BJ O&PM Brazilian Journal of Operations & Production Management

ISSN 2237-8960 (Online)

ABEPRO ASSOCIAÇÃO BRASILEIRA DE ENGENHARIA DE PRODUÇÃO

LITERATURE REVIEW

# Analysis of activities that make up reverse logistics processes: proposition of a conceptual framework

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**How to cite:** Melo, A.C.S., Nunes, D.R.L., Braga Júnior, A.E. et al. (2022), "Analysis of activities that make up reverse logistics processes: proposition of a conceptual framework", *Brazilian Journal of Operations & Production Management*, Vol. 19, No. 2, e20221376. https://doi.org/10.14488/BJOPM.2022.001.

## ABSTRACT

**Goal:** The need to discuss reverse logistics processes with a detailed and analytical approach, aiming at improving the reverse channel efficiency is notorious in the literature. Therefore, this research aimed to analyze and describe in detail the activities that make up the reverse logistics processes and, in addition, to propose a conceptual framework for a better understanding and definition of RL processes. .

**Design / Methodology / Approach:** This was achieved through a systematic review, which considered 3.517 papers, analyzing the RL concepts, definitions and objectives, as well as identifying its processes and activities. The activities were categorized as information (I-RL process) or materials (M-RL process) related.

**Results:** This research provides an entire RL activities blueprint. This approach promotes greater transparency, allowing to identify stages most impacted on the reverse channels, besides standardizing logistical procedures and also allowing to insert control points for measuring performance.

**Limitations of the investigation:** It is possible for a paper that focuses on one of the activities of the framework not to have been shown during the database if it doesn't mention the keywords "reverse logistics", "green logistics" and "sustainable logistics".

**Practical implications:** The concepts of reverse logistics activities presented in the framework can be implemented in reverse supply chains, serving as a basis for organizational strategies for managers involved with such processes.

**Originality / Value:** The authors of this paper believe that the results achieved can greatly contribute to the expansion of debates in the RL area, as well as serve as a basis for managers involved with RL processes.

**Keywords:** Reverse Logistics; Reverse Logistics Activities; Reverse Logistics Processes; Framework.

## INTRODUCTION

The demand for products nowadays has been growing and the corporations' strategy, in turn, has been focused on the progressive rise of sales and, with this, there is an increasing generation of waste, originated by productive activities (Yadav, 2015). In addition to this problem,

**Financial support:** State University of Pará - under Grant 626/18.
**Conflict of interest:** The authors have no conflict of interest to declare.
**Corresponding author:** vitor.martins@uepa.br
**Received:** 17 December 2021.
**Approved:** 15 Februarry 2022.
**Editor:** Julio Vieira Neto.

it seems that the industrial products' life cycles have been increasingly shorter, due to the growing competition between companies that present more sophisticated versions of their products, turning previous versions into objects of less interest for the consumer (Mellal, 2020). The idea of sustainable development involves the proper management of these wastes.

The search for sustainability within the industry has been based in part on the continuous and consistent waste generation reduction, and on increasing the efficiency of existing resources usability. In addition, several value recovery activities (reuse, recycling, remanufacturing, etc.) have contributed so that more and more return items (after-sales or post-consumption) from the entire direct chain are not destined for final disposal (i.e. landfills and incineration), which extends their life cycles, reduce the quantities destined for final disposal and extends landfill useful life. The bridge between the return items in the chain and the possible value recovery activities, as well as the wastes' final disposal, is done by Reverse Logistics (RL) process.

Analyzing the literature, it is possible to see that a definition still widely used for RL is provided by Rogers and Tibben-Lembke (1998, p. 2): "The process of planning, implementing, and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin to recapture value or proper disposal". Other definitions that are widely referenced in the literature also agree with this statement (Dowlatshahi, 2000; Fleischmann et al., 1997, 2001; among others). The research problem in this article is not the definition of RL, but the absence of theoretical discussions about the activities that compose RL processes, as well as its relationship with the structuring of a reverse channel. It is observed in the literature that the concept of activities that make up the RL processes is still quite broad and little-discussed (Agrawal et al., 2015; Kosacka-Olejnik and Werner-Lewandowska, 2020; Pokharel and Mutha, 2009; Prajapati et al., 2019).

Vahabzadeh and Yusuff (2015) and van der Wiel et al. (2012) highlighted the need to discuss RL processes with a detailed and analytical approach, aiming at improving the reverse channel efficiency, which, according to Rogers and Tibben-Lembke (1998), constitutes the essential characteristic of RL about its objectives of enabling the recovery of value and proper disposal.

According to the context presented, this research was guided by the following questions: "What are the activities that make up the RL processes and what are the definitions and characteristics of each one? What should a conceptual framework be like to define and clarify the RL processes?" Therefore, this research aimed to analyze and describe in detail the activities that make up the reverse logistics processes and, in addition, to propose a conceptual framework for a better understanding and definition of RL processes systemically. . For this, an extensive literature review supported the mapping of the possible activities that make up the RL process in reverse channels.

