Research Opportunities in Textile Reverse Logistics: A Systematic Review

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ORIGINAL PAPER

RESEARCH OPPORTUNITIES IN TEXTILE REVERSE LOGISTICS: A SYSTEMATIC REVIEW

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ABSTRACT. Background: The textile industry generates a large volume of waste due to the increasing demand for clothing for daily use and fashion. To reduce waste, reverse logistics (RL) has been proposed to ensure the recycling and reuse of waste textiles in the value chain. RL has been broadly examined in several manufacturing supply chains but less explored in the textile industry. The absence of a systematic review on textile reverse logistics (TRL) makes it difficult to identify existing knowledge gaps and research opportunities.
Methods: Using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, this paper contributes a systematic literature review of 28 relevant papers published on TRL between 1999 and August 2022.
Results: Overall, there is a shortage of recycling facilities in developing economies. There is a need for quantitative models that assess the location and potential disruptions and aversion of the resulting risks of TRL. Investigating consumers' perspectives on the desire to sort and transport old textiles to collection sites would be helpful to manufacturers. Additionally, system optimization to reduce emissions that emerge through the TRL production line would help reduce costs. It is also found that incentivizing clothing businesses that adhere to TRL practices would encourage more participation.
Conclusions: This study discusses research opportunities in TRL that are beneficial to the clothing and textiles industry and researchers in developing new waste management strategies.

Keywords: Textile Reverse Logistics; Textile Recycling; Textile waste management; Systematic review

INTRODUCTION

The textile industry is characterized by fast-paced fashion cycles coupled with consumers' lack of commitment to environmentally responsible buying habits [Gazzola et al., 2020; Hur, 2020; Pereira et al., 2021]. The proliferation of low-priced, mass-produced clothes from factories has led to wasteful consumerism and regular clothing and apparel discard [Gazzola et al., 2020; Hawley, 2009]. Fast-fashion retailing is defined by its emphasis on volume sales at discount prices, encouraging consumers to make regular clothing purchases. Consumers' propensity to acquire new items regularly and discard those still wearable promotes a "throwaway culture" [Joung, 2014]. The wasteful and excessive consumption is depleting our limited natural resources [Boryczko et al., 2014], which is problematic given that most of these resources do not regenerate. Consequently, numerous sustainability-related concerns emerge. Striving for resource conservation and zero waste in the textile industry is essential in order to address these concerns. Thus, the textile sector is under pressure to implement sustainable practices to reduce its adverse environmental effects. This increased pressure to implement environmental and sustainability practices has

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led to considerations for reverse logistics (RL) practices in the textile industry.

RL is the backward flow of products in the supply chain, employing a series of operations and processes for moving products from consumers to manufacturers due to defects or for recapturing values through recycling or remanufacturing [Banihashemi et al., 2019; Wadhwa et al., 2009]. RL enhances many aspects of supply chain management, including transportation, customer service, return processing, and inventory management, leading to new sources of income and more effective collaboration between manufacturers and suppliers [Li & Huang, 2021; Sharma et al., 2021]. Researchers and industrial practitioners are developing interests in RL due to its advantages to supply chain performance coupled with the increasing demands from stakeholders [Chauhan et al., 2022; Kitsis & Chen, 2021]. More ecologically concerned consumers and stringent environmental regulations set by authorities and competitors are beginning to pressure businesses to include environmentally responsible practices and RL processes in their strategic plans and operations [Govindan et al., 2015; Nik Abdullah, 2015; Vanalle et al., 2017]. These plans and operations deliver economic and environmental advantages by recapturing values from returned products as well as assisting companies to compete, particularly those facing fierce competition with thin profit margins [Elmas & Erdoğmuş, 2011; Uriarte-Miranda et al., 2018]. These greener production activities encourage a circular economy's goal of transitioning from a linear material flow model to one based on a closed-loop circulation of resources [Kalmykova et al., 2018] and result in increased sales income and decreased firm operating costs, allowing businesses to differentiate themselves from their competitors [Hashemi, 2021].

