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**CHARACTERISTICS OF THE RESEARCH ON
REVERSE LOGISTICS (1995-2005)**

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CHARACTERISTICS OF THE RESEARCH ON REVERSE LOGISTICS (1995-2005)

ABSTRACT

This paper aims to describe and analyse the main characteristics of articles on reverse logistics published in the production and operations management field, in order to determine the evolution of this current of research over recent years and improve our understanding of this issue. We built up a database with the articles on reverse logistics published in the most relevant journals within the period 1995-2005, and we have explored the topic, the methodology and the techniques of analysis, as well as other relevant aspects of the research. We have evaluated the first decade of research on reverse logistics, observing what has been done and how, where and by whom it has been carried out. The result is an extensive review of the research works that have created and developed the reverse logistics concept, outlining some directions of research for the near future and offering practical help to those who begin to research on this topic.

Keywords: Reverse logistics; product recovery; literature review.

1. INTRODUCTION

Reverse logistics is a research area that has been of particular interest to the academic community in recent years and this is reflected in the main journals on production and operations management. In view of this interest, we propose to analyse the main characteristics of these studies in order to evaluate what has been done and how, where and by whom it has been carried out. The answers to these questions will not only allow us to deepen our knowledge of the current situation of reverse logistics research, but will also help us to determine what still needs to be investigated, outlining some directions of research for the near future and offering practical help to those who begin to research on this topic. In this respect, the objective of this work is to analyse the main characteristics of a series of studies on the concept of reverse logistics that have been published in some of the most prestigious scientific journals in the period 1995-2005.

Clearly, the idea of tackling a literature analysis of this size is very ambitious and it must be appropriately delimited, so that the abundance and heterogeneity of the data available does not prevent us achieving the objectives we have set ourselves. In this respect, we should point out that we are only interested in those articles that can be considered essential points of reference in the reverse logistics field and we have therefore selected those papers published in the main international scientific journals.

The concept of reverse logistics has evolved over the years, passing through varying stages until becoming consolidated (de Brito and Dekker 2004, Fernández 2005). Among the many definitions that have been suggested for this concept (Stock 1992, Rogers and

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4 Tibben-Lembke 1999, Dowlatshahi 2000, among others), the proposal of the European
5 Working Group on Reverse Logistics, REVLOG, appears to us to be the most complete and
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7 will hence be the definition that we shall use in this current work. This research group
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9 defines reverse logistics as ‘the process of planning, implementing and controlling
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11 backward flows of raw materials, in process inventory, packaging and finished goods, from
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13 a manufacturing, distribution or use point, to a point of recovery or point of proper
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15 disposal’ (de Brito and Dekker 2004, p.5). Given its novelty as a research area, the
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17 definition of reverse logistics may cause certain confusion among those interested in the
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19 area, with the result that it can often be confused with issues that are related to it but strictly
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21 distinct from it: industrial ecology, green supply chains, waste management, etc. To avoid
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23 any possibility of ambiguity in the delimitation of the object of our work, we shall focus on
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25 those articles that have contributed to building and developing this line of research,
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27 ignoring those that do not explicitly examine any of the elements making up the concept of
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29 reverse logistics as defined here.
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39 Furthermore, we feel that it is necessary to analyse works of the highest quality, so
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41 that our findings lead to conclusions based on criteria of quality in the research. Thus, we
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43 have selected a group of journals of renowned prestige among the international academic
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45 community, completing the selection with other publications that are highly regarded in the
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47 area of production and operations management.
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51 Given these premises, the rest of this paper is structured as follows: first, we
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53 describe the methodology we have employed to build the database of articles to be
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55 analysed. We then present the main research topics within the reverse logistics field
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4 identified in our analysis of the specialized literature. In the following section we outline
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6 the main findings of our research. We end with a section outlining our conclusions and final
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8 reflections.
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10 11 12 13 **2. METHODOLOGY**

