliminated incorrectly, resulting in economic losses, raw material consumption and adverse environmental impacts.

Despite growing awareness of, and interest in RL, practical application of this concept in textile and footwear SMEs in Portugal is still little explored in the literature, revealing a gap in knowledge about the factors stimulating or hindering the adoption of RL in this specific concept. Previous studies have concentrated predominantly on large companies and in sectors such as electrical goods and electronics, cars and construction, with limited understanding of RL practices in traditional, labour-intensive sectors such as textiles and footwear (Govindan & Bouzon, 2018; Chileshe et al., 2015; Tesfaye & Kitaw, 2021).

This study aims to fill this gap by examining current RL practices in textile and footwear SMEs in Portugal, in order to identify barriers, facilitating factors and opportunities for wider, more effective adoption of RL.

This was done through an exploratory case study, analysing eight Portuguese SMEs in the textile and footwear sectors. In attempting to find out whether there are discrepancies between RL theory and practice, as well as proposing an implementation structure that considers the specific economic and political characteristics of Portugal, the study makes a valuable contribution to both the academic literature and business practice. This study aims to investigate how SMEs can overcome existing barriers and adopt RL practices that help increase their competitiveness and environmental and social sustainability.

The article is organised in five sections to allow detailed understanding of the barriers and strategies associated with implementing RL in the textile and footwear sector. The first section presents a review of the literature, exploring the fundamental concepts of RL, as well as the stimulating factors and obstacles faced. This is followed by the methodology used, including the approach and analysis of the data gathered from SME managers. The section analysing and discussing the results sets out the main challenges and strategies identified to overcome barriers to RL. The final section presents the conclusion and main results, together with suggestions for future research.

2. Literature Review

2.1. Reverse Logistics: Drivers and Barriers

Population growth and the consequent increase in consumption and scarcity of natural resources have caused significant changes in the supply chain and business management. Today, government agencies and consumers are demanding greater transparency regarding raw material extraction processes, sources of production, production methods and distribution. This pressure has forced companies to improve their environmental impacts and adopt a more responsible approach to the environment. (Nakiboglu, 2019).

In this context, RL has gained considerable relevance as an essential process to promote sustainability and efficient resource management. Due to the growing global awareness and the impacts of excessive consumption and consequent negative impact on the environment, RL emerges as a fundamental process to mitigate the negative effects of waste disposal, due to the valorization of materials through reuse and recycling (Abdulrahman, et al., 2014; Gomes et al., 2019).

RL management is also a crucial component of supply chain management, with the potential not only to reduce costs but also to create value for companies. This

management involves a set of operations destined to manage the return of materials, from customers to suppliers, frequently through processes of recycling, repair, elimination or re-use at the lowest possible cost (El Boudali et al., 2022).
The basic activities and flows of RL are represented in Figure 1.

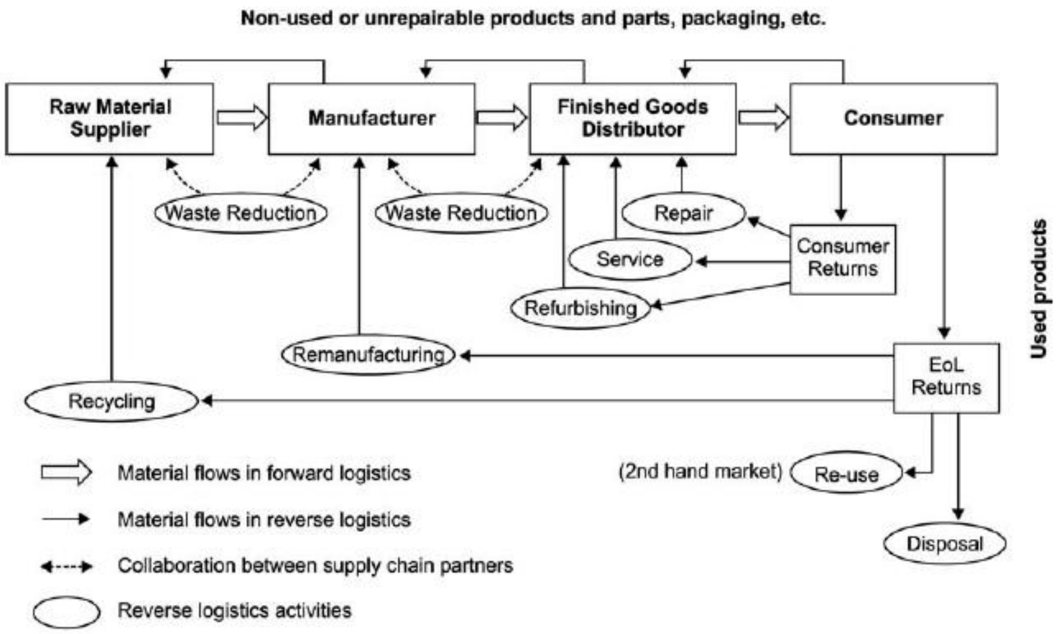

Figure 1 – Activities and flows of RL (Abdulrahman et al., 2014)

On one hand, greater environmental legislation enforcing stricter control, and on the other, consumers' greater ecological awareness, have forced industries to consider implementing RL as an integral part of their environmental management (Gao & Cao, 2020). Consequently, there must be better understanding of RL's development, the factors that stimulate and hinder its implementation, as well as the different perspectives of those involved (Kannan Govindan & Bouzon, 2018). RL is fundamental to improving the sustainability of companies, but its implementation is difficult and involves several factors. In this sense, it is crucial to identify the main motivations and barriers that hinder its implementation(Nakiboglu, 2019). For example, Lau and Wang, (2009) in their research, identified that the motivations for implementing RL may vary between companies but the obstacles tend to be the same. In the electrical and electronic industry in China, the main challenges include the lack of legislation and favourable fiscal policies to encourage manufacturers, the absence of economic support to cover the high cost of investment, low public sensitivity to environmental protection and underdeveloped recycling technology.

Based on a sample of 287 managers in five industries, Chileshe et al. (2015) identified four key factors influencing the implementation of RL in developing countries: economic, environmental, competitive and tertiarization factors. Strangely enough, factors such as legislation and corporate image were found to have little influence on RL performance.

Summarising, RL is a powerful tool to promote sustainability and responsible resource management. Nevertheless, its implementation faces significant obstacles that must be overcome in order to maximize it potential and ensure that companies can benefit, both economically and environmentally, from this practice.

2.2. Textiles and Footwear in Portugal

The Portuguese textile industry developed significantly after 1960, when Portugal joined the European Free Trade Association, becoming a vital sector for the country's economy in terms of added value, employment and exports (Truett & Truett, 2019).

In Portugal, around 6 thousand companies operate in all sub-sectors of the textile and clothing industry. Although some of these are vertical units, the majority are SMEs known for their flexibility, rapid response capacity, know-how and innovation, characteristics that make them competitive in both the internal and external market.

In parallel, the footwear industry has recorded steady growth, remaining an essential sector for Portugal's social and economic development. Portugal is one of the largest exporters of footwear in the world. This sector is made up of SMEs located mainly in the north and centre of Portugal, and is a pillar of the national economy (Ribeiro et al., 2021).

These sectors currently play a fundamental role in the Portuguese economy, due to their impact on employment, due to significant exports, and due to their ability to adapt and innovate. After going through a period of decline until 2009, the footwear industry implemented new strategies which resulted in a significantly improved image and performance. Since then, footwear exports have increased by more than 55%, with growth registered in most of the principal foreign markets (Marques et al., 2017).

In 2022, the country produced 85 million pairs of shoes, two million pairs more than Spain. In the last decade, footwear production in Portugal grew by 14.4%, while in Spain it fell by 14%. And although Italy remains in the lead, it has gradually lost ground to Portugal (APICCAPS, 2023).

2.3. Reverse logistics in the textile sector

One of the main environmental problems faced by the textile industry is the production of large amounts of waste at various stages of the production process. According to data from the National Statistics Institute (2020), the textile industry produces around 500,000 tonnes of waste a year in Portugal.

In addition, the growth of fast fashion has put pressure on companies to adopt more environmentally responsible and sustainable business practices. In this context, implementing RL has helped textile companies achieve economic and environmental benefits(Sumo et al., 2023). However, there are still several obstacles that have hindered their implementation. According Vishwakarma et al., (2022) to the main obstacles, there is a lack of communication between those involved, a lack of training and education in sustainability, limited capacity and a shortage of RL practices.

Although there is a significant shortage of recycling facilities, which poses an additional challenge for the adoption of sustainable practices, there is therefore an urgent need to apply quantitative models to assess the location of these facilities (Pinheiro et al., 2019). It is also necessary to optimize production systems in order to reduce emissions associated with the processing and transportation of textile waste and encourage clothing companies to adopt RL practices (Alimo et al., 2023).

2.4. Reverse logistics in the footwear sector

Leather footwear is the main product manufactured in the Portuguese footwear industry, representing approximately 75% of the sector's total production (APICCAPS, 2023). The consumption of leather in production is responsible for the emission of hazardous waste. This situation leads to an urgent need for all those involved to adopt new approaches to mitigate environmental impacts (Marques et al., 2017). To address these challenges, companies must recognize the competitive advantages of adopting sustainable practices and green design principles, and embrace sustainability as a core component of their business strategies. This process change implies the adoption of new approaches based on the four Rs: Reduce, Reuse, Recycle and Rethink (Marques et al., 2017), with RL having a fundamental role for manufacturing companies (Moktadir et al., 2020).

RL is widely recognised as an effective solution to mitigate the environmental impact of the footwear industry, a sector that contributes significantly to increased waste during the product's life-cycle (Rensburg et al., 2020).

Rensburg et al., (2020) make various points that reinforce the need for effective implementation of RL: the material used in producing leather footwear has serious environmental impacts throughout the whole life-cycle; there is a shortage of publications on thermochemical processes, such as pyrolisis, which could be viable alternatives to recover footwear waste after consumption; and there are many challenges in recovering footwear after consumption, including the inefficiency of current RL practices, difficulties in recycling mixed materials and the lack of an efficient value chain to recover that material.

Even so, most studies on the barriers to implementing RL have concentrated on international contexts and other sectors, leaving a gap regarding specific analysis of the leather footwear industry (Moktadir et al., 2020).

3. Methods

This study focuses on the textile and footwear industries, which due to the significant increase in their production have had a major impact on the environment, such as water and soil pollution, among other adverse effects (Vishwakarma et al., 2022). In order to mitigate these effects, RL practices are a solution that can help in the proper disposal of waste and promote more sustainable business practices (Singh & Goel, 2024). Adoption of RL in these industries is therefore fundamental to minimize the negative effects on sustainability.

The aim here is to identify the main barriers faced by textile and footwear SMEs regarding the implementation of RL, proposing practical, effective solutions to mitigate these difficulties and thereby promote their long-term competitiveness and sustainability. To this end, the method of analysis was the case study, as this is appropriate to explore complex issues that cannot be studied only through empirical surveys or experimental research, being especially useful when the aim is to answer the questions "how" or "why" about a specific phenomenon (Yin, 1994).

According to du Toit and Mouton (2013), interviewing supply chain managers is considered the more effective way to evaluate the needs and perspectives of those involved. Moreover, Creswell (2009) argues that a qualitative approach is more appropriate when the topic is new and the key variables are still unknown. Although a small sample in a case study can limit generalization of the results to the whole population, that limitation can be mitigated through careful selection of important, representative subjects for the study (Merriam, 1985).

Here, an intentional sample was chosen, as suggested by Bazeley (2013), allowing the researchers to acquire sufficient knowledge to fulfil the aims of the study and compare variations among the respondents. Initially, 26 potential experts were identified through company websites and professional networks such as LinkedIn. After sending out invitations, eight experts were selected, as presented in Table 2, based on their availability to contribute to the study. Although the number of interviewees may seem low, Mason (2010) and Bazeley (2013) indicate that data saturation can be achieved with only six interviews, depending on the quality of the data collected.

Each interview lasted approximately 30 minutos and was based on a semi-structured script to allow collection of relevant data. The semi-structured approach adopted ensured the interview followed a consistent, systematic direction, completely covering the themes identified without losing the flexibility necessary to capture the complexity of the issues (Pozo et al., 2019).
The case study is a robust, frequently used approach in studying RL, as it allows in-depth exploration of the various questions involved.