Implementing RL processes, particularly in the textile industry, improves a company's public standing by encouraging waste diversion [Di Vaio et al., 2022]. Waste diversion provides many product disposition options, such as direct reuse, repair, refurbishment, remanufacturing, recycling, incineration, and landfilling [Alarcón et al., 2020]. By implementing proper textile waste diversion through RL processes, the amount of waste sent to landfills can be reduced. The economy also benefits when the extra energy produced by incineration is put to good use. Studies on RL implementations in sectors such as the electronics industry [Atasu & Subramanian, 2012; Cole et al., 2018; Jauhar et al., 2021], the automotive sector [Kaviani et al., 2020; Makarova et al., 2018], the copier and printer industry [Savaskan & Wassenhove, 2006] and the pharmaceuticals industry [Narayana et al., 2019], have received increasing attention.

However, textile reverse logistics (TRL) has received relatively limited attention, mainly due to challenges in recycling textile waste, as discussed in some papers [Leal Filho et al., 2019; Wojnowska-Baryła et al., 2022]. Although many well-known researchers [Jäämaa & Kaipia, 2022; Matter et al., 2013; Pal, 2017; Pinheiro et al., 2019; Sinha et al., 2016] have contributed to the body of knowledge on TRL, no study has comprehensively examined and summarized all of the available research on the topic. Therefore, further study of the reverse logistics of textile waste is necessary. The importance of review papers in evaluating and appraising developments in a research field is crucial.

This study summarizes the current body of literature on TRL by contrasting and analyzing the key research foci of diverse authors, investigating and highlighting the significance and application of RL in domains of textile waste, and identifying potential areas for further study, which is currently lacking. To achieve this, we conducted a thorough systematic review of the literature published on TRL between 1999 and August 25, 2022. Furthermore, this study evaluates the most pressing and emerging research themes in the TRL literature. As such, the review adopts a multifaceted approach to identify leading journals publishing on TRL, the primary areas of interest, and the research methodologies adopted in the TRL literature.

The paper is organized as follows: Section 2 describes the approach adopted in this systematic review and defines the selection procedures and criteria. Section 3 presents the outcomes of the review in accordance with the standard four phases of LCA. Section 4 discusses the challenges of LCA on tires and research opportunities in the future. Section 5 concludes this reviewing study.

MATERIALS AND METHODS

We first developed our research objectives and search strategies to locate the relevant literature. The primary focus was papers archived in Scopus and Web of Science databases between 1999 and August 25th 2022. This scope was chosen because the publications on TRL started in 1999. These databases are justifiable by their prominence in academia, and publications indexed in them have undergone a thorough peer review. They are undoubtedly among the most dependable aggregators of high-quality scientific and academic publications such as journal papers, conference proceedings, and book reviews [Pranckutė, 2021]. In the second stage, we used a Boolean search with the following keyword combinations (textile) OR (apparel) OR (clothing) OR (garment) OR (fashion) AND (reverse) AND (logistics).

The following criteria were used to select the papers used in this review: (a) papers unrelated to the themes and objectives of our study were excluded; (b) only full literary works on textile reverse logistics published in the English language and indexed in Web of Science and Scopus were considered; (c) the scope included review papers, conference papers, and book chapters to incorporate all relevant literature on TRL.

The search was conducted on August 25th 2022, to ensure consistency across the two databases. It yielded 115 records from the two digital repositories utilizing the keywords. After eliminating duplicate papers (n=48), 67 publications remained. These publications included reviews, research papers, conferences, comments, and evaluation reports published between 1999 and 2022. In the next stage, we employed manual sorting or the Delphi method. Three researchers independently screened papers' topics, titles, abstracts, and keywords using various basic to advanced searches and query strings to eliminate irrelevant papers, leading to the removal of 39 papers. The remaining 28 papers qualified and were used for the review.

RESULTS

Overall, there were five papers (17.86%) published in Book Sections and Conference Proceedings each. Several journals have published one paper (3.57%). The total number of papers published can be grouped into five thematic areas covering environment and waste management of textile & fashion (50%), economics and business administration (28.57%), and operations management, and chemical and industrial engineering (21.43%). The diversity in these journals is an intriguing and remarkable trend that signals a rising interest in the TRL literature.

To understand the trend in TRL publications, we analyzed the number of papers published over time. The result shows that publication has been inconsistent for the past years. The highest number of publications was seen in 2016 and 2018, with four papers each. The scope of this review took in papers published between 1999 and 2022. This is because there was no literature on the topic before 1999. One paper was published in 1999, after which no work was recorded until 2011.