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16 The sources of information required for the present research consist of a group of
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18 specialized journals considered likely to include works in the reverse logistics field. We
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20 have excluded proceedings and doctoral theses, in the understanding that quality studies
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22 tend to be published in this type of journal eventually and in addition these publications are
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24 the most cited in scientific papers. In this point we coincide with the majority of previous
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26 studies carried out at the international level (Stahl *et al.* 1988; Bairam 1994).
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32 The next step was to select the scientific journals that would be considered in this
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34 study. We opted to select the most prestigious publications in the area of Business
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36 Management and for this we made use of the list of journals published by *ISI Journal of*
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38 *Citation Reports* (2004). Among the various topics used by this classification, we chose the
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40 subject categories '*Business*', '*Management*' and '*Operations Research and Management*
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42 *Science*', which we felt would be the most likely to include journals publishing works on
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44 the concept of reverse logistics. Obviously, not all articles on reverse logistics published
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46 during the period of analysis would have been published in impact factor journals. There
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48 are other prestigious scientific publications not included in the *ISI Journal of Citation*
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50 *Reports* that have published articles on this topic and we feel they should be included in our
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52 work in order to lend more significance to the findings that we obtain and also to be able to
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4 more accurately observe the evolution in the research on reverse logistics in the past
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6 decade. On the other hand, these journals are included in other studies analyzing the state of
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8 the research in the field of production and operations management (Babbar and Prasad
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10 1998; Barman *et al.* 2001; Prasad *et al.* 2001).
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15 For the present study, we ignore brief notes, introductions, editorials, professional
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17 commentaries and book reviews, which are common in the journals analysed and which
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19 cannot be classified as published articles. We have however opted to include articles
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21 appearing in monographic editions on Supply Chain Management and the Environment,
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23 since although these may distort the results somewhat because of their focus on a specific
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25 subject, we believe they reflect the interest of researchers on the topic that is object of study
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27 here, as well as the need to advance understanding in it.
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33 Our analysis relates to the period 1995-2005, since although there are articles
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35 centring on this issue prior to 1995 (among which, Guiltinan and Nwokoye 1975, Fuller
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37 1978, Ginter and Starling 1978), and even two monographs (Stock 1992, Kopicki *et al.*
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39 1993), it is really only after this year that the concept of reverse logistics itself becomes
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41 consolidated and we start to see works on the environmental aspects of Supply Chain
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43 Management finding space in this type of journal (Alfaro *et al.* 2003). Moreover, to the best
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45 of our knowledge, there are not articles on reverse logistics published in journals included
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47 in JCR, before this year.
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53 As we pointed out earlier, our idea was to analyse those articles that study aspects
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55 directly related to reverse logistics. With this in mind, we carried out a literature search
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4 using the terms '*reverse logistics*' and/or '*product recovery*' in the title, abstract or
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6 keywords of the articles appearing in the selected journals during the period of analysis.
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8 The inclusion of the term '*product recovery*' is justified because in a first search where we
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10 included only the concept '*reverse logistics*', we found that an important number of works
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12 were absent, works that were relevant in spite of not containing the term '*reverse logistics*'.
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14 This term has become consolidated only gradually, in parallel with the growing appearance
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16 of research papers on the topic in these journals. In any case, each work resulting from the
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18 search was then carefully analysed in order to confirm that its focus was indeed on reverse
19
20 logistics. Furthermore, we examined the bibliography of each article to detect potential
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22 omissions from the initial search and finally we compared the resulting database with the
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24 set of bibliographical references used in various monographs (Fleischmann 2001, Dekker *et*
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26 *al.* 2004, Dyckhoff *et al.* 2004). Thus, we completed our database, which contained a total
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28 of 186 articles published in 26 journals (see Table 1). A total of 68.28% of the articles were
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30 published in journals edited in Europe and the remaining 31.72% in publications from the
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32 United States. However, half of the journals included in this study have been edited in USA
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34 and the other half in Europe,
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44 Once we had built up our database we analysed each article using a data collection
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46 sheet in which we included, among other things, information concerning the research topic
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48 in which the article was framed, the methodology followed, the techniques of analysis
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50 employed, the number of authors, their origin and the number of references used.
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52 Moreover, in cases where it was relevant, we examined, complementary aspects of the
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research such as the information collection techniques, sources of information employed, the temporal and geographical scope of the study and the unit of analysis utilized.