## BACKGROUND

Different RL literature reviews studies have been developed in specific industrial sectors, such as the pharmaceutical industry (de Campos et al., 2017), construction industry (Brandão et al., 2021; Hosseini et al., 2015; Pushpamali et al., 2019; Schamne and Nagalli, 2016), plastic industry (Tesfaye and Kitaw, 2020), humanitarian operations (Peretti et al., 2015) and leather footwear industry (Moktadir et al., 2019). Regarding reviews for generic types of waste, Pokharel and Mutha (2009) used a content analysis method for their literature review. They chose keywords such as 'recycling', 'remanufacturing', 'product returns', 'product recovery', 'reverse logistics', 'end-of-life products', 'closed-loop supply chains', 'green supply chain' with a time frame of 1971 to 2009. They sought to show an integrated perspective of the reverse logistics system from inputs to outputs and then to inputs again. The authors considered only five RL activities; disassembly, remanufacturing, supply chain planning, coordinating, inventory control, and after-sales services.

Other authors have expanded the field of investigation. Agrawal et al. (2015) focused on presenting a comprehensive review on RL. The authors classified their 242 collected articles in five categories: (1) Adoption and implementation; (2) Forecasting product returns; (3) Outsourcing; (4) RL network from secondary market perspective; (5) Disposition decisions. The authors themselves highlight the limitation of their study as being the low number of select issues considered, and that further research is required. From another perspective, Govindan et al. (2015) have done a comprehensive review targeting RL and closed-loop supply chains in scientific journals. They investigated 382 papers, published between 2007 and 2013. As the paper's focus was from operational research (OR) point of view, the categories and discussions were mostly related to OR topics, such as types of decision variables, terms of period, product, and objective function. The paper does not mention a detailed description of any RL processes.

More recently, a state of art on RL analysis was performed by Kosacka-Olejnik and Werner-Lewandowska (2020). The research focused on the paper's titles, using the keywords "reverse logistics", "aftermarket logistics", "retrogistics" or "aftermarket supply chain" for the time … - 2018. Their results showed the stages of scientific evolution of RL, the geographic location of the research and the most targeted journals in the field.

A very detailed systematic review of the available RL literature was produced by Prajapati et al. (2019). During their analysis of past literature reviews on RL, they found 18 prominent papers and presented a detailed discussion for each of them. It is possible to see in the background presented that the results focus only on the project description and research methodology, industries, research areas, algorithms, OR tools, data analysis techniques, MCDM methods and theories from the literature on RL.

Given the scenario presented, it is possible to perceive the existence of several previous studies that deal with RL, however, few deal in detail about which activities belong to the RL processes, that is, they do not promote a detailed analysis and definition of each one activity that make up the reverse logistics processes. Therefore, a conceptual framework with the definition of the processes that constitute an RL system becomes an important tool for this understanding.

## METHODOLOGICAL PROCEDURES

The systematic review method proposes to map and assess a specific body of literature to recognize potential research gaps and produce a reliable knowledge stock (Tranfield et al., 2003). The methodology was based on a two-step strategy combining an exploratory review and snowball technique. In our exploratory literature review (see Fahimnia et al., 2015; Lozano et al., 2015; Mirabella et al., 2014; Ricciardi et al., 2020) the main research question was defined as: What are the phases/activities of the Reverse Logistics (RL) process presented in the literature? Given this, the defined search string was: TITLE-ABS-KEY ("Reverse logistics" AND (activities OR processes OR steps OR paths OR procedures OR operations)) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "re")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SRCTYPE, "j")). No geographical restrictions were used, and the considered period for data collection was papers published until January 2021.

The academic databases selected were Science Direct, Scopus and Web of Science. To achieve the highest level of applicability, only peer-reviewed complete articles written in English and published in International Journals were selected, whereas master and doctoral dissertations, notes, conference papers, textbooks and book chapters were excluded in this review. The inclusion criteria were papers that contained on the title, abstract or keywords one or more of the RL processes, regardless of the main publications subjects, context or waste analyzed. The results were downloaded in RIS format, and the RIS data was exported to Mendeley bibliography software, as the remaining procedures were carried out there.

In all, 3.517 articles were collected. From those, 1.708 were in duplicity and 1.809 had their titles and summaries for reading. Finally, we examined the content of each paper as a means to ensure that the article helps to answer the main research question. This analysis resulted in 121 journal articles to analyze.

Therefore, aiming to identify the state-of-the-art of RL processes this research applied the exploratory approach. Thus, our objective was to survey the concepts, definitions and objectives of the RL, as well as identify the RL processes and activities cited, presented through figures or described in the literature. Different names for the same activity were also identified, as well as, guided by the definitions, concepts and objectives of RL presented in the literature, possible omissions of relevant activities were found.

Based on the definitions of RL and the set of activities presented in the literature as components of an RL process, it was possible to propose a framework to guide the general analysis of RL systems, regardless of the residue considered. In this step, new descriptions were also proposed for each RL activity considered in the proposed framework.

## RESULTS AND DISCUSSION

### The current context of literature regarding the activities that compose RL processes

One of the contributions from this research is the definition of activities that make up the RL process. Based on this objective, we examine the most widely used definitions of RL in the literature (see Table 1) and compare them with the activities considered in the literature as components of the RL process. According to the researched papers in Tables 2 and 3, the definitions of LR presented in Table 1 are the most cited and used in research in the last 20 years. By analyzing these definitions, we deduced that there is no reason to consider recovery activities as components of the RL process.