Even though there was a fluctuation in publications between 2016 and the first half of 2022, this period saw a significant increase in research activities in textile reverse logistics compared to previous years. This tendency may be considered a reflection of the growing interest in RL literature. Figure 1 depicts a yearly distribution of published papers between 1999 and 2022.

Figure 2 shows the total number of papers published by geographical distribution covering 14 countries. Six publications originate from China, four from Brazil, and three from India. Turkey, Sweden, the United Kingdom, and the United States contributed two papers, while Finland, Malaysia, Morocco, Germany, Portugal, Pakistan, and Iran contributed one paper each. Together, three BRICS countries (China, Brazil, and India) contributed 46.4% of the total publications in the study period.

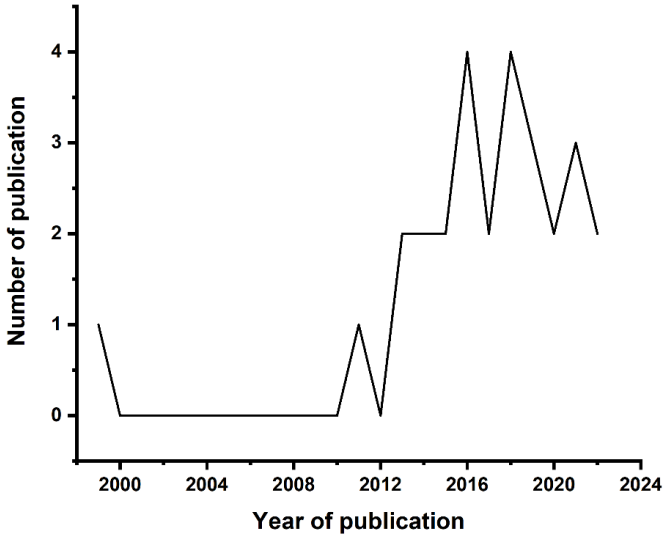

Fig. 1: The distribution of papers published over time

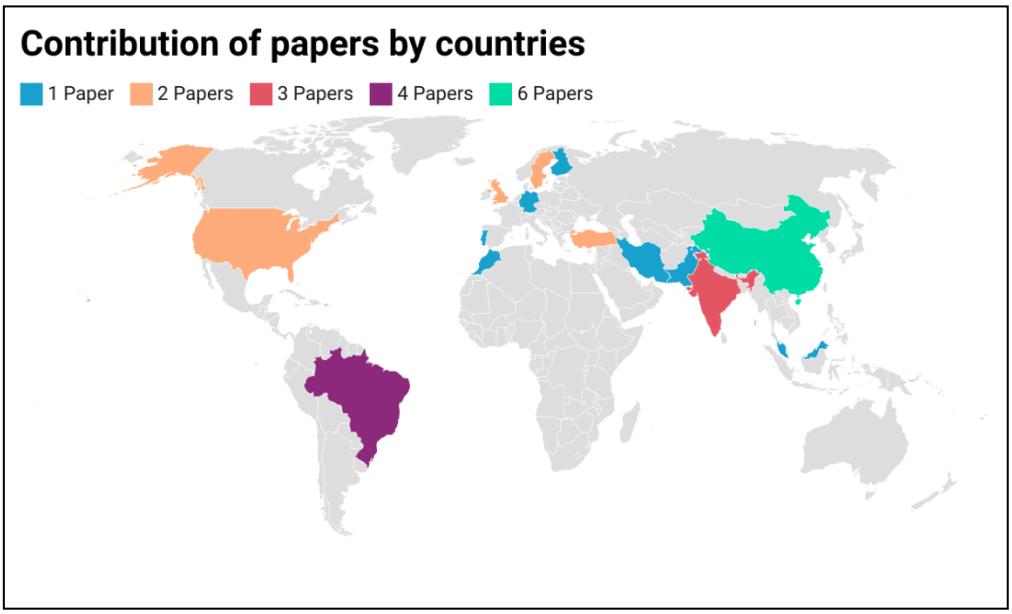

Fig. 2: Publications by countries

DISCUSSION

The papers have been classified into two categories. The first category is based on system optimization (n=9) using mixed integer linear programming (MILP), heuristics and hybridization, and game theory for cost optimization, supplier selection, and decision support. The second category includes qualitative research approaches (n=19). Studies in this category analyzed the current state of management and practices, identified challenges, and proposed recommendations and strategies. It also includes studies conducted through surveys, interviews, desk studies/reviews, field visits, and case studies, as presented in Table 1.