Table 1. List of journals

Journal	Articles
<i>California Management Review</i>	10
<i>Computers & Industrial Engineering</i>	9
<i>Computers & Operations Research</i>	1
<i>European Journal of Operational Research</i>	24
<i>Harvard Business Review</i>	2
<i>IEEE Transactions on Engineering Management</i>	1
<i>IIE Transactions</i>	5
<i>Industrial Marketing Management</i>	2
<i>Interfaces</i>	11
<i>International Journal of Physical Distribution & Logistics Management</i>	10
<i>International Journal of Production Economics</i>	29
<i>International Journal of Production Research</i>	25
<i>International Journal of Technology Management</i>	1
<i>Journal of Operations Management</i>	4
<i>Journal of Retailing</i>	1
<i>Journal of the Operational Research Society</i>	8
<i>Management Science</i>	7
<i>Naval Research Logistics</i>	2
<i>Omega</i>	3
<i>Operations Research</i>	1
<i>OR Spectrum</i>	11
<i>Production and Operations Management</i>	7
<i>Production Planning & Control</i>	5
<i>Technological Forecasting and Social Change</i>	1
<i>Total Quality Management & Business Excellence</i>	1
<i>Transportation Research Part E: Logistics and Transportation Review</i>	5
TOTAL	186

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4 In order to determine the main research topics in the reverse logistics field, we
5 considered it advisable to use the classification employed by Dekker *et al.* (2004), who
6 identify three fundamental areas of research on reverse logistics:
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- 10 1) Management of the recovery and distribution of end-of-life products
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- 12 2) Production planning and inventory management
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- 16 3) Supply chain management issues in reverse logistics
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27 Within the first research topic, 'management of the recovery and distribution of end-
28 of-life products', we find all those works analysing the different physical flows present in
29 the reverse logistics systems, especially those issues relating to the collection and
30 distribution of end-of-life (EOL) products. Thus, aspects such as the analysis of EOL
31 product returns, the design of the reverse logistics network and its interaction with the
32 forward logistics flow, the analysis of transport routes or questions of internal logistics,
33 among others, are covered by this research topic. The topic 'production planning and
34 inventory management' embraces those works in which the main object of the research is
35 the coordination of the processes of EOL product recovery and particularly aspects deriving
36 from the existence of a reverse flow of EOL products and its interaction with traditional
37 production planning. Among the main questions analysed by the studies in this topic, we
38 find: the effects that the existence of a reverse flow of EOL products generates in the
39 traditional models of inventory management, the dynamic capabilities of these reverse
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4 flows, specific aspects of planning production such as the design of disassembly operations
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6 and the coordination of manufacturing operations with economic recovery operations
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8 (remanufacturing, recycling, reuse). Finally, the topic 'supply chain management issues in
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10 reverse logistics' concerns those works that analyse the strategic decisions, which the
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12 existence of a reverse flow of EOL products generates in the management of the supply
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14 chain. Thus, questions such as the long-term behaviour of closed-loop supply chains, the
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16 role of IT, the impact of environmental regulation and the environmental management of
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18 reverse logistics, among others, are included in this topic.
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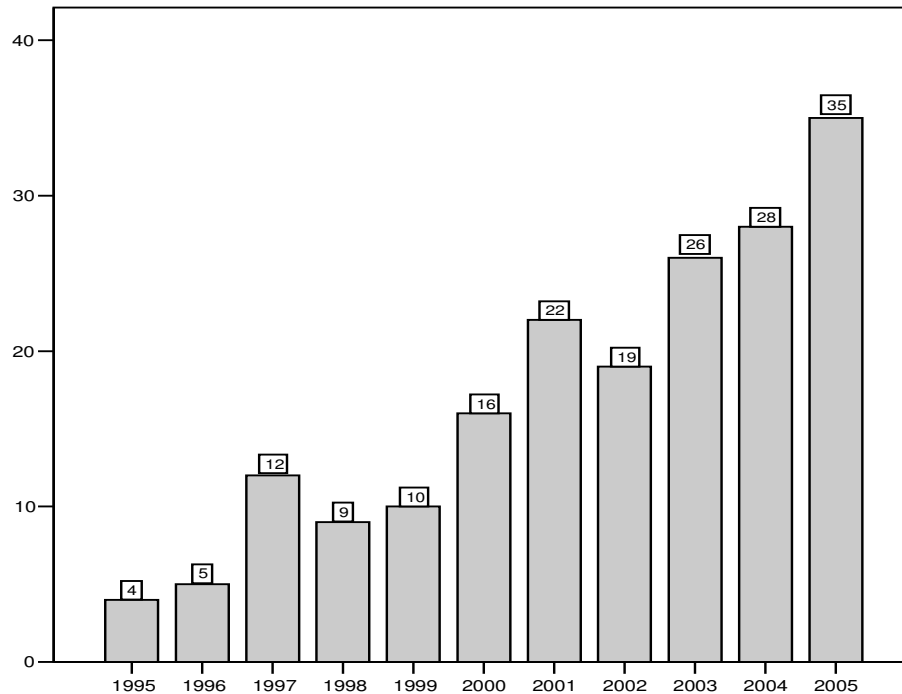
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25 We classified the articles within each research topic by examining the title, abstract,
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27 keywords and main body of the paper. This review was carried out independently by each
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29 member of the research team. Most of the articles were classified unequivocally into one of
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31 the three different topics. However 14.75% of them were either considered doubtful or two
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33 or more members of the team disagreed in their classifications. In these cases, we reviewed
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35 the articles again and then the team as a whole agreed on the most appropriate
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37 classification.
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42 **3. RESULTS**