**Table 1.** Reverse Logistics Definitions in Literature in the last 20 years

| Authors | Reverse Logistics Definitions |
|---|---|
| The Council of Logistics Management (CLM) (Stock, 1992 apud Brito and Dekker 2003, p. 2) | "...the term often used to refer to the role of logistics in recycling, waste disposal, and management of hazardous materials; a broader perspective includes all relating to logistics activities carried out in source reduction, recycling, substitution, reuse of materials and disposal." |
| Rogers and Tibben-Lembke (1998, p. 2) | "The process of planning, implementing, and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods, and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal." |
| The European Working Group on Reverse Logistics, RevLog (1998) apud Brito and Dekker, 2003, p. 3 | "The process of planning, implementing and controlling flows of raw materials, in process inventory, and finished goods, from a manufacturing, distribution or use point, to a point of recovery or point of proper disposal" |

Adapted from Brito and Dekker (2003).

It is important to emphasize that there may be a possible misinterpretation of definitions discussed in the scientific literature previously. Quesada (2003) raises the hypothesis that a misinterpretation can occur for a linguistic issue since the words "reverse" and "recovery" are considered synonymous in many cases observed by the author. Furthermore, this same author emphasizes that many authors mistakenly consider "Destiny" and "Descarte" as synonyms. In RL studies, "Destination" refers to the act of defining locations for returned goods (recovery or disposal) and "Disposal" refers to the definition of locations for waste whose recovery is not possible (landfill, incineration, and so on). Thus, definitions such as "At the simplest level, (RL) can be described as the disposal of returned goods (Tan et al., 2003)" can lead to a misinterpretation that RL would be responsible for the proper recovery or disposal of waste, rather than being responsible for identifying the sources, selecting, collecting, transporting, processing and sorting these wastes inappropriate locations for recovery or disposal, as well as returning the materials recovered from recovery points to markets and consumers.

According to the current literature (Table 2), considering the total number of articles deemed fit for full reading, and among the activities cited as making up the RL process, only 1 among the traditional materials logistics activities appears with a high citation count namely Collection (76.86%). The citation count of other material-related RL activities was Inspection/Testing (51.24%), Sorting (36.36%), Redistribution (33.88%), Transport (32.23%), Disassembly (28.84%), and Warehousing (27.27%). Regarding the Information related RL activities, there was a low citation count, with the following activities being the most mentioned: Acquisition (12.40%), Gatekeeping (9.92%), and Integration (4.96%).

**Table 2.** Percentage distribution of RL processes activities in the survey

| RL process activities | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Integr.** | **Acquis.** | **Gatekeep.** | **Collect.** | **Transp.** | **Insp./Test.** | **Warehous.** | **Disass.** | **Sort.** | **Redistr.** |
| 4.96% | 12.40% | 9.92% | 76.86% | 32.23% | 51.24% | 27.27% | 38.84% | 36.36% | 33.88% |
| **Non-RL process activities** | | | | | | | | | |
| **Recovery** | **Reuse** | **Repair** | **Refurbishing** | **Remanufacturing** | **Recycling** | **Disposal** | | | |
| 38.02% | 38.84% | 40.50% | 25.62% | 55.37% | 51.24% | 61.16% | | | |

The following activities were also identified, as composing the RL process: Disposal (61.16%), Remanufacturing (55.37%), Recycling (51.24%), Repair (40.50%), Reuse (38.84%), Recovery (38.02%), and Refurbishing (25.62%). In addition to the results presented in Table 2, other non-RL activities were mentioned, but in a less significant frequency, such as: Re-sale (Abdessalem et al., 2012; Bienstock et al., 2011; Borges et al., 2020; Fernandes et al., 2018; Pal, 2017; Peretti et al., 2015; Ravi, 2014; Škapa and Klapalová, 2012); Donation (Abdessalem et al., 2012; Fernandes et al., 2018; Peretti et al., 2015); Cannibalization (Agrawal et al., 2016a; Ang and Tan, 2018; Gonçalves et al., 2019); Washing (Shahparvari et al., 2018) and Recertification (Amini et al., 2005). Finally, some studies have also cited activities that can be considered sub-processes of the LR process: Packing or Repacking (Agrawal et al., 2016a; Borges et al., 2020; Godichaud et al., 2012; Peretti et al., 2015; Škapa and Klapalová, 2012); and Densification (Bai and Sarkis, 2013).

Within the papers surveyed, 87.60% mentioned at least one non-RL activity as a component of the RL process. In contrast, only 15 papers correctly highlighted the actual RL activities (see Table 3). Bai and Sarkis (2019) and Škapa and Klapalová (2012) were the authors whose most cited activities considered components of the RL process (6 out of 10 activities). It is also worth mentioning that none of the papers mentioned defined or described all 10 activities of the RL process.