3.1. Data Collection and Treatment

The interviews yielded detailed, spontaneous answers, encouraging direct interaction between interviewer and interviewees, which minimized possible problems in interpreting the questions asked (Creswell, 2009). The semi-structured format of the interviews allowed the flexibility necessary to explore in greater depth relevant themes emerging from participants' answers. This format meant questions could be adapted based on each interviewee's experience and specific knowledge and ensured wide-ranging understanding of the phenomena studied.
The interview script (Table 1) was in two parts. The first focused on characterising the interviewees and the firms involved, information such as the position held, interviewees' professional experience and their direct or indirect involvement in the RL process. This approach established a clear, detailed context for subsequent analysis, and facilitated identification of the individual and organisational perspectives of the topic.
In the second part, the script contained open questions related to the process of implementing and developing the RL network, so as to identify the main barriers faced by the companies and the strategies adopted to overcome them. This qualitative approach was essential to capture the complexities associated with RL, identify common challenges and promote the share of successful practices that can serve as a reference for other companies in the sector.

Table 1 – Interview Script

1st part	Identification of the interviewee: name, gender, age, academic qualifications, position in the company and length of time there.

	Identification of the company: name, location, year of foundation, number of collaborators.
2nd part	What motivates you to develop RL strategies? What are the immediate aims of the company's RL strategies? What are your strengths in terms of RL? And what do you consider you do less well and need to improve? How do you manage returned products? What is the main reason for clients returning products? Do you have any independent system of information management for the RL in force? What is the model/procedure used for collecting products? What are the waste management practices in operation? What are the main challenges the company faces currently in implementing RL? How could you tackle these challenges more effectively?

The interviews were held by video-conferencing in June and July 2024, lasting 30 minutes on average. They were held with those responsible for the companies' logistic processes, having a central role in implementing and managing RL practices. Choosing video-conferencing allowed greater flexibility in participants' diaries, at the same time ensuring a direct and focused environment of dialogue, essential in obtaining detailed, relevant information about the challenges and strategies associated with RL.

The average length of 30 minutes was enough to explore the key issues previously defined in the interview script, achieving a balance between the depth of answers and the objectivity necessary for the study. This format captured the interviewees' experiences and perspectives efficiently, ensured the quality of the data gathered and contributed to broad understanding of the logistics practices in the companies analysed. Table 2 characterises the interviewees.

Table 2 – Characterisation of Interviewees

Interviewee	Gender	Education	Position	Length of service
Interviewee 1	Male	Secondary	Director of Operations	25
Interviewee 2	Female	Degree	Director of Operations	18
Interviewee 3	Male	Secondary	Logistics Manager	8
Interviewee 4	Male	Degree	Responsible for Logistics Operations	12
Interviewee 5	Male	Degree	Responsible for Logistics Operations	8
Interviewee 6	Male	Master	Commercial	4
Interviewee 7	Male	Degree	Responsible for Logistics Operations	16
Interviewee 8	Male	Master	Transport Coordinator	4

After data collection, content analysis was performed using NVIVO 15.0 software. This gave systematic coding of the data and facilitated organisation and interpretation of the information. Use of this software allowed the creation of "tree nodes", a technique that

categorized and structured the information collected in a hierarchical way, allowing the main themes and emerging sub-themes to be identified and grouped.
In cases where the information was scattered or did not present sufficient elements to identify clear patterns, the word cloud analysis technique was used.
This method helps to identify the most recurrent themes by highlighting the words most frequently mentioned by the interviewees, contributing to a more intuitive understanding of the topics analysed.

4. Results Analysis and Discussion

Data analysis reinforces the relevance of RL for business operations. The word cloud created by the data analysis software, presented in Figure 2, shows terms such as "logistics", "reverse", "costs", "customer", “product” and "return" to be the most frequently mentioned. These terms show the centrality of RL, particularly in managing returns and the implications for costs and interaction with clients.
Analysis of the results shows that the main focus is on practices with returns and the need to optimize logistics processes to reduce costs and meet customer expectations. Terms such as ‘repair’, ‘quality’ and ‘production’ indicate that companies face a challenge in managing defective products.
The emphasis on the terms “returns” and “costs” reveals that companies face significant challenges regarding efficiency and cost control in managing returned products. Words like “reuse” and “reduce” also point to an interest in reuse and sustainability practices.
These data indicate a clear concern about logistics efficiency, managing returns and lowering costs, reflecting the operational and economic challenges faced by firms implementing RL practices.

Figure 2 – Word cloud

The analysis of this study focuses on six categories, to allow understanding of the different dimensions associated with RL in the textile and footwear sector. The first category explores the reasons for developing RL, highlighting factors that stimulate firms to adopt these practices. The second category examines the RL process, through analysing the stages and procedures involved in its implementation. The third addresses the destination of returned products, detailing the strategies of recovery, recycling or elimination. The fourth focuses on the reasons for returning products, covering aspects such as defects, client dissatisfaction or the end of articles' life-cycle. The barriers to implementing RL form the fifth category, reflecting the challenges companies face, while the sixth category explores strategies to overcome those difficulties, suggesting practical and innovative solutions. These categories provide a structured basis for discussion, through an integrated analysis of RL practices.

4.1. Motivation for developing Reverse Logistics

RL is fundamental for companies being able to improve both their financial and environmental performance. According to Govindan et al. (2016), the main motivations for adopting RL include reducing the environmental impact, increasing social responsibility and obtaining economic benefits. In addition, Rahimifard et al., (2002) underline that besides financial gains and complying with national and international legislation, reducing the negative impacts on the environment contributes significantly to improving firms' corporate image.

Client satisfaction also plays a crucial role in successful RL management. According to Klapalova (2016), this should be seen as one of the main results of implementing RL, being stimulated for financial and non-financial reasons. Moreover, Klapalova (2016) identified four key factors influencing the implementation of RL: economic, competitive, outsourcing and environmental. In this context, Nakiboglu (2019) agrees that the main reasons for adopting RL practices include legal requirements, seeking clients and improving the company image. Laribi and Dhouib, (2015) also underline that in the current competitive climate, firms wishing to gain a competitive advantage should pay special attention to implementing RL and its benefits.

According to the interviewees, the main reasons for implementing RL are client satisfaction, financial opportunities, social responsibility, competition, company image and sustainability (Figure 3):

> "(...) *the focus of RL in our company is on client satisfaction. If the client wants to return a product due to a fault, we deal with the return to ensure that satisfaction.*" (Interviewee 2)
>
> "(...) *the main reason for developing the RL strategy is to deal with faulty products, aiming for client satisfaction." (*Interviewee 6)

“(...) *one of the reasons is the financial opportunity involved, such as the recovery of returned material and lower costs associated with wastage.*” (Interviewee 5)

“(...) *our motivation is social responsibility, to reduce the environmental impact and improve our image.”* (Interviewee 3)

"(...) *Our main reason for developing RL is concern about the environment and sustainability.”* (Interviewee 4)

“(...) *the competition also puts pressure on us, as companies that implement efficient RL practices gain a competitive advantage in the market.”* (Interviewee 1)

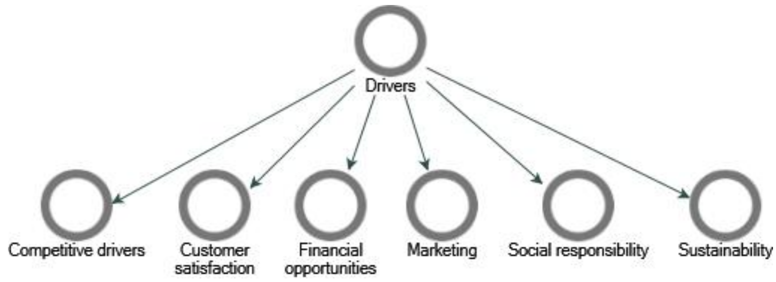

Figure 3 - Map of nodes (NVivo) for the results of the interviews (Drivers)

4.2. RL Process

The RL process follows various fundamental stages to ensure efficient management of returned products. Firstly, there is the collection and transport of those products to the company premises, where they will be processed. Next comes inspection and separation of the products, evaluating their state to determine the most appropriate destination, which can be re-use, sale, repair or recovery of its components. Finally, there is product treatment, which can include redistribution, repair, disassembly to recover parts, recycling, or as a last resort, controlled elimination (Alarcón et al., 2021).

According to Brito and Dekker (2003), RL activities can be divided in four main phases: (1) collection, (2) inspection/selection/classification, (3) reprocessing and (4) redistribution. Reprocessing can be of two types: direct recovery, when the returned products are in as good as new condition and can be re-used or re-sold directly; and processed recovery, which involves more thorough reprocessing.

Agrawal et al. (2015) also identify four main stages in the RL process: (1) acquisition of used products for subsequent processing, (2) collection, (3) inspection and separation, and (4) treatment, which can involve repair, re-manufacture, recycling, re-use or elimination, depending on the decision to recover the value or dispose of the product.

Regarding the procedures implemented in the interviewees’ companies, Figure 4 reveals that they are generally in line with those mentioned in the literature, despite using fairly rudimentary information systems. An exception to this trend was observed in the firm of Interviewee 6. They send directly to the final customer, whereas most of the companies produce for intermediaries, and demonstrated a more complex, structured approach to product returns. These differentiated procedures suggest greater sophistication in handling returns, compared to the other companies analysed:

> (...) *"We have a control team responsible for managing customers' complaints. The process begins with receiving the complaint, followed by a request for photographs of the product for initial evaluation. Based on analysis of the pictures and the customer's profile, we decide if the return will be accepted or not. If the return is approved, the product is sent back to the company, where it undergoes a repair process before it's available again."* (Interviewee 2)
>
> (...) *"When there's a problem with the product, the customer lets us know. First, we check the type of problem while the product is still with the customer. If it can't be repaired there, the product is sent back to our firm for detailed analysis. We check the size and seriousness of the problem and identify the supplier responsible. Together with the supplier, we decide if he will do the repair or if we need to produce new pieces. During that process, we take care of the transport. If the product can't be repaired, it's destroyed. Normally, it is destroyed under supervision, often in the presence of someone from the tax office, as required by the clients."* (Interviewee 4)
>
> "(...) *Collection can be in two ways: the client can send it directly to us, or we organise the collection through a sub-contracted transport company. We load and bring the products to our premises. Once repaired, the product is returned to the client."* (Interviewee 3)
>
> "(...) *We send the product duly packaged and create an e-mail and a specific section in our online shop for returns. Inside the package, we send a form and label for returns. If the customer decides to return it, they complete the form, attach the return label we sent and takes the product to the nearest transport company or they can ask for it to be picked up from their home. When the product reaches our company, we check that everything's in order. If it is, we send a new product or return the money in 24 hours."* (Interviewee 6).

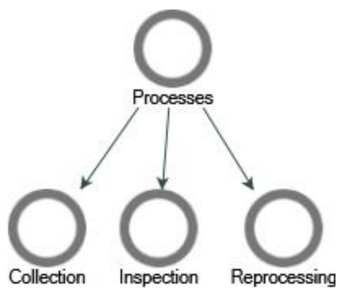

Figure 4 - Map of nodes (NVivo) from the results of the interviews (Processes)

4.3. Destination of returned products

RL is a management process that involves returned products, unused material or raw material, following a reverse distribution channel known as reverse flow (Akdogan & Coskun, 2012). It is a process covering planning, implementation and control of the efficient and economic flow of raw material, management of stock, finished goods and information, from the point of consumption to the point of origin, aiming to recover the value of the product or forward the waste for elimination.

Agrawal and Singh, (2019) and Safdar et al., (2020) present RL as the sequence of activities necessary to collect the product used by customers, in order to repair, transform, recycle, or in some cases, eliminate it as waste.

According to the interviewees, as shown in Figure 5, the main aim of RL is to recycle products, either on the company's own premises or in collaboration with third parties, repair damaged products, re-sell faulty items at a lower price, donate products that can still be used, or as a final alternative, eliminate them.