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46 In the first place, we observe that reverse logistics, as a research area in the field of
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48 production and operations management, has experienced increasing interest in the period of
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50 analysis considered, a fact that is mainly reflected in the growth in the number of articles
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52 published in the journals analysed (figure 1).
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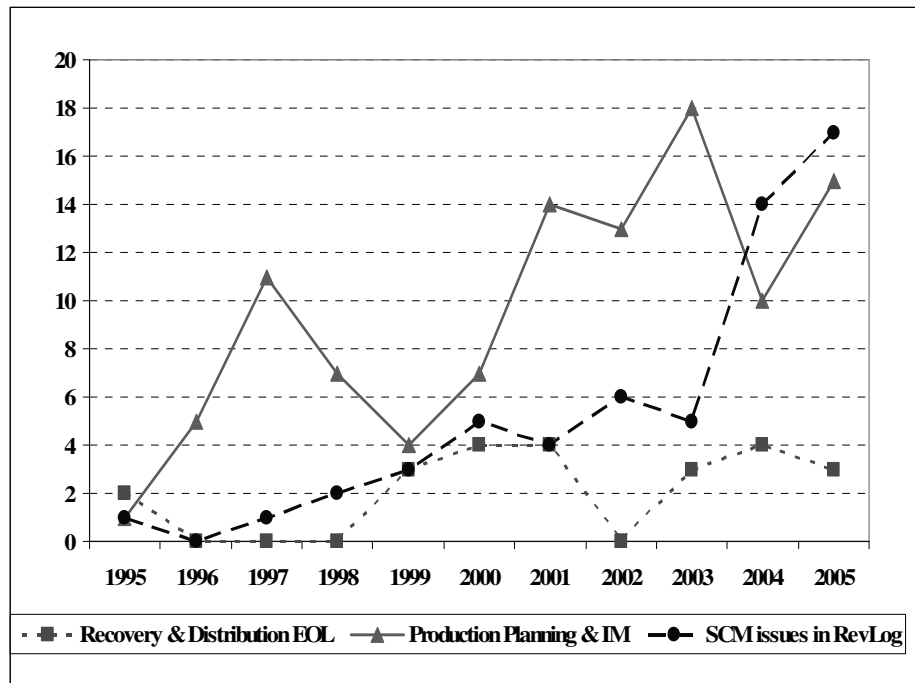
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One of the reasons for this spectacular growth is found in the monographs and special issues that various journals have dedicated to environmental questions associated with production and operations management. In fact, in 1999 *Computers & Industrial Engineering* dedicated an edition to the analysis of manufacturing processes that were respectful to the environment (Environmentally Conscious Manufacturing); in the year 2000, *Interfaces* published a monograph under the title ‘Sustainable Business’; in 2001, *OR Spectrum* and *Production and Operations Management* published issues on ‘Operational Research and Environmental Management’ and ‘Environmental Management and Operations’, respectively; in late 2003, *Interfaces* published another special edition, on this occasion on the problems thrown up by closed-loop supply chains. Finally, in 2004, *California Management Review* edited a special issue on ‘Closed-loop Supply Chains Management’. Throughout 2006 more special issues on reverse logistics will be published: *Omega* on ‘Reverse production systems’, *International Journal of Production Economics* on ‘Sustainable supply chain management’, *OR Spectrum* on ‘Product recovery’ and *Production and Operations Management* on ‘Closed-loop supply chains’. In addition to these special editions, in recent years various monographs on reverse logistics have been published: Stock (1998), Fleischmann (2001), Guide and Van Wassenhove (2003), Dekker *et al.* (2004) and Dyckhoff *et al.* (2004). Thus, we can clearly say that the interest of the academic community in this research topic has grown significantly in recent years, which has consequently contributed to its development, both quantitatively and qualitatively.

