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Reverse Logistics: Overview and Challenges for Supply Chain Management

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Abstract This paper is aimed at introducing the concept of reverse logistics (RL) and its implications for supply chain management (SCM). RL is a research area focused on the management of the recovery of products once they are no longer desired (end-of-use products, EoU) or can no longer be used (end-of-life products) by the consumers, in order to obtain an economic value from the recovered products. This way, RL has become a matter of strategic importance, an element that companies are considering in their decision-making processes related to the design and development of their supply chains. In addition, a description of the implications of RL for SCM will be discussed and, finally, an analysis of some of the opportunities and challenges that RL implies for SCM will be presented.

Keywords Closed-Loop Supply Chain, Reverse Logistics, Marketing, Consumer Behaviour

1. Introduction

As a research topic, reverse logistics (RL) has attracted the attention of not only companies and professionals but also academia, which has been tackling this issue over the last 15-20 years [1-3]. This growing interest in RL in the business community is evidenced by an increase in the level of related activities in leading sectors such as transport, consumer electronics, textiles, and the press and media to name but a few [4]. In the academic field, most research conducted to date has been focused on tactical and operational aspects rather than on strategic issues [3].

As has been previously reported [5, 6], there are numerous reasons for implementing or operating an RL system. The most important of these are the following:

- Economic: direct reasons (decreasing the use of raw materials, reduction of disposal costs, creation of added value for end-of-use products) and indirect reasons (demonstration of environmentally responsible behaviour, improved customer relations).
- Legal: in many countries (within the European Union, for example) companies are held accountable for the recovery or correct disposal of waste generated by products they produce or distribute.
- Social: the increased social awareness of the need to protect the environment has led to increasing demands for environmentally responsible behaviour by companies, particularly in terms of carbon emissions and waste generation.

In this paper, an introduction to the concept of RL will be presented in order to describe its implications for SCM and challenges for the future regarding the recovery of products once they are no longer desired (end-of-use products, EoU) or can no longer be used (end-of-life products) in order to recover their economic value through activities of reusing, recycling and remanufacturing. In the context of this research, we consider EoU and end-of-life to be synonymous.

To this aim, an overview of the concept of RL is provided as well as a brief review of the main contributions in this field. Secondly, a description of the implications that RL can generate for SCM in aspects related to the design of the SC network, the processes of planning and coordination, and inventory management will be examined. Finally, we focus on one of the main research challenges in this context: the marketing issues of the recovered products.

The sources of information employed in the present study consisted of a group of papers in the RL area published in top journals within the last 20 years. The papers were identified through a searching procedure carried out by using keywords such as 'closed-loop supply chain', 'reverse supply chain', 'reverse logistics', 'product recovery management', 'remanufacturing', and 'marketing'. In a second step, a more detailed analysis was conducted in order to detect papers unrelated to these topics. Furthermore, the references of the selected articles were examined with the purpose of identifying other interesting papers not identified previously.

2. Background

According to [6], the concept of RL has evolved over the years, passing through various stages before consolidation. In this sense, [7] provides an interesting analysis of the evolution of closed-loop supply chain (CLSC) research and uses five phases to highlight the evolutionary process of this research area. Several definitions have been suggested for the concept of RL [8-10]; however, the proposal of the European Working Group on RL, REVLOG, appears to us to be the most complete, and will hence be the definition that we shall use in this current work. This research group defined RL as '*the process of planning, implementing and controlling backward flows of raw materials, in process inventory, packaging and finished goods, from a manufacturing, distribution or use point, to a point of recovery or point of proper disposal*' [6].

The growing interest in this topic can also be observed in the number of reviews published in recent years, which can be checked to obtain a more detailed view of this field—for example [2, 3, 7, 11, 12]. Nevertheless, we can highlight a set of papers that have undoubtedly contributed to the development of this research area:

- One of the seminal works on product recovery management is [5], where the authors provide a description of product recovery options, distinguishing between them according to the reprocessing process: repairing, refurbishing, remanufacturing, cannibalization, and recycling.
- Without a doubt, [13] is one of the key papers on this topic by providing a thorough review of the main Operational Research models for RL focusing on three crucial issues: distribution planning, inventory management, and production planning.
- [14] is a clear contribution to this field by providing a characterization of product recovery networks in order to their topology, economics, parties involved and decision and control issues, and classifying them in three categories according to the recovery process: bulk-recycling networks, remanufacturing networks, and reusable item networks.
- In [15], the authors introduce the concept of the CLSC and present different structures of remanufacturing networks in order to analyse the interactions between forward and reverse channel decisions.
- Finally, [7] presents an overview of the evolution of CLSC from a business perspective, giving some insights about future research needs related to 1) the development of more sophisticated operational research models to gather the business perspective of the problem, 2) the need to become more familiar with CLSC practice, and 3) the opportunity to build relationships with other disciplines such as marketing or accountability.