> "(...) *To minimize this impact, we try to incorporate that material in new products, but with limited success."* (Interviewee1)
>
> "(...) *Besides that, we have partnerships for recycling; for example, a supplier of soles can use the returned shoes, taking them apart and incorporating them in the rubber or in thermoplastic."* (Interviewee 2)
>
> "(...) *The customer returned the shoe, we made the tests and corrections necessary, and then we send the product back."* (Interviewee 3)
>
> "(...) *When we receive something here, it's always to repair*. (Interviewee 5)
>
> "(...) *It can be sold in a sale, above all if it has a defect that doesn't affect its functioning*. (Interviewee 1)
>
> "(...) *In some cases, the material we aren't able to use can be sold at a low cost, donated, or in extreme situations, thrown away*. (Interviewee 2)
>
> "(...) *When a shoe is returned, we have two options: it is destroyed, or if the problem isn't very big and there's authorization, we sell the product to our employees or we donate it."* (Interviewee 4)

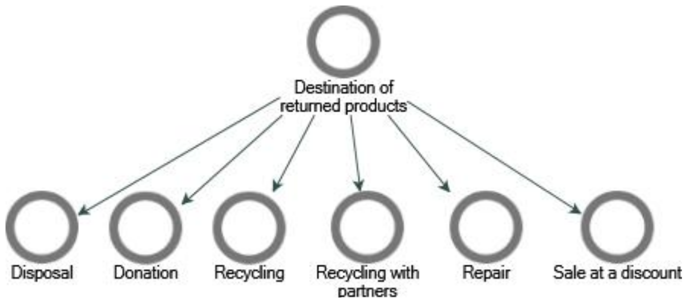

Figure 5 - Map of nodes (NVivo) from the results of the interviews (Destination of returned products)

4.4. Reasons for returning products

According to Sun et al., (2008), RL is essential to capture the value of returns, the main reasons for these including faulty products and the need to eliminate obsolete stock. This is particularly important to maintain good relations with clients. RL is crucial, especially when consumers who are dissatisfied with the products they have received choose to return them (Wei et al., 2021). Furthermore, products often don't live up to customer expectations due to their quality or function (Naseem et al., 2021).

In the interviews held, the participants underlined that the main reason for returns is the presence of defects in the products, followed by the issue of obsolete stock (Figure 6). Only one interviewee mentioned that the return was due to a mistake in the size, showing that dissatisfaction with quality is consumers' main concern:

> "(...) *The main reason for returning is usually quality. When the product isn't as it should be, the customer asks for this to be solved."* (Interviewee 3)
>
> "(...) *The main reason was to manage product quality. Around 95% of the time, RL is used to deal with faulty products."* (Interviewee 8)
>
> "(...) *When we sell on consignment, unsold products are returned at the end of the season."* (Interviewee 1)
>
> "(...) *In the company, RL refers to returns. That generally happens because the customer is dissatisfied and asks to return the product. Normally, before the return, the customer makes a complaint about problems to do with quality or the finishing of the product."* (Interviewee 1)
>
> "(...) *In the case of our own brand, there are also returns to exchange the size."* (Interviewee 6)
>
> "(...) *For there to be a return, there has to be a serious defect. Small defects are normally solved and agree between us, the suppliers and the client. A*

small repair can be carried out at the client, repackaging or other similar solutions." (Interviewee 4)

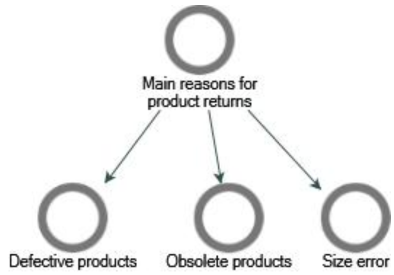

Figure 6 - Map of nodes (NVivo) from the results of the interviews (Main reasons for product returns)

4.5. Barriers to implementing RL

In recent years, manufacturing companies have sought to implement RL in response to stakeholders' demands, aiming to reduce negative environmental impacts, improve sustainable performance and increase their competitive advantage. However, the implementation of RL faces several barriers (e.g. U-Dominic et al., 2021).

In the study by Soares et al., (2024), the most relevant barriers identified were "uncertain quality and quantity of the returned products", "uncertainty about the economic benefits", "high costs" and "financial restrictions". Similarly, Ambekar et al., (2022) identified ten barriers affecting RL. Standing out at the macro level are lack of knowledge about RL, insufficient government policies and the absence of standardized codes. These macro barriers influence other strategic matters, such as companies' rigid mechanisms, lack of awareness about the potential economic benefits, inappropriate organisational policies and lack of training. Stakeholders' reluctance and the shortage of resources and finance were also mentioned as significant challenges. At the operational level, the main barrier identified was an inadequate information technology system.

The study by Vishwakarma et al., (2022) obstacles in the textile sector such as lack of communication between stakeholders, lack of sustainability training and education, limited capacity and lack of RL practices. Moktadir et al., (2020) indicated that a lack of interest and support from top management, and a lack of knowledge are the main barriers to implementing RL in the footwear sector.

Furthermore, the main problems include the unpredictable demand for RL, which is distributed almost at random in terms of time, place, quantity and destination. That prevents logistics companies' capacity to reserve sufficient resources in advance. In addition, clients' consumption habits do not fit in with tradition models of RL, where consumers must send returns back to collection points, increasing the cost of returns and affecting the purchasing experience (Wei et al., 2021).

According to the interviewees, the main barriers to implementing RL were the high costs, the complexity of operations, uncertainty regarding the quantity of products returned, the lack of an appropriate organisational structure, the absence of scale economies, the lack of information systems, the lack of support from other members, the lack of social responsibility and the absence of standardized procedures. Figure 7 illustrates the barriers identified by the interviewees.

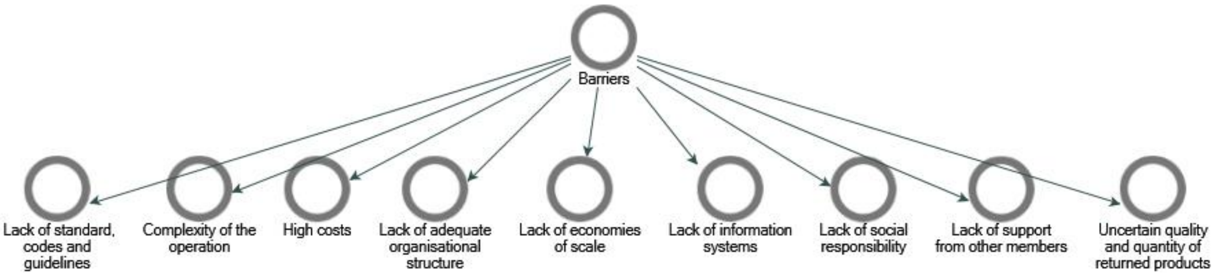

Figure 7 - Map of nodes (NVivo) from the results of the interviews (Barriers)

"(...) *RL is a high cost for the company, so we try to avoid it as much as possible. If clients have a lot of problems with our products, they may end up looking for another company, and we lose the business."* (Interviewee 2)

"(...) *One of the greatest barriers is the cost of the operation, especially the cost of transport, and often, the cost of repairs."* (Interviewee 4)

"(...) *the complexity of organising the return routes and the whole logistics process, from collection to processing of the returned material."* (Interviewee 2)

"(...) *The main barrier, without a doubt, is the very structure of the organisation, which is not duly prepared to develop RL".* (Interviewee 1)

"(...) *one barrier is the lack of a scale economy, the volume of returns is small in relation to the normal activity."* (Interviewee 2)

"(...) *there's also a lack of appropriate information systems to manage the whole returns process efficiently."* (Interviewee 6)

"(...) *in national companies, RL is done case by case, there are no standardized procedures.*" (Interviewee 5)

"(...) *another difficulty is the lack of coordination between companies to share those costs."* (Interviewee 2)

"(...) *the lack of social responsibility is one of the main barriers. Many companies don't yet see RL as an important part of their environmental and social responsibility."* (Interviewee 5)

4.6. Strategies to overcome the difficulties

The solutions to overcome the difficulties with RL involve a combination of complementary strategies that aim to improve the efficiency and sustainability of the supply chain.

For Arantes and Ferreira (2023), strategic collaboration between supply chain players promotes greater efficiency. According to the authors, collaboration increases information sharing, co-operation and co-ordination between the parties, facilitating the implementation of RL practices. Garg, (2021) states that collaboration between the main players plays a fundamental role in creating knowledge about the advantages of recycling and return, making society more receptive to these practices.

According to Prakash and Barua (2015) and Derse (2024), the standardization of RL processes helps to optimize operations and support consistency in procedures.

According Garg (2021) and Derse (2024) the initiative and commitment of senior management is key to supporting and prioritising RL activities and ensuring that the necessary resources are invested.

In the same way, according to Garg (2021), technological innovation is also key to reducing the challenges associated with returns management. Incorporating technological solutions helps to improve the RL process, thus facilitating the collection, separation and recovery of material. In the similar vein, Prakash and Barua (2015) point out that developing and investing in technology is key to modernising and optimising processes, providing greater efficiency and lower operating costs.

Derse (2024) underlines that to face those challenges, it is necessary to increase public awareness of environmental issues. That awareness makes consumers more willing to engage in recycling and return practices, increasing the efficiency of operations. Moreover, collaboration between functions and stakeholders is indicated as fundamental, with it being necessary to provide financial and administrative support, and appropriate infrastructure to ensure that the RL system functions effectively. Benchmarking of practices allows organisations to assess and improve their processes continuously, in order to maximize efficiency.

Another relevant factor, mentioned by Garg (2021) and Prakash and Barua, (2015) is the development of infrastructure and facilities to support RL activities. Investing in the right infrastructure is key to making the network more efficient.

Collaboration between members of the supply chain is also important in order to ensure greater coordination between those involved. According to Sirisawat and Kiatcharoenpol, (2018) the digitalisation of processes helps to share information in real time.

Finally, one of the most important points is the strategy that helps to avoid the return of products. Various authors, e.g., Prakash and Barua, (2015) and Garg, (2021) Hall et al., (2013), emphasise that it is important to develop proactive measures, such as improving product quality and communication with customers, to reduce the volume of returns. According to the authors, implementing these measures allows companies to focus their efforts on more effectively managing returns that are truly unavoidable.

According to the interviewees, the main solutions for implementation of RL include the development of strategic partnerships, particularly to share information and costs. Also stressed is public and top management's awareness, which is essential in raising the importance of RL in organisations.

In addition, the interviewees indicate the need to invest in technology and define standardized processes, which will help to simplify operations and increase efficiency. Another solution mentioned concerns the use of outsourcing for product collection and infrastructure, delegating these tasks to specialized partners. However, most interviewees focused on implementing strategies to avoid returns, given the high cost. Among the suggestions, repairs at the client and discounts for imperfect products are highlighted as effective ways to reduce the number of products returned, and consequently the financial impact of returns.

Figure 8 presents the strategies mentioned by the interviewees.

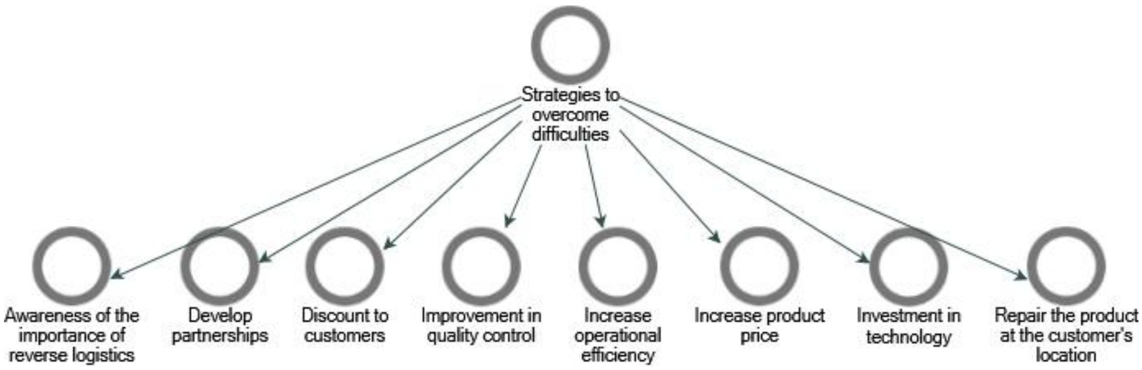

Figure 8 - Map of nodes (NVivo) from the results of the interviews (Strategies to overcome difficulties)

“(…) *Some clients contract their own controllers in Portugal, whereas others use external quality control firms. We also have internal controllers to ensure that products leave without defects.”* (Interviewee 6)

(…)*"We try to minimize RL as much as possible, when it occurs it's generally due to quality problenms. For that, we have clients' controllers in the company who accompany the production and do the final control. So almost 100% of the shoes are approved for quality before they're sent to clients. When there's a problem, our first approach is to offer discounts to avoid RL. For example, if we send products to Japan and two pairs of shoes have dirty laces or some other minor defect, we offer a discount of 1% or 2% to avoid returns. As a result, for small complaints, we avoid the return process, which is more costly and complicated"* (Interviewee 3)

“(…) *It would be important to adopt an approach more focused on quality. Invest in technology to improve quality control, such as artificial intelligence systems to detect faults automatically, to prevent problems.”* (Interviewee 8)