Figure 1. Number of articles published in the period

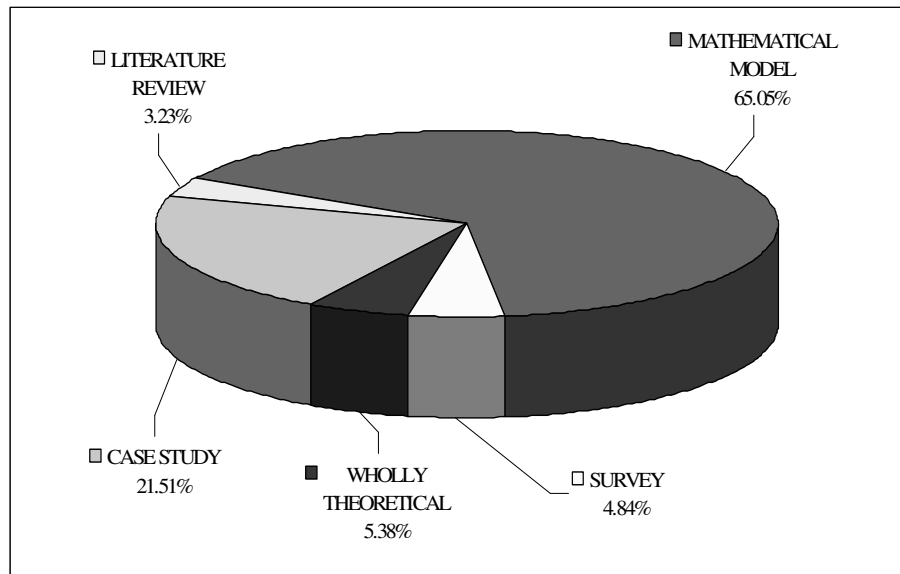
Analysing the articles by research topic, we observe that 56.45% can be included within the topic 'production planning and inventory management', 31.18% analyse questions of a strategic nature and can be framed within the topic 'supply chain management issues in reverse logistics', while 12.37% of the articles analyse questions relating to the 'management of the recovery and distribution of end-of-life products'. However, we note that the topic 'supply chain management issues in reverse logistics' has attracted the attention of researchers in recent years. In fact, most of the works published in 2004 and 2005 fall within that research topic (figure 2).