The conception of RL dates from long time ago, but the denomination of this term is difficult to trace with precision. During the 1980s, the definition was inspired by the movement of flows against traditional flows in the supply chain (reverse distribution, reverse channel); at the end of the 1990s, RL was characterized by recovery of the value of EoU products and the processes involved; now, a holistic view of the supply chain is proposed by considering forward and reverse flow from a business perspective, the so-called CLSC.

3. Implications for SCM

Successful implementation of RL networks requires many decisions relating to different hierarchical levels: strategic, tactical, and operational. However, the design of the RL network can be considered crucial in the decision making process. In practice, numerous RL networks can be observed that depend on the nature of the returned product (EoU, end-of-life, etc.), the recovery process (remanufacturing, reuse, recycling), or the forward channel

structure (centralized, decentralized). This way, the design of the RL network becomes a strategic issue in the context of SCM, and it is actually difficult to find a supply chain where RL is not present at least to some degree. Several contributions to this issue have provided a basic description of RL networks by identifying commonalities among them and indicating critical elements in their design and implementation. In [5], the authors classify RL networks according to the recovery option given to the EoU product: 1) direct use and resell, 2) repair, remanufacture, refurbishment, cannibalization and recycling, and 3) disposal. Similarly, [14] provides a classification (bulk-recycling networks, remanufacturing networks, and reusable item networks) based on the main characteristics observed in different business cases. In [16], a description of RL networks is developed using business cases that describe other elements related to organizational, environmental, technical and economic aspects. In the specific context of remanufacturing, [15] analyses four different configurations and classifies them according to their de-centralization degree, in order to describe the interactions between the forward and reverse channel decisions.

According to [17], the main alternative to consider when designing an RL network is the choice between an independent network for the recovery of EoU products and the integration of that network into the forward supply chain (CLSC). In this sense, [18] highlights that '*two interesting and relevant strategic questions from a practical perspective are 1) how can we design a product recovery network from scratch?, and 2) how can we design a new network if we already have an existing forward channel?*'. Similarly, [16] states that '*closing a supply chain may have consequences for the internal organizational structure of the initiator(s). It may impact design, sales, purchasing, production, distribution, after sales services and accounting departments*'. Other works, such as [13, 19], are also concerned about this issue, and consider it a crucial element in the decision process. In any case, an independent design (RL network) as a CLSC is set around two critical activities, namely: (i) the collection of EoU and (ii) the recovery of the economic value that they still incorporate (remanufacturing, reuse, recycling). In [20], a thorough analysis related to the design of RL networks is described, in order to identify the implications for the SCM according to 1) the right network structure, 2) the right collection strategy, and 3) the role of financial incentives in the collection strategy.

While networks design for EoU products recovery is an active area of research in the SC literature, further research effort is needed [18]. In this vein, [21] highlights that RL network configuration is a complex problem that requires the determination of the optimal locations and capacities of the collection centres, sorting centres, remanufacturing facilities and/or recycling plants.

Nevertheless, the design of an RL network is based on three basic activities:

1. Collection of EoU products: according to [17] collection of EoU products can be considered the starting point of the system, and three different collection options can be observed depending on whether the collection is made directly by the manufacturer or remanufacturer, through a network of distributors and retailers, or through third-party logistics providers.
2. Inspection and Classification: one of the main characteristics of the product recovery management is the uncertainty associated to the recovered products, in terms of quantity (how many products will be returned), quality (about the condition of the returned products), and time (when the EoU product will be returned). These activities (inspection and classification) will determine the condition of the returned products, so an analysis of the locations and capacities of sorting centres is required.
3. Recovery Process: can be considered as the key element of an RL network due to, in this phase, the economic value of the returned product being recovered through one of the following options:
   - Reuse: implies very basic activities to recondition the product (cleaning, minor repairs) that do not modify their structure or their nature (see [22] for a detailed analysis).
   - Remanufacturing: requires additional activities (disassembly, inspection, repair, and assembly) to recover the value of the returned products and give them similar qualities and technical characteristics to the original products: laptops, printers, mobile phones, etc.
   - Recycling: only the economic value of the raw materials is recovered, so the returned product loses its identity: packaging material, glass, paper, plastic, etc.