TRL has the potential to develop rapidly in a robust circular economy, which would increase the efficiency of resource usage, decrease environmental strain, and provide enormous economic rewards [Jäämaa & Kaipia, 2022]. However, these potentials are unachievable without stricter laws governing recycling practices [Liu & Yi, 2014]. Legal frameworks are essential for the T&A industry.

Considerations such as tightening regulatory framework requirements or establishing high ecological standards on the part of customers make RL crucial to tackling issues in the T&A industry [Zöllner et al., 2021]. They are beginning to significantly influence the development of RL processes in Europe, and a change in this trajectory would slow the growth of the recycling industry [Bouzon & Govindan, 2015; Zöllner et al., 2021]. Similarly, policy- and economy-related concerns were identified as the most influential factors for developing RL practices in the Brazilian clothing industry sector [Bouzon & Govindan, 2015; Pinheiro et al., 2019]. The decisions to implement RL for the textile industry are dependent on demands from government regulations and economic rewards, and the absence of these RL legislations makes Brazil a green awakening process for the management of used textile products [Bouzon & Govindan, 2015].

Despite the relevance of TRL, there is a shortage of recycling facilities in developing economies [Yan, 2019]. Recycling textile waste in developing countries is marred by poor collection and sorting mechanisms leading to high sorting, transportation, and logistics costs and no financial incentives resulting in an inefficient textile recycling culture [Garcia et al., 2019; Liu & Yi, 2014]. It is impossible to find solutions to these problems without robust TRL studies, the efforts of government agencies to execute RL and recycling, and the promotion of the positive effects of TRL processes [Abdulrahman et al., 2014; Garcia et al., 2019; Javed et al., 2021]. Many firms' motivation for implementing TRL processes stems from the potential financial benefits. However, economic viability in the TRL industry sector is significantly hindered by many fundamental constraints, including restricted technology, inferior recycled products, inefficient sorting mechanisms, etc. [Bouzon & Govindan, 2015; Pinheiro, 2018; Pinheiro et al., 2019].

Sorting recyclable textiles is particularly important in the recycling process [Dissanayake & Sinha, 2015; Realff et al., 1999]. Raising consumer awareness and facilitating an effective collection system lead to improved waste textile sorting [Zöllner et al., 2021]. Additionally, used consumer textiles are distinct from other domestic waste, such as glass and plastic, due to their material properties, requiring the development of ways to collect them in a manner that considers the unique characteristics of textiles and the limited means of collector entities [Jäämaa & Kaipia, 2022]. One way is by developing innovative technology that creates standardized sorting, grading, and disassembling processes [Dissanayake & Sinha, 2015]. Another strategy is offering customer incentives for returns at take-back places for used and old textile items to enhance recycling. The entire RL network is highly motivated by incentives through collecting recovered items, inspection, and forward/backward integration on RL networks [Garcia et al., 2019; Sorkun & Onay, 2018]. Incentives depend on the kinds of returns companies anticipate receiving from RL operations. Consumers' motivations to engage in RL activities are also affected by the location choice for collecting and inspecting returns [Sorkun & Onay, 2018].

Furthermore, insufficient communication and cooperation are crucial challenges among recycling companies preventing their TRL processes from reaching their full potential [Pinheiro, 2018]. However, forming partnerships with textile waste collectors and retailers can increase their output and reduce costs, since there are more synergies and spur innovations from the collaborations between sustainable designers, fashion retailers, and commercial waste collectors [Jäämaa & Kaipia, 2022]. The commitment of stakeholders and other players is necessary, but the involvement of collectors and customers is equally crucial to the success of TRL systems [Başaran, 2013]. The majority of inefficiencies experienced by recycling firms are attributable to the fragmentation and isolation of their respective processes [Abraham, 2011]. Building strategic partnerships based on, for instance, cloud alliance creates valuable and low-cost business models[Li et al., 2019] that enhance recyclers' profit maximization while decreasing collection and transportation costs (using the available return capacity of trucks in the same city) [Ahlaqqach et al., 2020; Torres et al., 2013]. The sharing economy and the use of light asset business models lead to the recycler's core competence and strategic partnerships to use the collective strengths of its members, such as access to resources and convenient locations, which are unachievable for recyclers operating alone [Guo et al., 2017; Li et al., 2019; Yan,