Figure 2. Evolution of Research Topics



The studies published during the period of analysis appear to be focusing on the analysis of tactical and operational decisions, a finding which should have some relation with the type of study carried out as well as the methodology followed. In this respect, the analysed works employ methodologies (figure 3) that are both quantitative (basically using mathematical models) and qualitative (case study, literature review or theoretical developments). A total of 19.89% of the articles analysed use two different research methodologies, with case studies being the most popular of the second methodologies chosen (54.05%).

Figure 3. Research methodology



With regards to the relation between the research topic and the journal in which the article appears (table 3), we find that **60.87%** of the articles analysing the ‘management of the recovery and distribution of end-of-life products’ are concentrated in just **four** journals: *Computers & Industrial Engineering*, *Interfaces*, *International Journal of Production Research* and *OR Spectrum*. Furthermore, all of the articles on this topic are published in just ten of the analysed journals. In turn, the works on ‘production planning and inventory management’ are published in a wider spread of journals. Indeed we find only seven publications that have not published articles on this research topic in the period of analysis. In any case, the European journals *European Journal of Operational Research*, *International Journal of Production Economics* and *International Journal of Production Research* published fully **57.14%** of the articles on this topic. With regards to ‘supply chain management issues in reverse logistics’, we find that **twenty** of the analysed journals

include works on this topic, with a similar level of concentration, since 67.24% of the works were published in a group of seven journals: *California Management Review*, *European Journal of Operational Research*, *Interfaces*, *International Journal of Physical Distribution & Logistics Management*, *International Journal of Production Economic*, *European Journal of Production Research* and *Transportation Research, Part E*.

Table 3. Journal and Research Topic

JOURNAL	Management of the recovery and distribution of EOL products		Production planning and inventory management		Supply chain management issues in reverse logistics		TOTAL
<i>CALIF MANAGE REV</i>	0	0.00%	0	0.00%	10	17.24%	10
<i>COMPUT IND ENG</i>	3	13.04%	4	3.81%	2	3.45%	9
<i>COMPUT OPER RES</i>	0	0.00%	1	0.95%	0	0.00%	1
<i>EUR J OPER RES</i>	2	8.70%	17	16.19%	5	8.62%	24
<i>HARVARD BUS REV</i>	0	0.00%	0	0.00%	2	3.45%	2
<i>IEEE T ENG MANAGE</i>	0	0.00%	1	0.95%	0	0.00%	1
<i>IIE TRANS</i>	0	0.00%	5	4.76%	0	0.00%	5
<i>IND MARKET MANAG</i>	0	0.00%	0	0.00%	2	3.45%	2
<i>INTERFACES</i>	4	17.39%	2	1.90%	5	8.62%	11
<i>IJPD&LM</i>	2	8.70%	1	0.95%	7	12.07%	10
<i>INT J PROD ECON</i>	0	0.00%	25	23.81%	4	6.90%	29
<i>INT J PROD RES</i>	3	13.04%	18	17.14%	4	6.90%	25
<i>INT J TECHNOL MANAGE</i>	0	0.00%	0	0.00%	1	1.72%	1
<i>J OPER MANAG</i>	0	0.00%	4	3.81%	0	0.00%	4
<i>J RETAILING</i>	0	0.00%	0	0.00%	1	1.72%	1
<i>J OPER RES SOC</i>	0	0.00%	6	5.71%	2	3.45%	8
<i>MANAGE SCI</i>	1	4.35%	5	4.76%	1	1.72%	7
<i>NAV RES LOG</i>	0	0.00%	2	1.90%	0	0.00%	2
<i>OMEGA-INT J MANAGE S</i>	1	4.35%	1	0.95%	1	1.72%	3
<i>OPER RES</i>	0	0.00%	1	0.95%	0	0.00%	1
<i>OR SPECTRUM</i>	4	17.39%	6	5.71%	1	1.72%	11
<i>PROD OPER MANAG</i>	2	8.70%	3	2.86%	2	3.45%	7
<i>PROD PLAN CONTROL</i>	1	4.35%	2	1.90%	2	3.45%	5
<i>TECHNOL FORECAST SOC</i>	0	0.00%	0	0.00%	1	1.72%	1
<i>TOTAL QUAL MANAG BUS</i>	0	0.00%	0	0.00%	1	1.72%	1
<i>TRANSPORT RES E-LOG</i>	0	0.00%	1	0.95%	4	6.90%	5
TOTAL	23	12.37%	105	56.45%	58	31.18%	186