“(…) *In cases of small imperfections, we try to negotiate a discount instead of taking on the cost of bringing the product back, especially when it's not possible to repair the defect."(* Interviewee 8)

“(…) *Sometimes, it's quicker and cheaper to solve the problem on location than to bring the material back. It has also happened that the clients themselves arranged a local company to carry out the repair, and we pay the costs.”* (Interviewee 2)

“(…) *It's important to sensitize and train managers and employees about the importance of RL. When everyone understands their role and the impact, both financial and environmental, it's easier to promote a culture of responsibility and efficiency in the whole organisation.”* (Interviewee 7)

“(…) *To face high costs, it would be fundamental to develop strategic partnerships.”* (Interviewee 5)

“(…) *It's crucial to invest in technology. Using advanced logistic management systems can allow more effective control of returns, identify faulty products quickly and optimize the collection process.”* (Interviewee 7)

“(…) *I believe that one of the main points to overcome the challenges of RL is definition of standardized processes. When we have clear, consistent procedures, the operation becomes more agile, and we can avoid mistakes and reduce the complexity of returns.”* (Interviewee 3)

"(...) *The key lies in sharing practices among companies. We've learnt a great deal by collaborating with other actors in the sector. When information and experiences are shared, everyone benefits."* (Interviewee 4)
"(...) *One solution I consider effective in dealing with some of the difficulties of RL is by resorting to outsourcing."* (Interviewee 1)

5. Conclusion

This study aimed to identify the main barriers faced by SMEs in the textile and footwear sectors in implementing RL, as well as proposing solutions to mitigate those difficulties and facilitate their adoption. RL is recognised as an essential tool to promote sustainability, reduce environmental impacts and improve companies' efficiency, but SMEs face various challenges in its implementation.
The study identified several barriers in line with those mentioned in the literature. Standing out among them are the high operational costs, the complexity of operations, uncertainly regarding the number of products returned, the absence of an appropriate organisational structure and the lack of efficient information systems. In addition, the lack of scale economies and weak collaboration among partners and stakeholders aggravate the process of implementing RL even more.
The results of the study show that these barriers have a direct effect on the competitiveness and sustainability of textile and footwear SMEs. Companies find it difficult to align implementation of RL with their strategic objectives, despite recognising the importance of RL for long-term sustainability and to respond to current market needs.
Highlighted among the solutions proposed is the need to develop strategic partnerships, to share costs and infrastructure, and to collaborate for more efficient logistics operations. The use of subcontracting to collect and process returned products was another solution suggested, allowing SMEs to concentrate on their core activities.
Subcontracting was another solution that was suggested for collecting and processing returned products, as it allows SMEs to concentrate on their core activities.
It was also mentioned that standardising RL processes and investing in innovative technologies were effective strategies for reducing the complexity of implementing the network.
The study also emphasises the importance of involving senior management and making stakeholders more aware of the importance of implementing an effective RL network. Training and internal awareness could be effective strategies for overcoming

organisational resistance. It is essential for companies to be more proactive in implementing RL in order to create value and improve their image in the eyes of consumers.

The study contributes to the literature by identifying the barriers to implementing RL in SMEs in the textile and footwear sector, providing a comprehensive overview of the challenges they face, and presenting specific solutions to overcome these obstacles. Managers and policy-makers can apply them to facilitate the adoption of RL, promoting SMEs' sustainability and competitiveness.

In carrying out this study, some limitations were identified. There is some subjectivity in analysing the results, especially in the process of coding and categorizing the data gathered in the interviews. Despite following the recommended guidelines, it is important to recognize that the qualitative methodology used tends to include some subjectivity. In addition, restricting the focus to the textile and footwear sectors limits generalization of the results, suggesting that future studies can cover other sectors, or countries, to determine the applicability of the barriers and solutions identified, in other contexts.

It would be important for future research to analyse the impact of government policies and tax incentives on reducing barriers to reverse logistics. New studies could also analyse companies that have failed to implement RL, identifying the predominant factors that led to these failures.

Another relevant aspect would be to compare different sectors and countries, to understand how contextual variations affect the effectiveness of RL. This study would make it possible to identify the key elements for success and common barriers, and thus increase knowledge about the implementation of reverse flows.

In conclusion, this study reinforces the importance of a strategic approach to the implementation of RL in SMEs, in order to mitigate barriers and thus ensure effective adoption that promotes sustainability, competitiveness and corporate social responsibility.

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Chapter 6

Reverse Logistics Strategies in the Textile and Footwear Sectors: A Fuzzy-Based Decision Approach[5]

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Abstract

Increased concern about environmental impacts, allied to the need to find sustainable solutions for the elimination and recovery of waste, has stimulated the adoption of Reverse Logistics (RL) practices. This study explores strategies for the implementation of RL in the textile and footwear industries, sectors that contribute significantly to environmental pollution. A hybrid model is proposed, based on the fuzzy analytic hierarchy process (F-AHP) and on fuzzy measuring of the alternatives and classification according to the compromise solution (F-MARCOS) in order to choose the most appropriate strategy for implementing RL. Through a survey of small and medium-sized enterprises (SMEs) in the textile and footwear sectors in Portugal, three strategic alternatives were evaluated: internal RL, partnerships and sub-contracting. The results indicate that sub-contracting is the most commonly used strategy, followed by partnerships and internal RL.

Keywords: Reverse Logistics; SME; Fuzzy AHP; Fuzzy MARCOS

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1. Introduction

The environmental impacts associated with production processes in the textile and footwear sectors have stimulated the debate on environmental sustainability as these sectors continue to expand. The textile and footwear industries put a great deal of pressure on the environment, contributing to increased pollution and waste.

The textile industry is amongst the most polluting in the world, representing a serious environmental and social challenge. Just to produce a simple cotton T-shirt, around 2700 litres of fresh water is required – the same as one person consumes in two and a half years. In Europe, in 2020, clothing and footwear production per inhabitant implied an average of 9 m^3 of water, 400 m^2 of soil and 391 kg of raw material, resulting in a carbon footprint of around 270 kg per person (European Environment Agency, 2020)

Textile production also accounts for approximately 20% of global pollution of drinking water, due to the use of chemical products in dyeing and finishing. In addition, the advent of fast fashion has speeded up consumption and consequently reduced these products' period of useful life. In Europe, each person throws away around 11 kg of textile products per year and only 1% of this is recycled, giving rise to a new product (European Commission, 2023).

This significant increase in consumption, and consequently production, due to dyeing and finishing processes, results in around 20% of global pollution of clean water. Besides the environmental problems arising from dyeing and finishing, washing this clothing accounts for 35% of primary micro-plastic entering the environment (European Commission, 2023).

Regarding the footwear industry, its environmental impact is no less significant. According to data from the APICCAPS (2023), in 2022, global footwear production reached 23,9 thousand million pairs, which corresponds to an annual increase of 7,6%. Consequently, this growth has increased the amount of waste that ends up in landfill.

Despite these environmental challenges, the textile and footwear sectors occupy a relevant position in global and regional economies, being drivers of job creation and economic growth. In 2024 the European Union had more than 197.000 companies in the textile sector, a turnover of 170 thousand million euros and around 1,3 million employees (Euratex, 2024). Portugal is among the four largest European employers in the textile and fashion industry, representing 10% of the sector's turnover in the European Union (Euratex, 2024). Similarly, the footwear sector is one of the pillars of the Portuguese economy, with the country being among the ten largest producers of leather footwear in the world. In 2023, exports of Portuguese footwear rose to a figure of 2 thousand million euros, especially to European markets such as Germany and

France. The sector employs approximately 40.000 people, involving both major international brands and domestic companies (APICCAPS, 2024). However, the environmental impacts arising from these sectors require immediate solutions. The significant growth in consumption, together with constantly changing fashion trends, has led to increased waste and put pressure on waste management infrastructure. The increased demand for footwear and textile products, associated with shorter and shorter life-cycles and their easy disposal, reinforces the need for sustainable solutions such as re-use, re-manufacture and recycling (John & Rahman, 2024).

In this context, sustainability has an increasingly relevant role in these sectors, above all in markets with more demanding consumers, such as Europe, where both product quality and responsible business practices are valued. Therefore, technological innovation and modernisation of production processes have become decisive factors, so that companies can reduce their ecological footprint and respond to customers' expectations (Filho et al., 2024). In this scenario, the implementation of responsible practices, such as Reverse Logistics (RL), can lessen the environmental impacts and allow these sectors to grow more sustainably and according to economic and environmental requirements (dos Santos et al., 2023; Pereira et al., 2023).

RL, which includes practices to recover products and material, is an effective approach to lessen these negative effects, attributing value to recyclable material and promoting the circular economy (Agrawal & Singh, 2019; Safdar et al., 2020). Besides the environmental aspect, this approach brings economic benefits for firms as it helps to increase profits and reduce production costs (Liu & Cai, 2015).

Based on the above, this study aims to support manufacturing industries in choosing the most appropriate strategy to implement RL. The aim is to evaluate the relevant criteria and support the choice of the most effective strategy. It is therefore a question of multicriteria decision-making (MCDM), determining the criteria weightings, and based on them, creating a hierarchy of the strategic RL alternatives. To this end, an innovative hybrid model was developed, combining the fuzzy analytic hierarchy process (F-AHP) with fuzzy Fuzzy Measurement of Alternatives and Ranking according to Compromise Solution (F-MARCOS). The F-AHP method is recognised in the literature on MCDM, highlighted for its simplicity, speed and applicability (Kubler et al., 2016). F-MARCOS is a very recent MCDM methodology, but has shown great effectiveness in analysing and ordering alternatives (Stanković et al., 2020).

Despite recognition of the environmental impacts of the textile and footwear sectors, gaps remain in the literature regarding the use of decision-making tools to help companies choose more sustainable strategies. Furthermore, few studies explore the technical, economic and environmental criteria associated with implementing RL, especially in industries that are traditionally resistant to change, as is the case of the textile and footwear sector.

Aiming to fill this gap, this study intends to contribute by proposing a hybrid model to support decision-making, combining F-AHP and F-MARCOS. Firstly, integrating these methods will attribute weights to decision criteria based on subjective opinions expressed in an imprecise way, and secondly, classify the strategic alternatives according to their relative performance, providing a more precise and realistic hierarchy. This approach will make up for the absence of structured models guiding the adoption of RL in sectors with a high environmental impact, allowing decision-making that is more informed, sustainable and adapted to the business situation.

The study is divided into different sections addressing the main aspects of implementing RL in the textile and footwear sectors. The introduction (Section 1) is followed by a review of the literature on Reverse Logistics and methods to support decision (Section 2). Section 3 describes the research proposal, highlighting the implementation strategies considered. Section 4 presents the methodological model adopted, while Section 5 analyses the data gathered. The results are discussed in Section 6. Section 7 addresses the implications of the study, its limitations and proposes future lines of research. Section 8 presents the main conclusions.

2. Literature Review

2.1. Reverse Logistics

The environmental impacts resulting from production chain processes, as well as the effects already caused and potential future impacts, have intensified the debate about environmental issues and the need for more responsible business practices. In this scenario, managers have shown growing interest in RL, stimulated by environmental legislation, consumer pressure and the benefits these practices bring for organisations' image and reputation (dos Santos et al., 2023).

According to Agrawal and Singh, (2019), RL is a process of planning and controlling the flow of raw material, stock management, finished goods and information from the point of consumption until the point of origin.

RL has therefore become a competitive requirement oriented towards sustainability. However, the limited resources available for implementing strategies to develop RL has significantly affected operational costs and compromised expectations (Dabees et al., 2023).

2.2. Multi-Criteria Decision-Making in implementing RL

A search of articles on Web of Science identified, until February 2025, 121 studies related to the topic of RL resorting to MCDM. Analysis of them reveals that RL has been widely studied, due to its importance for sustainability and efficient supply chains. These studies approach RL from different perspectives, namely selection of suppliers, logistics network management, performance assessment and the environmental impact of operations.

In dealing with the topic, researchers have used diverse methodologies, highlighting among them the Analytic Hierarchy Process (AHP), the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Mixed-Integer Linear Programming (MILP) and the Decision Making Trial and Evaluation Laboratory (DEMATEL). MCDM methods are found to be fundamental for decision-making, as they allow simultaneous evaluation of multiple criteria and identification of balanced solutions to problems associated with RL.