New opportunities for research in this stream can be considered, particularly those related to empirical application that could be of immediate help to practitioners [20].

4. New Research Issues in CLSC Management

The interest of academics and professionals in activities related to CLSC, RL, and remanufacturing has provided a better understanding of the characteristics, processes and implications that the recovery of EoU products has on business activity. Despite this, some concerns require our attention; for example, those related to the strategic aspects of the CLSC, and particularly the marketing issues associated to the recovered products. There is a broad consensus that one of the challenges for CLSC research in the coming years is the need to examine in

depth its relationships with the market and consumers [7, 12, 23, 24]. In this specific area of research, most of the problems analysed in the literature have been approached from a point of view related to operations research, management science and engineering fields, by describing the flow of goods from the consumer back to the producer or to the recovery agent, e.g., collection, recovery value (reuse, remanufacturing, recycling), inventory management, etc. [6]. However, there has been limited work from the marketing perspective, especially surrounding issues such as commercialization of recovered products, their acceptance by consumers, the existence of new markets for these products and how these markets can be developed, which marketing strategies are best suited for this purpose, or what type of consumer should be targeted [25, 26].

According to [24], recent reviews of CLSC research have highlighted the need for an empirical treatment of market factors. In this sense, [7] also claims for more interdisciplinary research with marketing and accounting areas to validate assumptions that many of the CLSC models are based on, in order to '*keep the business model perspective rather than optimizing an isolated part of the problem*'. In [23] the authors recognize that '*the marketing aspects of remanufacturing are largely unexplored by academic research*', so now would be a good time to begin to explore some of those aspects.

Although a more detailed review can be found in [24, 25], we are reviewing those studies that are focused on analysing some particular marketing issues in the context of the CLSC, for example:

1. The willingness to pay (WTP) for remanufactured products: [26] uses experimental auctions to describe consumers' WTP for remanufactured products, finding evidence that consumers tend to value the remanufactured product (in this case, a single-use camera) less than the original one, and are not willing to pay a premium for the remanufactured product, as can be observed for other kind of products (organic foods, for example). In [27] an analysis about how a company makes remanufacturing decisions is developed as well as a study of consumer behaviour based on an estimation of the fraction of consumers that, for a given price difference, would switch from the new to remanufactured product. Some remarkable findings of this paper are that consumers would be more willing to pay for remanufactured products if they had clear information about terminology used in this market (refurbished, returned, rebuilt, remanufactured, etc.) and about product's history (why was it returned, when, and where). Because of this absence of information, consumers tend to use price as a way to judge product quality, so a low price would indicate a low product quality, and so only a few consumers switch from a new to a remanufactured product. In [28] the authors analyse the consumers' WTP for recycled products considering seven different types of products, as well as the switching behaviour of consumers from recycled to new products due to price differences. These authors find that consumers' WTP premium price for recycled products is product-specific, and there exists a tremendous variation both in relative price and switching range for different types of products.
2. Cannibalization: [23] shows that remanufacturing does not always cannibalize new product sales, and if it does the additional profits of remanufacturing can outweigh the cannibalization costs; for this same issue, [29] uses a novel procedure to determine consumers' WTP for remanufactured products and, at the same time, assess the effect of cannibalization of new product sales.
3. Competition: this is another marketing issue in the context of CLSC, for which [30-32] can be considered as basic references for the study of this topic and its implications for the different participants in the remanufactured products market. In this sense, for example, [30] suggests that direct competition between original equipment manufacturers (OEMs) may have a significant impact on the profitability of remanufacturing. In [31] the authors show that manufacturers that also have remanufacturing operations may benefit from managing both new and remanufactured products. In the same vein, [32] provides a study about price competition between an OEM and a local remanufacturer, and the effect of different strategies on the competitive prices and quantities in the market, as well as the players' profits.
4. Other issues: [25, 33] discuss different aspects of consumer perceptions of remanufactured products, meanwhile [24] evaluates several factors that explain purchase price differentials between new and remanufactured products.

Although these papers may appear to be a large number of references on this topic, they are only a fraction of the total of the work published on CLSC, despite some of the most cited authors in this area calling for more research into issues such as consumer behaviour and the market for remanufactured products [7, 12, 20].

In order to illustrate this issue, an experiment designed to analyse a purchasing scenario of a remanufactured laptop will be presented [34]. This study is aimed at describing the relations between the price of the product, considering the conventional (new) product and two remanufactured versions of the laptop, as well as the

'reputation' of the remanufacturer (original equipment manufacturer vs. third-party remanufacturer) and the purchase intention of the consumers.