Table 4. Articles by topic and methodology

	CASE STUDY	LITERATURE REVIEW	MATHEMATICAL MODEL				SURVEY	WHOLLY THEORETICAL
MANAGEMENT OF THE RECOVERY AND DISTRIBUTION OF EOL PRODUCTS	Guide Jr. & Van Wassenhove, 2001 Guide Jr. et al., 2005 Jahre, 1995 Klausner & Hendrickson, 2000 Krikke et al., 1999a Krikke et al., 1999b	Kroon & Vrijens, 1995 le Blanc et al., 2004 Listes & Dekker, 2005 Ravi et al., 2005 Rudi et al., 2000 Schultmann et al., 2003	Fleischmann et al., 2000	Baumgarten et al., 2004 Beamon & Fernandes, 2004 Dethloff, 2001 Fleischmann et al., 2001 Jayaraman et al., 2003	Krikke et al., 2003 Lowers et al., 1999 Savaskan et al., 2004 Sodhi & Reimer, 2001	Guide Jr. & Jayaraman, 2000		
PRODUCTION PLANNING AND INVENTORY MANAGEMENT	de Brito & Dekker, 2003 Ferrer & Whybark, 2001 Ferrer, 2001 Guide Jr. et al., 2003 Kekre et al., 2003 Linton & Johnston, 2000 Spengler et al., 1997	Guide Jr., 2000	Aksoy, 2005 Aras et al., 2004 Bayindir et al., 2003 Bayindir et al., 2005 Beltrán & Krass, 2002 Brander & Forsberg, 2005 Buchanan & Abad, 1998 Ching et al., 2003 Debo et al., 2005 DeCroix & Zipkin, 2005 DeCroix et al., 2005 Dobos & Richter, 2004 Dobos, 2003 Emmons & Gilbert, 1998 Erdos et al., 2001 Ferrer & Ketzenberg, 2004 Ferrer, 2003 Fleischmann & Kuik, 2003 Fleischmann et al., 2002 Golany et al., 2001 González & Adenso, 2005 Guide Jr. & Spencer, 1997 Guide Jr. & Srivastava, 1997a Guide Jr. & Srivastava, 1997b Guide Jr. & Srivastava, 1998	Guide Jr. et al., 1997a Guide Jr. et al., 1997b Guide Jr. et al., 1998 Guide Jr. et al., 1999 Guide Jr. et al., 2000 Guide Jr. et al., 2005 Guide Jr., 1996 Guide Jr., 1997a Guide Jr., 1997b Gungor & Gupta, 2002 Heisig & Fleischmann, 2001 Hu et al., 2002 Inderfurth & van der Laan, 2001 Inderfurth et al., 2001 Inderfurth, 1997 Inderfurth, 2004 Inderfurth, 2005 Johnson & Wang, 1995 Johnson & Wang, 1998 Ketzenberg et al., 2003 Kiesmüller & Minner, 2003 Kiesmüller & Scherer, 2003 Kiesmüller & van der Laan, 2001 Kiesmüller, 2003a Kiesmüller, 2003b	Kleber et al., 2002 Kleineidam et al., 2000 Koh et al., 2002 Krikke et al., 1998 Mahadevan et al., 2003 Mangun & Thurston, 2002 Minner & Kleber, 2001 Minner, 2001 Mostard & Teunter, 2005 Mukhopadhyay & Setoputro, 2005 Nakashima et al., 2002 Nakashima et al., 2004 Richter & Dobos, 1999 Richter & Gobsch, 2003 Richter & Sombutzki, 2000 Richter & Weber, 2001 Richter, 1996a Richter, 1996b Richter, 1997 Robotis et al., 2005 Souza & Ketzenberg, 2002 Souza et al., 2002 Spengler et al., 2003 Stanfield et al., 2004 Tang & Grubbstrom, 2005	Tang & Naim, 2004 Tang et al., 2004 Teunter & van der Laan, 2002 