Standing out in the analysis of the literature is the topic of management of RL suppliers, due to the impact partner selection can have on operational efficiency and supply chain sustainability. Chen et al., (2021), Abu Seman et al., (2019) and Mishra and Satapathy, (2022) study the choice of RL suppliers from MCDM approaches, integrating economic, environmental and social criteria to determine the most efficient options. These studies showed that sub-contracting RL activities to specialised suppliers can contribute to greater profitability. In turn, Wang et al., (2021) and Kafa et al., (2014) used hybrid models of MCDM, by combining the AHP method and FTOPSIS, to compare suppliers and thereby define the main strategic criteria for outsourcing of RL operations. Pourjavad and Mayorga, (2018) also contribute to the subject through a study that integrates fuzzy set theory in decision-making to cope with the uncertainty and subjectivity associated with the choice of logistics partners.

The articles analysed in this research also emphasize the environmental aspect of RL, and show a significant increase in companies' concerns about combining their logistics operations with the principles of sustainability. Here, efficient RL management is recognised as a strategic factor aiming to respond to environmental requirements and improve organisations' economic and operational performance.

Boudali et al., (2022) demonstrated that efficient RL management helps to lower costs, and Bajar et al., (2022) concluded that structured implementation of sustainable practices increases competitiveness and customer satisfaction. Ali et al., (2021) and Gao, (2019) incorporated carbon restrictions in RL models, applying methods such as DEMATEL and AHP to assess the effectiveness of those practices. These studies demonstrate that companies that adopt RL manage to reduce their carbon footprint significantly, comply with environmental regulations and also ensure economic viability.

The literature also highlights the concern about optimizing logistics networks and the location of premises. Li and Huang, (2018) Couto and Lange, (2017) and Aljuneidi and Bulgak, (2020) studied the configuration of ideal RL networks. To do so, they applied MILP models and heuristic algorithms to determine the best distribution of centres for collection and processing of returned material. By analysing different scenarios, the authors concluded that the strategic location of premises can maximize logistics efficiency and lower operational costs. In the same connection, Tian et al., (2019) applied the grey DEMATEL method to evaluate different processes of collecting vehicles at the end of their lives in China, identifying solutions that are economically viable and minimize the environmental impacts.

Combining RL and sustainability is not limited to supplier management or reducing the carbon footprint, but also extends to recovery of materials. In this aspect, various studies demonstrate that the application of MCDM models supports optimization of re-use and recycling processes, contributing to a reduction in waste and reducing the dependence on natural resources.

Biancolin et al., (2023) analysed how RL can be integrated in the principles of the circular economy, through models oriented towards re-manufacturing and re-use of materials. Noroña and Acot, (2020) and Simsek et al., (2022) also analysed the relation between product life-cycle and RL, applying MCDM analysis models to assess different recycling and re-manufacturing strategies. The results of these studies show that MCDM methods can identify solutions that are both sustainable and economically viable, promoting the valorisation of products at the end of their life-cycle and reducing the need for new raw material.

Besides optimizing the re-use of materials, another greatly analysed topic in the literature is the selection of strategies to implement RL. Strategic decision-making in this domain has been the subject of various studies, trying to identify the most effective approaches in the different organisational situations. Prakash and Barua, (2016) proposed a model based on the FAHP process to evaluate and prioritize criteria in selecting RL partners. Zhang et al., (2021) developed an MCDM methodology considering the circular economy in choosing suppliers for re-manufacturing, combining AHP and TOPSIS to define the best options. Senthil et al., (2018) also applied hybrid methods of MCDM to analyse the risks of RL, using case studies in firms recycling plastic.

The most recent research has also focused on integrating advanced technology in RL operations, aiming to respond to the requirements of efficiency and digitalization.

Krstic et al., (2022) analysed the applicability of Industry 4.0 technology in the RL sector and used the MCDM model based on the best-worst method (BWM) and the COmprehensive Distance Based Ranking (COBRA) classification technique. The results demonstrated that the adoption of digital technology significantly increases the efficiency of RL processes and lowers operational costs. Ocampo et al., (2019) and Zarbakhshnia et al., (2023) applied MCDM approaches to optimize the location of collection and distribution centres by combining DEMATEL, Analytic Network Process (ANP) and AHP.

Finally, assessing the performance of RL activities is also a very important field of research in identifying the most effective medium and long-term strategies. Hernandez et al., (2016) used the ANP technique to identify relations among RL activities and determine the strategies with the best results in the long term. Mohammadkhani and Mousavi, (2022) proposed a decision framework based on BWM to assess RL service providers, in order to choose the most suitable option considering operational, economic and environmental criteria. Kumar et al., (2022) used a method for sorting criteria based on approximate set theory to define the most important factors when choosing RL suppliers.

Summarising, the literature review shows that multi-criteria decision methods are used to solve challenges associated with RL. The studies analysed confirm that, whatever the approach adopted, the use of MCDM methods is decisive in structuring decisions and optimizing RL practices in organisations

Based on this analysis, and in line with what was proposed by Prajapati et al., (2023) in a study in India, here three models are proposed for the implementation of RL in industries: internal RL (IRL), RL with joint venture (JVRL) and externalized RL (ERL).

2.3. Criteria for evaluating the RL strategy

Nowadays, companies recognise the importance of protecting the environment and conserving natural resources, and their responsibilities in this matter, making efforts to adopt more sustainable practices. However, effective integration of RL implies a restructuring of operational flows and careful management of the supply chain (Rachih et al., 2022).

Despite the economic benefits that can arise from RL, its implementation presents significant challenges for firms trying to remain competitive and simultaneously accept responsibility in social and environmental aspects, in the scope of a sustainable development model (Abdel-Basset et al., 2021).

Here, selecting appropriate criteria is determinant for successful implementation of RL. Le (2023) identifies three fundamental areas to consider in this process: economic, competitive and environmental factors, reflecting companies' main reasons for adopting RL practices. In this line of thought, Fidlerova et al., (2021) specifies that the most relevant criteria include cost reduction, minimizing the environmental impact, gaining a competitive advantage, economic benefits and operational flexibility.

Considering these contributions, this study adopts the criteria and sub-criteria used by Prajapati et al. (2023), presented in Table 1, giving a wide-ranging structure of analysis adjusted to strategic assessment of RL.

Table 1 – Criteria and Sub-Criteria based on Prajapati et al. (2023)

Criterion	Sub-Criterion	Definition
Cost	Technical specialization	Cost associated with taking on a technically qualified person or a company to implement reverse logistics.
	Initial investment (	Cost associated with creating a unit for processing returns, including machines and infrastructure.
	Transport costs in reverse logistics	Cost of transporting returns from collection points to the processing units.
	Risks of reverse logistics	Inherent risks of implementing RL, such as design risks, environmental risks, technical risks and legal risks.
	Stock management costs in reverse logistics	Cost associated with storing and managing returns.
Benefit	Reduced production costs	Carrying out the 6R operations in returns can reduce production costs significantly.
	Recovering value from waste	Recovering the value of the product after its primary use.
	Government policies and regulations	Government policies favouring the implementation of RL are another advantage.
	Social responsibility	Improved public image, customer loyalty and greater collaborator satisfaction lead industries to adopt RL.
	Competitive advantage	RL can reduce costs through strategic re-use of products or through providing services at competitive prices.
	Reduced emissions	Implementing RL reduces waste and the carbon footprint.
	Energy savings	RL allows significant energy savings, reducing the processing of raw material, reducing the industry's waste and maximizing the use of transport.
	Ethical and transparent practices	Maintaining ethical standards is a good practice that improves the company's reputation and image.

2.4. Proposed strategy for implementing RL

Based on the literature and particularly the studies by Prajapati et al., (2023), Gu et al., (2019) and Gu et al., (2021), this research proposes three models for implementation of RL in the textile and footwear industries: internal RL, partnership and sub-contracting. Although many companies have already adopted RL practices, it is necessary to decide if they should perform activities by themselves, resort to partnerships or sub-contract to third parties.

In the past, SMEs only acquired raw material outside and carried out all other operations internally. However, to remain competitive in an increasingly dynamic market, these companies have sub-contracted some of their activities. Sub-contracting consists of contracting external entities to perform certain business functions, such as manufacture, maintenance, accounting or logistics (Kumari et al., 2015). This approach allows firms to focus on their essential competences, while trying to reduce costs related to secondary activities (Sanders et al., 2007).

In the scope of RL, Khaleie et al., (2012) found that sub-contracting can contribute to reduced costs, since external service providers frequently benefit from scale economies. Moreover, by transferring these activities to third parties, firms can reduce their asset base and use the capital for other more productive areas.

According to Kumari et al. (2015), the advantages of sub-contracting RL include lower costs, less uncertainty, less need for capital investment, a greater focus on the main activities, greater flexibility, greater capacity to respond to customers and easier access to new technology. Nevertheless, these advantages only arise if the right decisions are made regarding what to sub-contract, when to sub-contract and who to trust with these operations. Otherwise, sub-contracting can become complex and create additional costs, due to problems such as the lack of flexibility, operational complexity and difficulties in managing service providers (Tadelis, 2007).

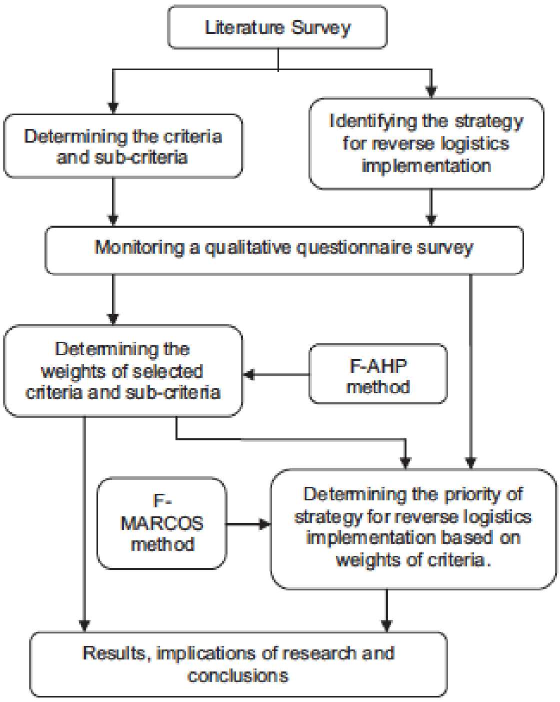
In any of these approaches, the company has to interact with different entities, negotiating prices, conditions and responsibilities, which requires efficient management of contractual relations (Mirmousa & Dehnavi, 2016). In the form of internal RL, the company directly manages all activities related to RL, which lets it keep total control of the quality, quantity and flows of information. This approach gives a faster response capacity and direct access to operational data, but requires high investment in technology, human resources and management, besides presenting higher risks and the absence of scale economies (Yang et al., 2024).

Between these two models are partnerships. In this case, various companies that are geographically close or with similar products cooperate to create a shared structure of collection, logistics and reprocessing. This collaboration allows shared investment, operational costs, technology, labour, ownership, profits and even the associated risks (Gu et al., 2021).

Similarly, Gu et al., (2019) claim that partnerships give advantages such as scale economies, shared resources, risks and average operational costs, despite only moderate control of the RL, due to the need for consensus among partners.

3. Research framework proposed

This study proposes a methodological model adopted to identify the most suitable strategy for implementation of RL. This model aims to support strategic decision-making in the textile and footwear industries, based on an MCDM approach.



The first phase of the process consists of defining the viable alternatives when implementing RL: internal RL, RL through partnership and externalized RL. In parallel, the criteria and sub-criteria influencing selection of the strategy are established, based on the specialized literature review and on previous studies recognised in the area.

Afterwards, qualitative data are gathered from specialists in the sector, by carrying out a survey to assess the relative importance of each sub-criterion. The sub-criteria are weighted using the FAHP method, which is particularly suitable to handle the uncertainty and subjectivity inherent to human evaluations, attributing more reliable weights to the elements considered.

After determining the weights, the strategic alternatives are evaluated based on the F-MARCOS method. This method allows direct comparison of the alternatives, by attributing normalized scores that consider the ideal solution and the least favourable one, facilitating identification of the most advantageous option in an objective and grounded way.

The most appropriate strategy is selected from the combination of sub-criteria weights with the scores given to each alternative, making it possible to form a hierarchy of the options according to their suitability in the specific context of the companies analysed.

Figure 1 presents the conceptual model developed, illustrating the stages in the process of strategic selection for implementation of RL.

Figure 1 – Research proposal based on Prajapati et al. (2023)

4. Methodological approach

The most suitable approach for implementation of RL involves various factors, the process being a case of MCDM. The complexity of the issue arises from the need to assess simultaneously economic, environmental, technical and social variables, as well as the strategic impacts associated with each alternative. MCDM methods are tools that can support decision-making in various domains, as they allow consideration of various criteria with different levels of importance (Stević et al., 2020).