2019]. Thus, reverse logistics chain collaboration results in greater market knowledge, a more predictable business environment, and improved profitability [Abraham, 2011].

The high rate of return in the garments industry justifies a thorough investigation of upstream textile manufacturers. However, these examinations lack solid conceptual frameworks due to the scarcity of academic publications on performance measurements, especially Key Performance Indicators (KPIs) [Ahlström et al., 2020; Pal, 2017]. Developing performance measurement frameworks enable firms to access mitigation, gatekeeping, collection, sorting, and disposal indicators, allowing them to emphasize environmental sustainability, and can assist them in decision-making [Ahlström et al., 2020].

Most of the studies that employed a system optimization analysis of TRL mainly focused on cost optimization, with less emphasis on other system management processes [Ahlaqqach et al., 2020; Choi et al., 2018; Guo et al., 2017; Li et al., 2019; Singh et al., 2016]. In addition, several optimization strategies have been proposed to enhance decision-making to make the RL process more efficient [Ghanbarzadeh-Shams et al., 2022; Jain, 2016; Realff et al., 1999; Torres et al., 2013]. These models are necessary for understanding the RL network design, the optimization of return processing, the planning and scheduling of return products, the optimization of the secondary market, and the maximization of revenue from product disposition [Singh et al., 2016]. MILP is the widely used modeling method identified in the papers surveyed. It has broad adoption in the reverse logistics literature and was first employed in TRL by Realff et al. [1999]. Designing and developing mechanisms for collecting and reprocessing such a massive amount of valuable textile material is essential, particularly for supporting reverse logistics design and production decision-making processes [Ghanbarzadeh-Shams et al., 2022; Jain, 2016; Realff et al., 1999; Torres et al., 2013]. Notably, many of these models are insensitive to modifications in their variables. Such insensitivity leads to the unreliability of data capture and output prediction, affecting the volume of recyclable items and collection costs. Moreover, such a deficiency significantly affects profitability, defeating the purpose of TRL. Thus, optimizations that improve on the current scope is the first research opportunity identified.

Firms employing system optimization models see significant reductions in operating costs and increases in profit margins. This is especially true for smaller recyclers who purchase truckloads of unsorted items from various suppliers aiming to maximize earnings [Torres et al., 2013]. For such a smaller recycling facility, establishing flexible production schedules and deciding how many truckloads to buy and process from each supplier during a given period is cumbersome [Torres et al., 2013]. These challenges can be addressed by establishing coalitions among smaller recyclers [Ahlaqqach et al., 2020; Guo et al., 2017; Li et al., 2019]. The papers reviewed were lacking a more in-depth examination of how coalitions among recycling companies help lower their costs.

Many capabilities of RL directly impact the recyclers' performance, which positively affects their returns policies and cost positions. However, storage facilities, collection centers, and processing and disposal facilities incur high costs that must be considered when designing a TRL network. Even though Yan [2019] highlighted these costs, they were not extensively explored in the studies identified. Efforts to lower transportation and inventory costs are crucial because they make up a significant portion of the total cost of the reverse supply chain network [Singh et al., 2016]. Effective management of these cost positions creates positive relationships between strategic emphasis on TRL operations and the profitability of recycling activities, enabling recycling facilities to develop economic, organizational, marketing, and public relations balances [Realff et al., 1999; Singh et al., 2016]. Therefore, significant consideration must be given to exploring how information such as recyclable items' quality and location might be utilized to design reverse flows of used textiles. Furthermore, the uncertainty connected with recyclable product quality and variation linked with each player in the chain necessitates introducing different models that consider the development of stochastic techniques.