**Table 3.** Papers that cited only RL process activities

| Authors | Integration | Acquisition | Gatekeeping | Collection | Transport | Inspection / Testing | Warehousing | Disassembly | Sorting | Redistribution |
|---|---|---|---|---|---|---|---|---|---|---|
| Wang et al. (2017) | | | | | | | | X | | |
| Shiue and Lin (2012) | | | | X | | X | | | | |
| Bazan et al. (2015) | | | | X | | X | | X | | |
| Hervani et al. (2017) | | | | | X | | X | | | X |
| Genchev et al. (2011) | | | | X | X | X | | | X | |
| Han and Cueto (2016) | | | | X | X | X | | | X | |
| Lin and Te Chang (2009) | | | | X | | | | | | |
| Pyke and Tang (2010) | | X | X | | | | | | | |
| Bai and Sarkis (2019) | | | | X | | X | X | X | X | X |
| Bienstock et al. (2011) | | | | X | X | X | | | X | X |
| Škapa and Klapalová (2012) | | X | | X | X | X | X | X | | |
| Chaves et al. (2020) | X | | X | X | | X | | | | |
| Godichaud et al. (2012) | | | | X | X | | | | | |
| Galvez et al. (2015) | | | | | X | | | | X | X |
| Barker and Zabinsky (2011) | | | | X | | X | | | | X |

Figure 1 presents the evolution per year considering the frequency of papers that cite, display figures or describe RL processes or activities. Since 2009, there's been a substantial increase in the citation count. However, such growth has been occurring mostly in non-RL activities (Figure 2) rather than actual RL activities (Figure 3). Regardless, all these results highlight the growing interest of the literature in RL processes or activities in the last 10 years.

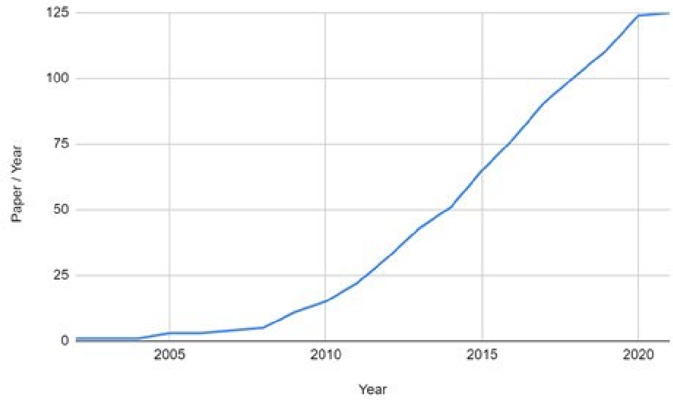


**Figure 1.** Counting evolution of the papers that mention or treat RL processes or activities in the literature

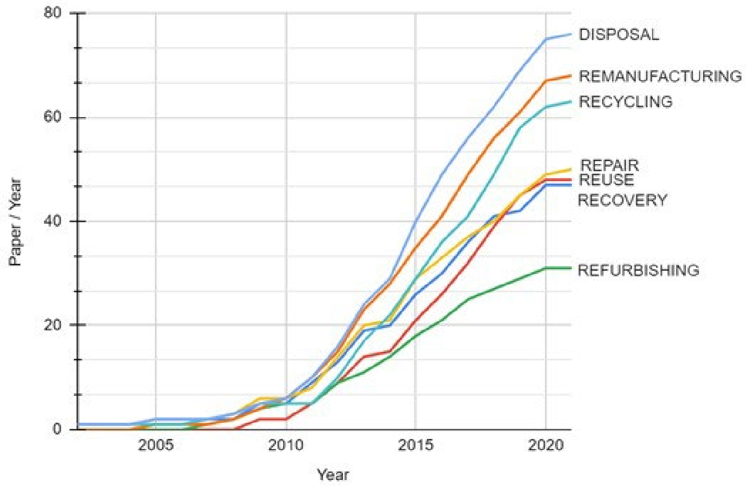


**Figure 2.** Evolution of the citation counting of non-RL process activities mentioned in the literature

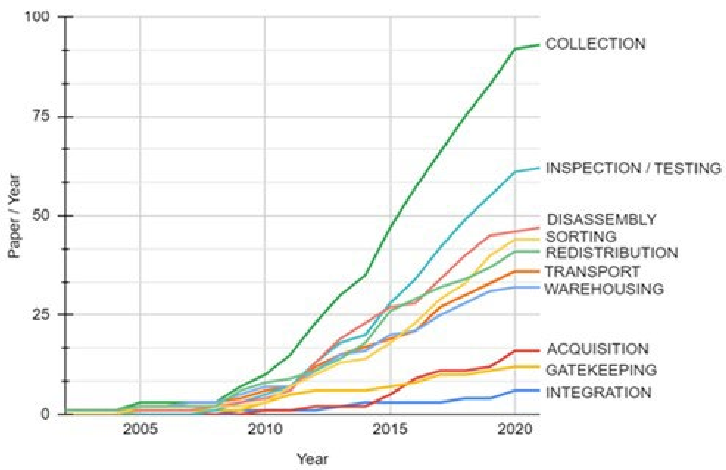


**Figure 3.** Evolution of the citation counting of RL process activities mentioned in the literature

As previously mentioned, matching the results in Figures 2 and 3, it is possible to see that non-RL activities have been mentioned in more RL papers than actual RL activities, with Collection being the only exception. Is worth highlighting that among the actual RL activities (Figure 3), those associated with information flows (i.e. I-RL Process: Acquisition, Gatekeeping and Integration) are barely mentioned or defined in the literature compared to RL activities related to material flows.

## Proposed conceptual framework

Initially, it is important to highlight that the conceptual framework proposed in this study took into account the analysis of concepts and definitions of the activities that are part of the RL processes found in this literature review and, in addition, considered a frequency analysis regarding the activities found in the literature. It is noteworthy that the conceptual framework proposed here is a systematic flow that aims to provide a basis for the consolidation and definition of activities that are part of the processes that make up the RL systems. Additionally, an analysis, description and characterization of each activity are performed.