MCDM is a robust approach widely applied in decision-making, allowing analysis of the alternatives based on different criteria (Alpay & Feyzio, 2021). In complex contexts, its advantage is clear, principally when it is important to combine economic, environmental and operational objectives (Manirathinam et al., 2023).

Standing out among the MCDM methods used are FAHP and Fuzzy F-MARCOS, both able to handle the evaluations of multiple specialists. These methods can analyse the inexactness and ambiguity associated with the preferences of different specialists, thereby ensuring a more rational and grounded decision (Boral et al., 2020).

Given this scenario, this study proposes a hybrid model combining the FAHP and F-MARCOS methods, reconciling the advantages of both methods for a more precise, consistent and structured evaluation. The methodology used aims to study selection of the most appropriate strategy for implementation of RL in SMEs in the footwear and textile sectors, and suggest an efficient decision-making process in line with the specific challenges of these industries. This approach contributes to the adoption of sustainable and competitive solutions responding to the environmental and economic demands of today's market.

4.1. Fuzzy AHP Process

MCDM aims to identify the alternative that best satisfies a set of previously defined criteria or objectives, and so a rigorous, grounded ordering process is essential. Standing out among the most commonly used methods in this area is the AHP process, which has been applied to structure and solve complex decision-making (Saaty, 1990). The main advantage of AHP lies in its capacity to incorporate intangible criteria, frequently present in situations of high uncertainty, joining mathematical simplicity with an intuitive structure, which makes it more accessible than other MCDM methods (Javanbarg et al., 2012).

In recent years the fuzzy version of this method, FAHP, has been developed, with a growing number of studies exploring new areas of application. Recent studies have demonstrated the importance of FAHP in the most varied sectors, such as health, energy, transport, aviation and information technology. However, the method has stood out in studies focused on the green supply chain and the circular economy, contexts where the complexity and uncertainty in decision-making require more robust methodologies (Sirvent et al., 2022).

The method stands out due to the capacity to deal with decision-makers' linguistic and subjective assessments, one of its main characteristics which gives a more realistic representation of human preferences (Sirvent et al., 2022).

The advancement of FAHP has been stimulated by various researchers who have contributed to developing Saaty's theory. After the original method was published, Van Laarhowen and Pedrycs (1983) proposed a method where judgements are expressed through triangular fuzzy numbers (TFNs).

Subsequently, Chang (1996) introduced the FAHP analysis method, which could reduce the complexity of the algorithm and consequently stimulate its practical application. This advancement made FAHP more accessible, contributing to its adoption in different organisational and research contexts.

In the method proposed by Chang (1996), the comparisons between criteria are made using TFNs. Based on the comparison matrix, the extended synthetic values of each criterion are calculated, providing a more robust and flexible assessment of the alternatives. This process can quantify the relative preference of each alternative according to the criteria defined. In the method suggested by Chang (1996), each element x_i is considered individually and submitted to the extension analysis for each criterion g_j. Therefore, for each element, m values of extension analysis are obtained, represented as follows:

$M^1 g_j, M^2 g_j, \ldots, M^m g_j, \quad i = 1, 2, \ldots, n$

where all the $M^{m}g_{j}$ (j = 1, 2, ..., m) correspond to triangular fuzzy numbers.

The next steps describe the functioning of the method as proposed by Chang (1996) and used in the work by Prajapati et al. (2023) and Rodrigues et al. (2014).

a) Calculating the Value of the Fuzzy Synthetic Extension

The value of the fuzzy synthetic extension in relation to the object i is calculated, according to the equation:

$$S_i = \sum_{j=1}^{m} M_{g_i}^{j} \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} \right]^{-1}$$

$$\sum_{j=1}^{m} M_{g_i}^{j} = \left(\sum_{j=1}^{m} x_j, \sum_{j=1}^{m} y_j, \sum_{j=1}^{m} z_j \right)$$

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} = \left(\sum_{i=1}^{n} x_i, \sum_{i=1}^{n} y_i, \sum_{i=1}^{n} z_i \right)$$

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} z_i}, \frac{1}{\sum_{i=1}^{n} y_i}, \frac{1}{\sum_{i=1}^{n} x_i} \right)$$

where x is the value of the lower limit, y is the most promising value and z is the value of the upper limit.

b) Comparison of fuzzy values

The degree of possibility of $S2(x2,y2,z2) \geq S1(x1,y1,z1)$ is defined as follows:

$$V(S_2) \geq V(S_1) = \overset{SUP}{yx} \left[\min\left(\mu_{S_1}(x), \mu_{S_2}(y) \right) \right]^{y \geq x}$$

and expressed as follows:

$$V(S_2) \geq V(S_1) = hgt(S_1 \cap S_2) = \mu_{S_2}(d)$$

$$\mu_{S_2}(d) = \begin{cases} 1, & y_2 \geq y_1 \\ 0, & x_1 \geq z_2 \\ \dfrac{x_1 - z_2}{(y_2 - z_2) - (y_1 - x_1)}, & \end{cases}$$

where d is the ordinate of the highest point of intersection between mS1 and mS2. To compare S1 and S2, the values of V(S1) ≥ V(S2) and V(S2) ≥ V(S1) are necessary.

c) Calculating the weight of priority

The degree of possibility of a convex fuzzy number being greater than k convex fuzzy numbers S_i (i = 1,2,...,k) can be defined as follows:

$$V(S \geq S_1, S_2, \ldots, S_k) = V[(S \geq S_1),\ (S \geq S_2),\ \ldots,\ (S \geq S_k)]$$
$$= \min V\ (S \geq S_i),\ i = 1,\ 2, \ldots, k$$

assuming that $d_0(A_i)$ = minV(Si≥Sk) k = 1,2, ..., n and k ≠ i.
Therefore, the equation of the weight vectors is given as follows:

$$W' = (d'(A_1),\ d'(A_2),\ \ldots,\ d'(A_m))^T$$

d) Calculating the normalized weight vector

The normalized weight vectors are calculated as follows:

$$W = (d(A_1),\ d(A_2),\ \ldots,\ d(A_m))^T$$

W is a non-fuzzy number. According to the decreasing order of W weights, the criteria can be classified, indicating their importance and applicability.

4.2. Fuzzy measurement of the alternatives and classification according to the compromise solution method

Stević et al. (2020) presented the MARCOS method as an innovation in the field of MCDM, conceived to classify alternatives based on previously defined criteria. The authors applied this method to selecting and prioritizing suppliers in the health sector, demonstrating its effectiveness in solving complex decisions. To validate the robustness of the approach, they compared the results obtained with the six established MCDM methods, concluding that the MARCOS was a viable alternative, which justified its introduction as a new model to support decision-making.

MARCOS is a relatively recent MCDM methodology, grounded on functions of usefulness and stands out by integrating the approach based on ratios with ordering by points of reference. Compared to other MCDM methods, MARCOS emerges as a simple, robust tool, and more suitable to optimize multiple objectives (Boral et al., 2020).

From the beginning of the assessment process, this method considers the ideal and anti-ideal solutions, analysing each alternative's relation with these two extremes. Based on these relations, the degree of usefulness of each alternative is determined, reflecting its proximity to the ideal solution and distance from the anti-ideal one. This procedure ensures stability in the final classification and choice of solution, even when the problem involves a high number of criteria and alternatives (Stević et al., 2020).

The MARCOS algorithm is based, therefore, on defining the relation between the alternatives and the values of reference, from which the functions of usefulness are calculated. These functions serve as the basis for classification by compromise, determining the relative position of each alternative in relation to the points of reference. Therefore, the best alternative will be the one presenting the highest degree of usefulness, being closest to the ideal solution and simultaneously furthest from the anti-ideal one (Stević et al., 2020).

Aiming to extend the method's applicability, Stankovic et al. (2020) improved MARCOS by integrating fuzzy set theory, giving rise to the F-MARCOS method. This version was applied in assessing road traffic risk, considering variables in a dynamic context subject to uncertainty. The effectiveness of F-MARCOS was validated in comparison to two other MCDM methodologies, demonstrating its superiority in analysing and evaluating complex scenarios.

In this study, F-MARCOS is used to support definition of the most efficient strategy for implementation of RL. The choice of this method is justified due to its capacity to cope with uncertainty and the reliability demonstrated in evaluating multiple alternatives. The methodology adopted follows the structure proposed by Stankovic et al. (2020) and will be presented in detail in the next steps.

a) Building the initial fuzzy decision matrix

MCDM models begin by defining a set of n criteria and m alternatives, resulting in an initial fuzzy decision matrix.

b) Expanding the initial fuzzy matrix

The initial matrix is extended by identifying the fuzzy anti-ideal (Ã(AI)) and fuzzy ideal (Ã(ID)) solutions, to serve as references in analysing and comparing the alternatives.

$$\tilde{X} = \begin{array}{c} \\ \tilde{A}(AI) \\ \tilde{A}_1 \\ \tilde{A}_2 \\ \dots \\ \tilde{A}_m \\ \tilde{A}(ID) \end{array} \begin{array}{c} \begin{array}{cccc} \tilde{C}_1 & \tilde{C}_2 & \dots & \tilde{C}_n \end{array} \\ \left[\begin{array}{cccc} \tilde{x}_{ai1} & \tilde{x}_{ai2} & \dots & \tilde{x}_{ain} \\ \tilde{x}_{11} & \tilde{x}_{12} & \dots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \dots & \tilde{x}_{2n} \\ \dots & \dots & \dots & \dots \\ \tilde{x}_{m1} & \tilde{x}_{22} & \dots & \tilde{x}_{mn} \\ \tilde{x}_{id1} & \tilde{x}_{id2} & \dots & \tilde{x}_{idn} \end{array} \right] \end{array}$$

The fuzzy anti-ideal solution (Ã(AI)) represents the worst alternative, while the fuzzy ideal solution (Ã(ID)) corresponds to the alternative with the best performance. Depending on the type of criterion considered, Ã(AI) and Ã(ID) are determined by applying the following equations:

$$\tilde{A}(AI) = \min_i \tilde{x}_{ij} \; if \; j \in \; B \; and \; \max_i \tilde{x}_{ij} \; if \; j \in C$$

$$\tilde{A}(ID) = \max_i \tilde{x}_{ij} \; if \; j \in \; B \; and \; \min_i \tilde{x}_{ij} \; if \; j \in C$$

B belongs to the group of maximization criteria, while C belongs to the group of minimization criteria.

c) Constructing the normalized fuzzy matrix $\tilde{N} = [\tilde{n}_{ij}]_{m \times n}$ obtained by applying the previous equations

$$\tilde{n}_{ij} = \left(n_{ij}^{l}, n_{ij}^{m}, n_{ij}^{u}\right) = \left(\frac{x_{id}^{l}}{x_{ij}^{u}}, \frac{x_{id}^{l}}{x_{ij}^{m}}, \frac{x_{id}^{l}}{x_{ij}^{l}}\right) if\ j \in C$$

$$\tilde{n}_{ij} = \left(n_{ij}^{l}, n_{ij}^{m}, n_{ij}^{u}\right) = \left(\frac{x_{ij}^{l}}{x_{id}^{u}}, \frac{x_{ij}^{m}}{x_{id}^{u}}, \frac{x_{ij}^{u}}{x_{id}^{u}}\right) if\ j \in B$$

The elements $x_{ij}^{l}, x_{ij}^{m}, x_{ij}^{u}$ and $x_{id}^{l}, x_{id}^{m}, x_{id}^{u}$ represent the elements of the matrix X

d) Calculating the weighted fuzzy matrix $\tilde{V} = \left[\tilde{v}_{ij}\right]_{m \times n}$ **matrix V**

is obtained by multiplying matrix N by the fuzzy weight coefficients of the wj criterion according to the equation:

$$\tilde{v}_{ij} = \left(v_{ij}^{l}, v_{ij}^{m}, v_{ij}^{u}\right) = \tilde{n}_{ij} \otimes \tilde{w}_{j} = \left(n_{ij}^{l} \times w_{j}^{l}, n_{ij}^{m} \times w_{j}^{m}, n_{ij}^{u} \times w_{j}^{u}\right)$$

e) Calculating the fuzzy matrix S_i using the following equation:

$$\tilde{S}_i = \sum_{i=1}^{n} \tilde{v}_{ij}$$

where $\{S\}_i\left(s_i^l, s_i^m, s_i^u\right)$ represents the sum of the elements of the weighted fuzzy matrix V

f) Calculating the degree of usefulness of the alternatives K_i by applying the equations

$$\tilde{K}_i^{-} = \frac{\tilde{S}_i}{\tilde{S}_{ai}} = \left(\frac{s_i^l}{s_{ai}^u}, \frac{s_i^m}{s_{ai}^m}, \frac{s_i^u}{s_{ai}^l}\right)$$

$$\tilde{K}_i^{+} = \frac{\tilde{S}_i}{\tilde{S}_{id}} = \left(\frac{s_i^l}{s_{id}^u}, \frac{s_i^m}{s_{id}^m}, \frac{s_i^u}{s_{id}^l}\right)$$

g) Calculating the fuzzy matrix T_i using the equation:

$$\tilde{T}_i = \tilde{t}_i = \left(t_i^l, t_i^m, t_i^u\right) = \tilde{K}_i^{-} \oplus \tilde{K}_i^{+} = \left(k_i^{-l} + k_i^{+l}, k_i^{-m} + k_i^{+m}, k_i^{-u} + k_i^{+u}\right)$$