Some studies [Abraham, 2011; Choi et al., 2018; Jäämaa & Kaipia, 2022; Pal, 2017; Sorkun & Onay, 2018] were narrowly focused on their methodologies and data sourcing, limiting the ability to generalize their results. In addition, factors beyond the purview of these studies, such as regulations relating to product guidelines, were often given less consideration. They did not adequately capture the value development process or illustrate the varying impacts of many design components toward value creation. The studies also paid little attention to the viewpoints of final customers. Many studies did not specify the type of textile studied. Furthermore, many failed to adequately account for crucial factors, including location (collection sites, warehouses), potential disruptions, and the specific business practices of remanufacturing and recycling firms throughout the supply chain. Additionally, many of the studies did not go deeply enough to investigate the inclusion of the upstream textile supply chain players with reverse logistics players.

Unlike Brazil, where few studies tend to address firms' and consumers' corporate social responsibilities [Bouzon & Govindan, 2015; Garcia et al., 2019; Pinheiro, 2018], the rest lack or fail to discuss aspects of social responsibilities adequately and topics on CO_2 emissions were rarely addressed. Many of the firms mentioned in the identified studies are independently run, with weak connections with textile waste collectors and retailers. Incorporating social sustainability considerations and connecting with textile waste collectors and retailers could help them increase output, spur innovation, and reduce costs in the supply chain. A major barrier to achieving RL goals and social sustainability is the public's lack of understanding of environmental protection, especially consumers' lack of information on take-back channels for end-of-life items, which was not addressed in many of the studies. Due to small sample sizes, several papers could not fully investigate the correlation between enterprises' RL goals and the structures of their RL networks.

The concept of a closed-loop system with recycling is the primary solution for assisting the garment industry in addressing these challenges. However, even though the closed-loop system is broadly examined in other reverse manufacturing supply chains, it is less explored in the T&A industry. The absence of extensive research in the textile reverse supply chain has led to knowledge gaps. In addition, there are many uncertainties regarding the recovery of waste materials through recycling and the timing of their arrival, the quality of the recycled products in comparison to virgin ones, the demand for manufactured goods, the cost of remanufacturing, and the complexity of the remanufacturing operation considering logistics, inventory, and production planning.

Regardless of these lapses, developing nations stand to benefit economically from the textile reverse supply chain operations, as they bring about innovations and employment opportunities. The economic reasoning behind the cooperation and integration of services may be understood in broad strokes if these aspects are defined in the recyclers' value offered to consumers and partners. The practice of recycling textiles has the potential to have significant environmental and economic advantages. Considering the current state of the textile waste recycling industry across many developing countries, it is crucial that a comprehensive textile recycling and reuse system be established. This is crucial because the accumulation of unwanted textiles in these countries has long been a source of social unease. One way to contribute to this establishment is by conducting robust studies.

CONCLUSION

In conclusion, this study reviewed 28 relevant papers on TRL published between 1999 and August 25th 2022. The results of this research provide a more in-depth comprehension of TRL using the systematic representation of archival material across essential TRL themes. This research contributes to the academic discourse on TRL literature by capturing the literary growth of the field. Additionally, it provides input to policymakers in TRL design and policymaking. The results of this study also shed light on potential future areas of attention.

The results show that there is a need for more research regarding the strategic process of value creation and adoption in the TRL context, the development of quantitative models for measuring the effects of attributes and enablers with measurable levels of value, and an in-depth

study on business models. These processes contribute to TRL literature by developing methods that stochastically assess the location and potential disruptions and aversion of the resulting risks. Future studies should investigate consumers' perspectives and desire to sort and transport old textiles to collection sites. Such initiatives would give a deeper understanding of the mechanisms that make textile sorting appealing to consumers, as efficient waste textile sorting is crucial for the smooth operation of a TRL system.

Further studies are needed on system optimization to examine the connection between TRL systems and other RL functions while also considering the number of emissions the TRL processes produce. More investigations of TRL processes, particularly in developing countries, are required to unearth possible alternatives for ideal management strategies. These investigations are necessary as they mandate clothing businesses to consider the most crucial RL drivers influencing their management processes. Studies employing large sample sizes and those providing international comparisons among TRL processes are needed to provide in-depth knowledge of how coalitions amongst recycling companies might help lower operating costs.

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