In Figure 4 a conceptual framework proposal is presented, in which the main stages that make up the RL process are highlighted. In this proposal, the RL steps were organized into 2 classes. Those stages related to the collection, processing and integrated management of RL information, composing the RL process associated with information flows, were grouped in a macro process named in this article I-Reverse Logistic Process (I-RL Process). Another set of RL activities, focused on material flow management, were gathered up in a macro process called M-Reverse Logistic Process (M-RL Process). It is also important to note that some logistical activities can happen throughout the logistical process associated with the objectives of the RL, thus including RL activities that support activities directly related to the recovery processes (reuse, repair, refurbishing, remanufacturing and recycling) or proper final disposal (incineration and landfilling). Integration and Warehousing are examples of steps in the RL process that have this characteristic. For this reason, in Figure 4, the Integration step "contains" all activities of the RL process (I-RL and M-RL Processes), in addition to forwarding Supply Chain, Recovery options and Proper Disposal. The RL activities that make up the Warehousing steps, in addition to being necessary for the Inspection/Testing, Disassembly, Sorting and Redistribution (M-RL Process) steps, are also essential RL activities to support the processes related to Recovery options and Proper Disposal. Thus, in Figure 4, Inspection / Testing, Disassembly, Sorting and Redistribution, in addition to Recovery options and Proper Disposal, "are contained" in the Warehousing step. Perhaps due to this peculiarity many previous papers have presented recovery options, or proper disposal alternatives, as part of the RL process although evidence suggests that they do not belong to this process.

The RL activities presented in Figure 4 will be defined and described in the following, according to the surveyed papers in this research. For incipient RL activities definitions or descriptions we proposed complementary definitions and descriptions based on forwarding logistics activities analogies.

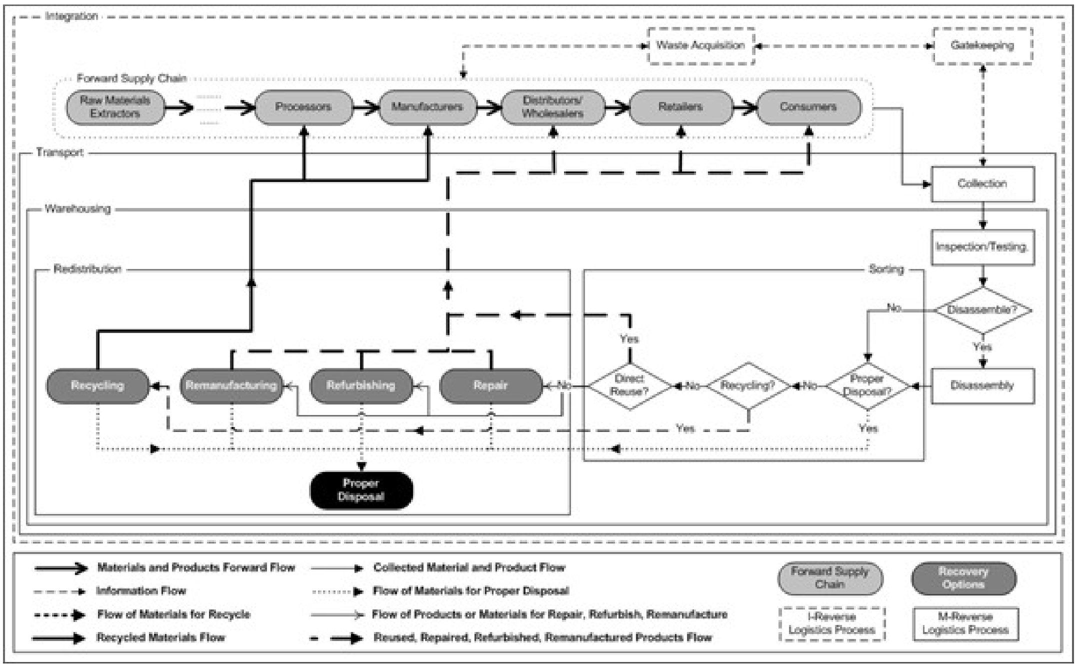


**Figure 4.** Conceptual Framework of RL Process

### Integration

According to Chaves et al. (2020) it is also called the Coordinating System, the first and most important key element of the RL process since it is responsible for this system’s overall management and performance. It is the planning stage that takes place throughout the whole RL process. It involves the identification and integration of sources of origin (suppliers), other points of the reverse channel and destination facilities (customers) for waste which will be collected, processed, recovered and reintegrated to forward supply chains. For waste in which recovery options are not feasible or available (i.e. unrecoverable waste) the Integration will connect the first RL process's steps to proper disposal facilities (landfilling, incineration plants, etc.).

It also searches integrating the whole of RL process’s stages by information sharing between all reverse channel's members exactly as a reverse supply chain. In this step, fundamental logistical information still in gross (or aggregated) mode will be made available to support decisions, especially in the starting (Waste Acquisition) and ending (Redistribution) stages of the RL process. Reverse supply chain management approaches and strategies must be applied to also better integrate other activities of the RL process and connect other important reverse channel members, including government, recovery options, proper disposal alternatives and other forward supply chain members. It considers the gathering of information about specifications, types and potential amounts of waste generated that will be recovered for efficiently integrating (matching) offers and demands these wastes. Though in more aggregated levels of information, it contributes to dimensioning and capacity planning (long term) as well as a performance measurement of every RL process stage.