Next, it is necessary to determine a new fuzzy number D using the equation:

$$\tilde{D} = \left(d^l, d^m, d^u\right) = \max_i \tilde{t}_{ij}$$

and then, it is necessary to break down the D using the expression thereby $df_{crisp} = \frac{l+4m+u}{6}$ obtaining the dfcrisp number.

h) Determining the functions of usefulness in relation to the ideal $f\left(\tilde{K}_i^+\right)$ solution and anti-ideal solution $f\left(\tilde{K}_i^-\right)$

$$f\left(\tilde{K}_i^+\right) = \frac{\tilde{K}_i^-}{df_{crisp}} = \left(\frac{k_i^{-l}}{df_{crisp}}, \frac{k_i^{-m}}{df_{crisp}}, \frac{k_i^{-u}}{df_{crisp}}\right)$$

$$f\left(\tilde{K}_i^-\right) = \frac{\tilde{K}_i^+}{df_{crisp}} = \left(\frac{k_i^{+l}}{df_{crisp}}, \frac{k_i^{+m}}{df_{crisp}}, \frac{k_i^{+u}}{df_{crisp}}\right)$$

Afterwards, it is necessary to defuzzify to $\tilde{K}_i^-$, $\tilde{K}_i^+$, $f\left(\tilde{K}_i^+\right)$, $f\left(\tilde{K}_i^-\right)$ and apply the next step:

i) Determining the usefulness function of the fK_i alternatives by the equation:

$$f(K_i) = \frac{K_i^+ + K_i^-}{1 + \frac{1-f\left(K_i^+\right)}{f\left(K_i^+\right)} + \frac{1-f\left(K_i^-\right)}{f\left(K_i^-\right)}};$$

j) Classifying the alternatives based on the final values of the usefulness functions.

Finally, the alternatives are classified based on the final values obtained through the usefulness function, reflecting the relative position of each alternative regarding the ideal and anti-ideal solutions. This usefulness value can form a hierarchy of the options analysed, identifying the one coming closest to the ideal solution, and consequently representing the most advantageous choice in the context assessed.

4.3. Data collection and characterisation of the sample

A questionnaire was elaborated and sent to various Portuguese SMEs in the textile and footwear sectors, in order to gather opinions about the implementation of RL. The questionnaire was considered the most appropriate tool to understand companies' perceptions and practices regarding the management of reverse flows of products and material. It consisted of three main sections: the first gathered demographic data from the participating companies, the second aimed to compare, in pairs, the relevant sub-categories in choosing the best RL strategies, and the third was a decision-making matrix evaluating different alternatives based on those sub-criteria. A response was requested from those responsible for logistics or other activities related to reverse process management in the companies. The participants were invited to share their opinions and preferences, using the linguistic scale provided, in order to facilitate assessment of the strategic alternatives and decisions when implementing reverse logistics.

For this study, 40 Portuguese SMEs in the footwear and textile sectors were contacted through online channels, namely e-mail and institutional contact platforms. Companies were selected based on their availability to collaborate in the study. During a period of three weeks, 14 complete answers were received. This number corresponds to the number of specialists used in the study by Sirisawat and Kiatcharoenpol (2018). According to Saaty, (1987) the method is based on specialists' opinion, with the quality of this being more important than the size of the sample.

As shown in Table 2, of the 14 participating companies, 8 belong to the footwear sector and 6 to the textile sector. Regarding the experience of the executives who responded to the survey, 14% have less than 5 years of experience, 43% between 5 and 10 years, and 33% more than 10 years of experience.

Total number of participating companies	14
Footwear companies	8
Textile companies	6
Executive's experience	Under 5 years:14% Between 5 and 10 years:43% Over 10 years:33%

Table 2– General information about the companies and respondents

Despite the total number of companies contacted, the number of responses obtained was considered sufficient for a preliminary and indicative analysis, considering the exploratory characteristics of the study and the specific nature of the sector. In addition, the responses gathered gave access to relevant, up-to-date information about the practices and challenges faced by these firms in the specific context of the domestic market.

5. Data Analysis

5.1. Calculating the relative importance of the selected criteria

The F-AHP method was used to evaluate the relative importance of the 13 criteria selected. The weight attributed to each criterion resulted from analysis of the data obtained in the survey, considering the mode of linguistic values as a reference for comparison between pairs. After converting the linguistic judgements into numerical values, the procedures described in Section 4.1 were applied to calculate the respective weights. Table 3 presents the fuzzy and crisp weights attributed to each criterion. Based on the crisp weights, a hierarchy of the criteria's importance was established. The results indicate that transport costs, competitive advantage and government policies are key factors to be considered by industries intending to implement RL practices in their respective supply chains. Therefore, these criteria are revealed to be determinant in defining sustainable and efficient strategies.

Table 3 – Relative importance of the criteria

Sub-Criterion	x	Y	z	Ranking
Technical specialization	0.022	0.024	0.029	13º
Initial investment	0.102	0.111	0.116	4º
Transport costs in reverse logistics	0.156	0.18	0.193	1º
Risks of reverse logistics	0.038	0.039	0.043	10º
Stock management costs in reverse logistics	0.049	0.05	0.052	8º
Reduced production costs	0.084	0.085	0.085	5º
Recovering value from waste	0.069	0.077	0.083	6º
Government policies and regulations	0.107	0.114	0.12	3º
Social responsibility	0.034	0.035	0.04	11º
Competitive advantage	0.136	0.155	0.167	2º
Reduced emissions	0.038	0.042	0.047	9º
Energy savings	0.064	0.064	0.064	7º
Ethical and transparent practices	0.023	0.025	0.029	12º

5.2. Assessing the strategies for implementation of RL based on the weights of the selected criteria

After determining the weights attributed to each criterion, the strategies for implementing RL were assessed through the F-MARCOS method. The responses gathered in the survey were analysed, having calculated the mode the linguistic responses. Subsequently, according to the procedures described in Section 4.2, the necessary calculations were made to obtain the usefulness function associated with each strategy. Table 4 presents the results regarding the degree of usefulness, the usefulness function and the respective defuzzified value of the alternatives considered. Based on these results, the strategy with the highest usefulness value is the most appropriate for implementation of RL.

Table 2 -Assessment of strategies

Strategy	Si	Ki-	Ki+	f(K)	Ranking
Internal	0,726	1,117	0,726	0,578	3
Partnership	0,825	1,269	0,825	0,657	2
Sub-contracting	0,934	1,421	0,924	0,735	1

The results demonstrate that in the context of Portuguese SMEs in the footwear and textile sectors, sub-contracting is the preferred strategy for implementation of RL. Strategic partnerships emerge in second place, followed by internal development of RL. This hierarchy shows a tendency for SMEs to turn to external solutions in order to benefit from RL and promote sustainable practices.

6. Discussion of the results

The environmental impacts arising from production chain processes, as well as the effects already caused by these activities and their potential future impacts, have increased the debate about environmental issues. In this context, managers' interest in adopting RL has intensified, in response to more stringent environmental legislation, consumers' growing demands and the benefits these practices bring for the organisation's image (dos Santos et al., 2023).

Here, thirteen criteria were defined in order to evaluate three alternative strategies regarding the implementation of RL in Portuguese SMEs in the footwear and textile sectors, namely internal management of RL, the formation of partnerships or sub-contracting. These criteria covered economic, technical, social and environmental aspects considered relevant for the decision-making process, allowing a wide-ranging and grounded analysis of the options studied.

Based on the results obtained, the criteria were classified in order of importance as follows: transport costs of reverse logistics, competitive advantage, government policies and regulations, initial investment, reduced production costs, recovering value from waste, energy savings, stock management costs in reverse logistics, reduced emissions, risks of reverse logistics, social responsibility, ethical and transparent practices, and finally, technical specialization. This order shows that the participating companies give greater relevance to factors that can stimulate their competitiveness and operational efficiency.

However, in the study by Prajapati et al., (2023) the criteria were organised as follows: government policies and regulations, risks, reduced emissions, technical specialization, transport costs in reverse logistics, social responsibility, energy savings, initial investment, inventory management in reverse logistics, ethical and transparent practices, reduced production costs, recovering value from waste and competitive advantage.

The prominence given to the transport costs of RL reflects major concern about containing costs and the economic efficiency of operations, while competitive advantage clearly shows these companies' focus on customer satisfaction and differentiation in the market.

Similarly to what was found in other research (e.g. Prajapati et al. (2023); Agrawal et al., (2016); Serrato et al., (2007); Wang et al., (2021), this study concludes that firms in the sector analysed show a preference for sub-contracting RL operations. This strategy appears in first place, followed by the formation of partnerships and finally the option to keep RL operations internal. Various reasons help to explain this choice by companies. According to Prajapati et al. (2023), RL is still a relatively recent practice and there is still uncertainty regarding its effectiveness. By sub-contracting, companies are able to concentrate on their core business, delegating collection operations to entities that specialize in these processes and thereby lowering the risks inherent in implementation. Sub-contracting allows greater operational flexibility, access to specialized technical knowledge and more efficient use of the available resources.

7. Implications, limitations and suggestions for future research

This study investigates the cost and benefit criteria in implementing an RL network, providing industries with a support base on which to choose the most appropriate implementation strategy for their needs.

Besides financial performance, nowadays the social and environmental impact has a fundamental role in assessing companies' performance. It is therefore crucial for firms to develop RL solutions that are effective, competitive and customer-focused.

Turning to contributions from specialists in the area, it was possible to elaborate a normative model that aims to support companies in choosing the most suitable RL strategy, above all in scenarios marked by irregular and unpredictable returns. Inefficient management of returns can mean a significant loss of value, and so it is essential that firms are prepared to respond to different types of uncertainty, with solutions adapted to each situation.

This research provides managers with a clearer vision of the various approaches to RL and allows identification of more effective practices. It used a decision-making model that combines the F-AHP and F-MARCOS methods, to identify the most appropriate strategy considering the specific demands of each organisation.

F-AHP stands out as a consolidated methodology to support multi-criteria decision-making, while the more recent F-MARCOS demonstrates great accuracy in analysing alternatives. Incorporating fuzzy numbers helps to reduce distortions caused by imprecise data, increasing the model's reliability. Therefore, the framework proposed allies rigour and practical usefulness.

The applicability of the model was validated in various studies with industries, allowing them to identify the most advantageous RL strategy. However, the model is flexible enough to be adopted by companies in different sectors and geographical areas, since the issue of managing waste and returns is transversal to most countries.

Despite the contributions of this study, it is important to recognise some limitations, particularly the low number of companies surveyed, associated with the fact of the sample being formed exclusively by Portuguese firms in the footwear and textile sectors. These characteristics limit the representativeness of the data and prevent generalization of the result to other sectors, international contexts or larger organisations. Moreover, the analysis focused on only 13 previously defined criteria and considered three specific strategies when implementing RL, which restricts the scope of the study and omits other potentially relevant factors and approaches.

The limitations give rise to various suggestions for future research on the topic. A first is for studies examining RL strategies based on different criteria in order to cover a wider range of factors influencing the adoption and success of those strategies. A final suggestion is to apply the model used here to companies in the footwear and textile sectors in other countries, aiming to validate its applicability in different industrial and cultural contexts.

8. Conclusion

The implementation of RL practices is recognised today as a fundamental tool helping to mitigate the environmental impacts associated with the textile and footwear industries. These sectors, fundamental from the economic and social point of view, face challenges in managing waste and the sustainability of their production processes. In this context, it is important to implement effective RL strategies in response to growing environmental requirements and help companies evolve towards more sustainable and resilient business models.