The information required to carry out this work was gathered by a self-administered questionnaire applied to a sample of 1,529 students from two Spanish universities in 2011. Prior to application of the definitive questionnaire, two pre-tests were conducted in order to identify potential sources of error and ensure that all the variables and elements of the analysis were correctly represented in the questionnaire.

The questionnaire was designed to obtain useful information about the behaviour of remanufactured product consumers and their purchase intention, as well as to observe the knowledge of respondents about remanufactured products. The intention to purchase is analysed through an experiment in which potential buyers (respondents) have to indicate which product—in this case, which laptop (original, remanufactured by the original equipment manufacturer, or remanufactured by a third-party remanufacturer)—they would purchase in each of the five different proposed scenarios. The basic characteristics of this experiment are shown in Table 1.

Scenario	Original laptop	Reman. by OEM	Reman. by third party
1	750 €	750 €	750 €
2	750 €	600 €	575 €
3	750 €	525 €	500 €
4	750 €	450 €	400 €
5	750 €	375 €	300 €

Table 1. Purchasing Simulation Data

The program IBM SPSS statistics v19 was used to analyse the data.

The results suggest that at the present time, remanufactured products remain a market to be discovered. Most of the respondents are not familiar with this kind of product and, according to the results, only 17.79% of the respondents claimed to know exactly what remanufactured products were; only around 42% had heard of their existence, but did not know exactly what they were. For this reason, remanufactured products can be considered a business opportunity for remanufacturers who should focus their marketing strategies on this segment of consumers, trying to identify their consumption preferences, willingness to pay for this type of products, etc.

In addition, the results of this research show that respondents are willing to buy a laptop remanufactured by an original equipment manufacturer rather than an original laptop when the price of the remanufactured product is at least 20% lower than the price of the original one. It suggests that individuals would consider the price to be a significant attribute in the purchase of this kind of product. Similar results can be found in [25, 29], which show that consumers have a lower valuation of remanufactured products compared to their original counterparts, so that the WTP for new products is higher than that for remanufactured products. Another interesting finding is that respondents are willing to purchase an OEM remanufactured laptop instead of one from a third party remanufacturer in each of the simulated scenarios, in spite of its higher price. This suggests the reputation of the manufacturer's brand to be a noteworthy aspect that can significantly influence purchase intention, possibly because it is able to signal details of product or service quality and help to mitigate uncertainties faced by buyers of remanufactured products [24].

It is necessary to note that the greater knowledge of remanufactured products the respondents have, the more willingness they show to purchase a remanufactured laptop. Therefore, companies might implement information campaigns for the promotion of this kind of product among consumers as a way to increase demand and the WTP of consumers for remanufactured products. As in other previous works [30], a group of consumers has also been found that makes decisions based on environmental criteria—defined as green consumers—so they too can be seen as a target segment for remanufacturers.

Naturally, we must acknowledge certain limitations of the present work. First of all, we recognize that the participation of undergraduate students in the survey is a controversial issue that has already been addressed in other studies, receiving arguments both for [35] and against [36]. In this case, we believe that, because of their evident knowledge of the generic product under study, i.e., computers, undergraduates may be regarded as a satisfactory example of the consumer of this type of product. Secondly, we are aware of our study focuses on a specific remanufactured product and a particular segment of consumers. So, some future research should be carried out in order to analyse whether similar results can be obtained with other kinds of products or consumers.

Of course, there are many additional issues to be analysed—for example, those related to the potential commercial activities and marketing policies that firms might implement according to the purchasing preferences shown by respondents. Nevertheless, this investigation should be considered a first step in the process of connecting marketing with SCM, in what we trust would be a fruitful relationship.

5. Conclusions

RL is a research topic that has evolved during the last two decades but at the present time can be considered a consolidated topic of research, with hundreds of papers published since 1995 in the most prestigious scientific journals. RL is not only an interesting issue for researchers, but also for companies and professionals who are considering the recovery of EoU products as a business opportunity, who are taking these activities into account in their strategic processes of decision making.

RL has several implications for SCM, but probably the most challenging is related to the design of the RL network. For this reason, a description of the basic activities related to the design process has been examined: collection, inspection, and recovery process. In spite of the relevance of the literature on the design of RL networks, new lines of research are still open.

The interest of academics and professionals in activities related to CLSC, RL and remanufacturing has provided a better understanding of the characteristics, processes and implications that the recovery of EoU and end-of-life products have on business activity. In spite of this fact, some concerns require our attention; for example, those related to the strategic aspects of the CLSC, and particularly those issues related to the potential commercial activities and marketing policies that firms can establish.

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