### Waste Acquisition

In this activity, based on some of the information gathered in the Integration step, generation sources are identified, waste types are defined and mounts to be collected can be estimated accurately. Can be also called Product acquisition, which is the process of acquisition of used products, components or materials from the end-users for further processing (Agrawal et al., 2015, 2016b). From this information, environmental awareness actions must be promoted to instruct and encourage people about the best procedures for qualified selection and optimized pick up of potentially recoverable waste.

Thus, visits and presentations must be made for informing and raising awareness among everyone involved in the waste generating sources about the importance of waste recovery for the environment, current environmental procedures and regulations as well as best practices for selecting, cleaning, packaging and storing waste for collection and transport. Furthermore, more reliable information promotes more accurate capacity planning (short term) and realistic logistical resource management, to maximize recovery efficiency of waste potentially identified and estimated in the previous step.

### Gatekeeping

It is the refined selection (filtering) of waste and accurate definition of quantities to be collected and transported to processing facilities. Also called Grading, it starts when materials to be collected must be screened for entering the return stream according to their functionality and determining the flow to be followed in the RL process (Chaves et al., 2020). According to Agrawal et al. (2015) this stage represents the main entrance of RL and constitutes a set of practices performed usually by retailers to identify the products which are allowed into the RL system or given back to the user after resolving issues at their end or to proper disposal (Agrawal et al., 2016a). As an example, if a consumer returns the product to retail, then the retailer decides either the product returned must be sent for further processing or given back to the consumer, this decision is known as Gatekeeping.

Information like a list of materials and recovery methods available must be used to identify, select and collect residues with the highest recovery rate. This step aims to prevent the entry of inappropriate waste for recovery in reverse channels, contributing to maximizing the efficiency of activities related to waste reverse flow. From the RL process performance perspective, it would be recommended that this step should always be carried out at waste generation facilities. However, restrictions such as lack of space and infrastructure at generation sources or specific issues associated with waste etc, require this step only to be performed after collection and transport at processing centers.

**Collection**

The information acquired from previous RL processes constitutes the consolidation of selected waste (based on information from gatekeeping) from generating sources facilities (based on information from waste acquisition) to processing centers, in which the inspection/testing, disassembly and sorting processes take place. This is the general way in which this process is presented in the literature (Alshamsi and Diabat, 2017; Bai and Sarkis, 2019; Zouari, 2019). The collection begins with the transfer of the return items in possession of the generating sources (companies and consumers) to the processing centers. This transfer can occur passively, when the collection agents go to the point of generation, or actively when those responsible for generating the waste perform some type of movement for the transfer to occur. In the passive collection, those responsible for transferring the waste can be: the industry itself with or without outsourcing (Starostka-Patyk, 2019), public urban cleaning companies (Fagundes et al., 2017) or independent companies that negotiate directly with the market that promotes recovery. Inactive collection, those responsible for generating the waste can transfer directly to the collection points (Cline et al., 2015; Lechner and Reimann, 2015; Tsoulfas et al., 2002). The transfer can occur in a combined way as observed in the literature (Agrawal et al., 2015; Alshamsi and Diabat, 2017).

**Transport**

Although 39 papers (representing 32,23% of the total) have cited this activity as a part of the RL process, only one describes it. Zouari (2019, p. 3) characterizes it as "[...] moving secondary assets along the processing stream".

However, given the relevance of the transport activity, this research attempts to provide a much more detailed definition. Thus, for the proposed framework, we consider transport any activity strictly related to the movement of collected wastes (products, components, parts or materials) from the generating sources facilities, moved throughout processing centers and recovery facilities, to finally deliver in forwarding supply chains or proper disposal plants. In other words, it is an activity solely related to the movement of the material (transportation, uploading/downloading, handling) between facilities or activities in the reverse channels. Decisions about fleet (e.g. capacity or type of vehicles/equipment), crew (e.g. working/resting hours, overtime), pattern size of loads (e.g. less than truckload/truckload), routes (e.g. distance or type), etc., are related to the distribution activity. Therefore, this activity must be considered in any waste streams as interfacility as interactivities, through all the reverse channels in which the RL process takes place.

Hence, transport can be considered a collection complementary activity when the pickup zones are more distant from the processing facilities. Specific cases (e.g. difficult access areas or narrow streets) can be related to wastes moved by a low load capacity equipment (wheelbarrow, cargo cart, cargo bikes, cargo trailers, etc.) carrying out the collection from the generating sources. It also can refer to the short distance movements between stages of processes within processing centers, recovery facilities or proper disposal plants. So, the streams generated, for example, in picking activities of materials to be recovered, to be disposed of or already recovered materials must be considered transport activities. In the same way, this activity must be considered complementary for warehousing activities, especially related to materials handling at facilities (processing, recovery, proper disposal, etc.) that compose the reverse channel.

### Inspection/Testing

This process, in general, has the same objective as Sorting, which is the definition of the appropriate destination for the returned product. Some researchers have considered Inspection/Testing and Sorting synonymous (Agrawal et al., 2015; Chaves et al., 2020; Conti and Orcioni, 2019; Nel and Badenhorst, 2020; Shi et al., 2012; Starostka-Patyk, 2019; Zouari, 2019). However, in other situations there is a separation between these two processes (Alshamsi and Diabat, 2017; Chan et al., 2012; Cline et al., 2015). This is due to the complexity of the items considered, in the case of batteries a simple classification as type and model may be sufficient to define the best destination (Shi et al., 2012). In other cases, such as carpet (Cline et al., 2015) and vehicles (Chan et al., 2012), there is a need for a disassembly process after Inspection/Testing so that more information is obtained from the product of the component in the sorting process, which can define the best destination.