The model proposed here, combining the F-AHP and F-MARCOS methods, emerges precisely as specific support for strategic decision-making. By evaluating the alternatives based on economic, environmental and operational criteria, the model provides an approach adapted to the situation of SMEs. The complementary nature of the two methods contributes to a more robust and realistic analysis of the options available.

The results of the study show that SMEs in the Portuguese footwear and textile sector prefer to sub-contract RL operations. This strategy is recognised for its operational flexibility, cost reductions and the possibility of obtaining specialized technical competences. Besides the advantages described above, the strategy allows companies to focus on their main activities.

Concerning the criteria, transport costs, competitive advantage and government policies were those highlighted in the study.

Transport is a major challenge in implementing the RL network, due to its cost implications. In turn, competitive advantage shows the need for companies to respond to customers' expectations. Finally, government policy is a factor that can help stimulate or pressurize companies to adopt more efficient environmental practices.

This study contributes to improved understanding of RL as a strategy and proposes guidelines for its implementation in the textile and footwear sector. Nevertheless, it presents limitations, such as the small number of participating companies and focusing exclusively on Portugal. Future research could extend the analysis to other countries and different sectors.

It would also be pertinent to explore new decision-making criteria, as well as going deeper into the role of emerging technology and organisational and cultural factors in adopting RL. This could reinforce the usefulness of the model, supporting companies in the transition to more sustainable and effective practices in line with present and future challenges.

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Part III

Chapter 7

7.1. Final Considerations

The introduction contained the general objectives of this research: (1) to identify the main barriers to implementing RL in small and medium-sized enterprises (SME) in the textile and footwear sectors; (2) map scientific production on RL and sustainability, highlighting research trends, theoretical approaches and application contexts; (3) analyse the inter-relation between those barriers, assessing how they influence each other; and (4) propose specific strategies that can mitigate the obstacles identified and encourage effective adoption of RL in these sectors.

Chapter 2 corresponds to a systematic literature review, summarising the state-of-the-art on RL and sustainability, identifying gaps and orienting the subsequent empirical research. Chapter 3, through the Fuzzy Delphi Method and with the support of specialists, identified and validated the main barriers to implementing RL in the SMEs studied. Chapter 4 deepened the analysis of these barriers through application of ISM and a MICMAC analysis, revealing the interdependences between them and allowing better understanding of their hierarchy of influence.

Chapter 5 is devoted to a qualitative case study, based on semi-structured interviews, showing managers' perceptions of the practical difficulties faced and the solutions implemented. In Chapter 6, a hybrid multi-criteria approach, FAHP-F-MARCOS, is followed to prioritize mitigation strategies, considering environmental, economic and social criteria.

This chapter presents the main conclusions of the research, highlighting the results corresponding to the questions formulated at the beginning.

To answer the five main questions of this research, five distinct empirical studies were carried out. We now present the answers to these questions, based on the results obtained in the studies.

What are the main research trends in RL?

To answer the question, the study entitled “Reverse Logistics and Sustainability: A Systematic Review of the Literature from the Firm Perspective” was carried out, identifying four distinct clusters. Cluster 1, the biggest, focuses on developing mathematical optimization models and strategies to support implementation of RL networks. Cluster 2 deals with theoretical evaluation of RL performance. Studies in this cluster aim to provide conceptual understanding for measurement and analysis of the performance of RL activities, considering aspects such as sustainability, customer satisfaction and key performance indicators. Cluster 3 is formed of articles that explore outsourcing of RL activities, analysing the suppliers of specialized services, as well as tertiarization practices, supplier selection and strategic partnerships in RL management. Cluster 4 concentrates on the obstacles faced when implementing reverse flow networks, such as organisational resistance, a lack of awareness and limited resources, as well as identifying the motivating factors, such as environmental regulations, stakeholder pressure and economic benefits.

This study found that increased environmental concerns and legislation have made industry reconsider the impact of its operations on the supply chain (Kumar & Kumar, 2016).

Ghisolfi et al. (2017) showed that efficient RL can lower costs, minimize environmental impacts, improve social performance and bring competitive advantages.

Despite all the advantages of implementing an RL network, companies face various obstacles (Govindan et al., 2019).

What are the most significant barriers to implementing RL?

The question was answered through a study entitled "Identification and analysis of the barriers to Reverse Logistics through a Systematic Literature Review and the fuzzy Delphi method".

This study identified a total of 61 barriers to implementing RL, classed in seven groups: economic, technological, governance, policy, knowledge, market and management questions. Among the main barriers, the specialists highlighted "Uncertainty about the quantity and quality of returned products", "Uncertainty about the economic benefits", "High costs", "Lack of administration commitment", "Lack of clear government policies", "Lack of technical knowledge" and difficulties in "Coordination among supply chain partners". Although the literature frequently mentions "Lack of management support" and the "Absence of public policies", the specialists did not attribute a great impact to these questions in practice. The study also revealed divergence in perception of the impact of the barriers related to the market and competition.

How are these barriers inter-related?

The study entitled" Modelling the barriers to reverse logistics: A combined ISM and MICMAC analysis approach" followed a structured approach to identify and analyse how the main barriers to implementing RL interact, using the ISM method to create a map of cause and effect relations among the barriers and the MICMAC method to assess their degree of influence and dependence. This analysis led to the conclusion that the most influential barrier is the "Lack of appropriate organisational structure and support for RL practices", placed at the highest level in the ISM model. With a direct influence on the lack of social responsibility, this barrier shows the importance of a solid organisational structure to promote a culture of social responsibility and facilitate the adoption of RL practices. In addition, the study revealed that the "Lack of support from other members of the supply chain" and the "Lack of shared understanding of the best practices" are also key barriers, with them influencing, and being influenced by, other barriers, forming a complex system in need of coordinated priority actions.

The MICMAC analysis reinforced that various barriers, such as the "Complexity of operations", "Difficulties with members of the supply chain", "Lack of support from members of the supply chain", "Lack of shared understanding of the best practices", "Lack of social responsibility" and "Lack of an appropriate organisational structure and support for RL practices", belong to the group of independent barriers, as they present great power of influence and low dependence, which indicates that mitigating them could be significant in reducing barriers. On the other hand, the "Lack of support infrastructure" and "Lack of qualified professionals" are greatly influenced by other barriers, which suggests their mitigation depends on actions directed to barriers with a bigger impact.

What are the main reasons and barriers to implementing RL in SMEs in the textile and footwear sectors?

The study entitled "Barriers and Motivations for Implementing Reverse Logistics in the Textile and Footwear Sector" sought to identify the main reasons, barriers and strategies for efficient implementation of an RL network in the textile and footwear sectors.

According to the study made, the reasons for implementing RL are centred on environmental sustainability, economic benefits and social responsibility. As underlined by Govindan et al. (2016) and Rahimifard et al. (2002), companies are stimulated by objectives such as a lower environmental impact, complying with national and international legislation, an improved image and economic factors. In this study, the interviewees reinforced that perspective, mentioning sustainability, social responsibility and economic factors as the main concerns. Their motivations included reducing the environmental impact of their activities, promoting a positive image in customers' eyes, financial opportunities, recovering material and reducing the costs of waste.

Customer satisfaction is also considered a critical factor, especially in the context of returned faulty products. In the study, some interviewees mentioned that one of the focuses of RL is on ensuring customer satisfaction by managing product return processes.

However, the interviewees also said they faced various barriers in implementing the RL network. They mentioned that high operational costs, the complexity of operations, uncertainty about the volume of products returned, the lack of an appropriate organisational structure and inefficient information systems are major challenges for firms in the textile and footwear sectors. It was also mentioned that the absence of scale economies and the lack of collaboration among partners aggravated the difficulties and limited firms' capacity to implement RL, despite recognising its importance for long-term sustainability.

To lower the barriers to implementing RL, the interviewees propose the development of strategic partnerships, sharing infrastructure and costs and outsourcing RL activities, standardization of processes and investment in innovative technology. They also stressed the need for top management involvement and internal awareness in order to overcome organisational resistance, agreeing with what was found in the previous study.

What strategies can be conceived to mitigate the obstacles to implementing RL in these business contexts?

The study entitled "Reverse Logistics Strategies in the Textile and Footwear Sectors: A Fuzzy-Based Decision Approach" explores the strategies to mitigate the obstacles to implementing an RL network.

The study revealed that sub-contracting of RL operations is the main strategy of Portuguese SMEs in the textile and footwear sectors. Outsourcing of RL allows companies to concentrate on their core business, and reduce operational costs and risks.

Strategic partnerships are another relevant solution, as they support the share of costs, infrastructure and know-how among companies and stakeholders. These collaborations help to mitigate the lack of scale economies, common in SMEs, and also strengthen operational synergies.

7.2. Implications

This research produces various relevant implications for the theoretical and practical domains. It makes an important contribution to RL, by including quantitative and qualitative methodological approaches in analysing the specific context of SMEs in the textile and footwear sectors in Portugal. By combining methods such as Fuzzy Delphi, ISM-MICMAC, FAHP and F-MARCOS, it not only enriches the existing literature with a robust, multi-dimensional framework, but also contributes to filling gaps in the research on barriers, their inter-relations and mitigation strategies.

Concerning the practical aspect, this research proposes a number of operational strategies directed towards mitigating the barriers identified and adapted to the situation of Portuguese SMEs in the textile and footwear sectors. The strategic priority obtained from applying FAHP and F-MARCOS is particularly useful in decision-making in environments marked by uncertainty and a lack of information, as is frequently the case in SMEs. The proposals to outsource logistics activities and develop partnerships provide a viable path for gradual integration of RL, with regard to the typical limitations of scale and capacity in these organisations. Therefore, this thesis provides not only a diagnosis but also a set of instruments to support decision-making that can be used by managers and those in charge of the supply chain.

Finally, the results of this research provide evidence for the formulation of policies that are more sensitive to the SME situation. Finding that the lack of an appropriate organisational structure is one of the most influential barriers to implementing RL reinforces the need for professional training and technical support, encouraged by public entities, associations and regulating bodies. In addition, the data gathered can serve as a basis for developing specific financial incentives for the adoption of RL practices, particularly in the area of circular economy policies. By precisely identifying the obstacles and motivations involved in adopting RL in these sectors, this study contributes to building an ecosystem more favourable to sustainability and innovation in Portuguese supply chains.

Summarising, this thesis makes a relevant, transversal contribution to advancing knowledge and to improved organisational practices given today’s challenges in the areas of sustainability, competitiveness, and corporate social responsibility.

7.3. Limitations and future research

Throughout this research some limitations and gaps were identified, suggesting orientations for future research.

In the SLR, one of the limitations was due to restricting the key-words used in the search. The study focused on the key-words of "reverse logistics" and "sustainability", which may have led to excluding relevant articles on the topic, such as "closed-loop supply chain management" or "circular economy". Due to the complexity of RL, diversifying the terms of the search might allow a more wide-ranging and deeper analysis of the literature, incorporating complementary views. It is therefore recommended that future research should use a broader range of key-words to ensure a more robust theoretical review.

As for identifying the main barriers to implementing RL, those were validated by academic specialists. A suggestion is to extend the research to different sectors, applying multi-criteria decision-making tools. Also suggested are studies with mixed groups (academics and professionals), to ensure a balance between theory and practice.

Identifying the interaction among barriers contributed to better understanding of the difficulties in implementing RL, but some limitations are present here too. Firstly, the sample analysed was relatively small, which limits generalization of the results. In addition, the data refer exclusively to the Portuguese context. This implies caution in extrapolating the conclusions to other European markets, given the diversity of economic, cultural and legal characteristics between countries.

In order to mitigate the limitations identified and deepen knowledge of the topic, future research should use larger samples and replicate the study in other countries. In parallel, it would be relevant to carry out comparative studies among sectors, in order to explore the particularities of each.

As in the previous studies, the qualitative study also presents limitations. The subjectivity inherent to qualitative data analysis, especially during the coding and classifying of the information gathered in the interviews is one limitation of the study. Despite following recommended methodological guidelines, it is important to recognise that qualitative approaches, by their very nature, present some degree of subjectivity. Here too, some research opportunities were identified in order to deepen knowledge about RL. Therefore, a suggestion is to study the impacts of government policies and tax incentives in mitigating the obstacles to implementing RL. Another suggestion is to study companies that were unsuccessful in implementing RL, in order to identify the main critical factors in failure.

The study aiming to identify strategies to implement RL in SMEs in the textile and footwear sector also presents limitations that should be considered. The small number of companies participating and restricting their location to Portugal limits generalization of the conclusions to other contexts. These limitations suggest the need for wider searches, for example, studying different countries and sectors.

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