Therefore, to provide a robust framework we will consider these two processes separately, being Inspection/Testing a most detailed investigation of the collected waste, considering patterns of technology and materials statements, general conservation and functioning status (Alshamsi and Diabat, 2017; Chan et al., 2012; Cline et al., 2015), aiming to evaluate the most sustainable recovery alternative, namely Reuse. Whether such a recovery alternative is not possible, assessment of needs for waste disassembling must be carried out for better classification of components (modules, parts, elements, materials, etc.) and recognition of best recovery alternatives (repair, refurbishing, remanufacturing and recycling) or suitable ways of disposal. Depending on the residue characteristics, this step must consider from an observation of general condition and simple test of operation (turn on/off) to thorough tests, using advanced testing techniques, tools and technologies.

### Disassembly

This activity represents the dismemberment of waste (product, material or parts of these) into primary parts or components. Due to the simplicity of this concept, only four papers presented any kind of definition of this activity (Bai and Sarkis, 2013, 2019; Chan et al., 2012; Tsoulfas et al., 2002). Thus, we consider that this activity constitutes a specific and necessary RL step for some types of residues, in general, from higher added value products, such as vehicles, industrial equipment, agricultural machinery, electronics appliances, etc. Also, must be considered waste composed of different materials that need to be dismembered or dismantled considering that portions, parts or components of them may be directly reused as well as repaired, refurbished, remanufactured or recycled and then redistributed to forward supply chains. Is characterized by the organized dismemberment/dismantling of partial or total waste in portions, parts, subparts or basic components. This will help to analyze the waste condition, to find which can be recovered indeed. Such information can support decisions for the sorting stage especially for defining the most suitable means of recovery or proper disposal alternatives. However unfortunately most of the manufactured products have not been designed to be disassembled despite the imperative necessity for recovery of them.

### Sorting

It is a step related to analysis and general assessment of the conservation status of waste, parts, subparts or basic components of it (Alshamsi and Diabat, 2017; Chan et al., 2012; Cline et al., 2015). In fact, from now on, the most appropriate recovery and disposal alternatives are defined, considering certain associated criteria. The techniques, tools, technologies, basis of analysis and criteria for assessment to be applied will depend on the types of waste considered. However, it should generate enough information to support decisions regarding the destination of waste (parts, subparts, basic components or materials) to most suitable recovery options or proper disposal manners.

It is also important to highlight that, by the end of this activity, there will be groups of materials with different possibilities for recovering. Particularly, direct reuse (1), repairs (2), refurbishing (3), remanufacturing (4) and recycling (5), in addition to unrecoverable waste (6) that must be sent to the proper disposal alternatives. For each of these 6 different groups, it may be necessary to propose a logistical structure and strategies that consider those specific aspects and resources.

## Redistribution

This stage is mentioned as an RL activity in 41 papers (or 33,88% of the total). Nevertheless, merely two works conceptualized it (see Abdessalem et al., 2012; Agrawal et al., 2016a). A more comprehensive definition would be decomposing this activity into two stages.

The first stage refers to the RL process associated with 3 different groups of materials: direct reuse products (1), products or materials to be recovered (i.e. recoverable residues) (2) and materials to be properly disposed of (i.e. unrecoverable residues) (3). It consists of all activities related to the effective forwarding of processed materials (i.e. inspected/tested, disassembled and sorted materials) from processing points to the recovering plants or proper disposal facilities. Effectively it aims to meet the main objectives of the RL process, that is, make available used products for direct reuse, residues for recovery (i.e. repair, refurbishing, remanufacturing or recycling) and rejects for proper disposal (e.g. incineration, landfilling etc.). Based on the provided information from the Sorting or Inspection/Testing activities, this stage seeks to define distribution requirements, as well as resources, customers, routes, and delivery schedules of the products and materials from processing points to market (direct reuse products), recovering plants (residues) or proper disposal facilities (rejects). In this stage it still is worth noting that direct reuse products and materials to be repaired, refurbished or remanufactured demand a different RL process than materials to be recycled or to be disposed of properly. From a logistical perspective, this happens due to these previous four types of recovered materials presenting an added value status very similar to new products manufactured in the forward supply chain, requiring resources, strategies or activities of logistics quite different from the RL process performed to distribute materials to be recycled. For this same reason materials to be recycled also require a different distribution process from materials to be disposed of properly.

The second stage of this activity is one of the final steps of the RL process, associated with 2 different groups of recovered materials: recycled materials (1) and remanufactured, refurbished, repaired or for direct reuse products (2). It consists of all activities related to the effective forwarding of recovered materials to consumer markets. It aims to reintegrate direct reuse products and recovered materials or products to the most adequate productive cycles (Industry, commerce and services) along forwarding supply chains. Based on the demand information generated from the Integration activity, this second redistribution stage seeks to define the types and quantities of recovered materials, customers, and delivery schedules and routes, as well as the transportation of these materials from recovery points to the customer's facilities. It also is worth noting that recycled materials demand different RL resources than remanufactured, refurbished, repaired or direct reuse products. From a logistical point of view, it happens due to these last four types of recovered materials presenting an added value status very similar to new products manufactured in the forward supply chain, requiring logistical activities quite different from the RL process performed for recycled materials.

## Warehousing

As it happened with 'Disassembly', this activity is only mentioned in six studies (Abdessalem et al., 2012; Ang and Tan, 2018; Bai and Sarkis, 2013, 2019; Shi et al., 2012; Tsoulfas et al., 2002; Zouari, 2019) and no definition or detailed description was found in any surveyed articles for this activity. Thus, this activity refers to all actions aimed at maintaining the current conservation status of waste to be recovered (i.e. from inspection/testing activity to RL activities before recovery) or the new consumption status of already recovered waste (i.e. from RL activities after recovery to re-entry into forwarding supply chains). It also refers to all actions aimed at reducing the environmental impacts of the surrounding areas where the unrecoverable waste will be properly disposed of.

Also called Storage it considers all materials handling and internal movement activities in the facilities that compose the reverse channels, including unloading, compliance, control of quantities, varieties and, if applicable, storage deadlines, as well as picking, packaging, dispatching and loading of materials, spare parts, components and products. It considers any kind of waste, in all stages of the reverse channel (i.e. waste just collected, in processing, ready to be recovered or already recovered waste, as well as waste to be disposed of or already disposed of properly). Thus, it involves a set of logistical tasks that take place in all facilities of the reverse channels, from the processing centers, involving the inspection/testing, disassembly and, if necessary, sorting stages. It also considers going through recovery facilities and redistribution centers, until the resupply of direct channels, enabling the fulfillment of the 1st objective of the RL, associated with the Circular Economy paradigm. Finally, it also covers proper disposal facilities, such as incineration plants or landfills, helping to fulfill the 2nd objective of the RL, which refers to the proper disposal of unrecoverable waste.

## CONCLUSIONS

Considering the results achieved, it is possible to perceive that the research objectives were achieved and that it is possible to answer the questions raised in the introductory section. The results demonstrate a detailed analysis, characteristics and descriptions of each RL activity considered in this study and in addition, it was possible to arrive at the proposition of a conceptual framework with information in a systemic way and that aims to consolidate the activities that belong to the RL processes.

The RL processes add logistical value and provide infrastructure able to identify, move and select waste through all the adding value stages of the reverse channels as well as resupply the forward supply chains. Recovery options add functional value and bring back (by repair, refurbishing or remanufacturing) products, components, parts, etc. to their original functions or attributing to the new functions (by recycling). Proper disposal alternatives add environmental value by converting nonrecoverable waste to inert materials to the environment.

Despite the growth in research that cites or describes RL activities, in the period from 2010 to 2020, (see Figure 1), the total of analyzed studies (121 papers) only represents 6,68% of the total of collected papers fit for analysis (1,809 papers). In addition, as presented in Figure 2, whereas the citation counting of non-RL activities followed this same trend, the growth pattern is not observed with the same magnitude for RL activities, specially I-RL process activities (see Figure 3).

The current literature still presents broad definitions regarding RL activities. Given this, the objective of this study was achieved, since the proposed RL conceptual framework (Figure 4) presents conceptual details for each of the RL activities considered. It is noteworthy that none of the 121 articles analyzed mentions all ten RL activities that were considered in this study.

An objective blueprint of RL activities that help define RL costs more transparently. It also improves monitoring performance as well as a level of sustainability of the logistics processes. From a process-oriented approach, the RL activities can be organized in a standardized sequence of procedures and tasks aiming for a simpler decomposition in fixed/variable and direct/indirect costs for each one of them. This approach also allows inserting control points for measuring the operational and sustainable performance of the RL processes.

Highlights the importance of I-RL process activities for the overall performance of the RL process. Integration promotes information exchange between members of forwarding and reverse channels. Waste acquisition predicts nature, amount, source, and moment for collection. Gatekeeping defines which waste will be collected, considering the potential demands of this waste as well as technologies or capacities available for recovery or proper disposal. Such activities have the potential to reduce uncertainties on waste supply, and therefore could minimize the risk and costs of the other RL activities, and thus increase RL performance.

The limitation of this study was the design of the research protocol to address the topic of reverse logistics. For that reason, all of the scientific papers analyzed had a reverse logistics perspective. Therefore, it is possible for a paper that focuses on one of the activities of the framework not to have been shown during the database, if it doesn't mention the keywords "reverse logistics", "green logistics" and "sustainable logistics".

Future studies could investigate this framework within different contexts of waste, environmental regulations, supply chain stakeholders aiming to identify, describe and define the relationship among the RL activities, the information, material, and financial flows which compose the reverse channels as well as the responsibilities of the members of these channels related to each RL activity. This framework could also provide a basis for proposing RL activities performance indicators, aiming to improve the efficiency and sustainability levels of RL processes. This could also be useful for identifying more suitable SCM strategies for solving integration problems in reverse channels as well as improving the performance of RL processes. Another future research direction could be to investigate RL activities associated with information flows, which are barely mentioned in the scientific literature. This knowledge gap could greatly affect the effectiveness and efficiency of the RL processes, discouraging the structuring of reverse channels.

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**Author contributions:** All the authors contributed equally to this paper.