Teunter & Vlachos, 2002 Teunter et al., 2000 Teunter et al., 2004 Teunter, 2001 Teunter, 2001 Teunter, 2004 Totkay et al., 2000 van der Laan & Salomon, 1997 van der Laan et al., 1996a van der Laan et al., 1996b van der Laan et al., 1999 van der Laan et al., 1999 van der Laan, 2003 Vlachos & Dekker, 2003 Vlachos & Tagaras, 2001 Voutsinas & Pappis, 2002 Yang et al., 2005 Yao et al., 2005 Yuan & Cheung, 1998		
SUPPLY CHAIN MANAGEMENT ISSUES IN REVERSE LOGISTICS	Amini et al., 2005 Barros et al., 1998 Dhanda & Hill, 2005 Dowlatshahi, 2005 Ferguson & Browne, 2001 Fleischmann et al., 2003 Geyer & Jackson, 2004 Goggin et al., 2000 Goldsby & Closs, 2000 Hicks et al., 2004 Johnson, 1998	Krikke et al., 2004 Maslennikova & Foley, 2000 Matthews, 2004 Nagel & Meyer, 1999 Seitz & Peattie, 2004 Spengler & Schröter, 2003 Tan et al., 2003 Thierry et al., 1995 Tibben-Lembke, 2004 van Nunen & Zuidwijk, 2004	Fleischmann et al., 1997 Gungor & Gupta, 1999 Kleindorfer et al., 2005 Tibben-Lembke, 2002	Bufardi et al., 2004 Fandel & Stammen, 2004 Freire et al., 2001 Georgiadis & Vlachos, 2004 Heese et al., 2005 Horvath et al., 2005 Jayaraman et al., 1999 Linton et al., 2002	Majumder & Groenevelt, 2001 Nagurney & Toyakasi, 2005 Okumura et al., 2003 Ravi & Shankar, 2005 Sheu et al., 2005 Walther & Spengler, 2005 Yalabik et al., 2005	Autry et al., 2001 Autry, 2005 Daugherty et al., 2005 González-Torre et al., 2004 Knemeyer et al., 2002 Kulp et al., 2004 Richey et al., 2005a Richey et al., 2005b	Blackburn et al., 2004 Dowlatshahi, 2000 Fassoula, 2005 Guide Jr. & Van Wassenhove, 2002 Guide Jr. et al., 2000 Krumwiede & Sheu, 2002 Linton & Jayaraman, 2005 Stock et al., 2002 Toffel, 2004 Toffel, 2003	

As far as the methodology employed in the articles is concerned, we grouped the articles by research topic and examined the main methodology in order to determine if there were correspondences between the topic and the methodology (table 5). From our findings, we observe a clear association between the topic ‘production planning and inventory management’ and mathematical modelling as a methodology of analysis (fundamentally operational research and control theory techniques). The works on ‘supply chain management issues in reverse logistics’, in coherence with its strategic focus, tend to employ qualitative methodologies such as the case study, conceptual descriptions and the literature review. **However, at the same time as this topic expands, it can be seen that there has been a trend to use mathematical models in recent years.** For its part, ‘management of the recovery and distribution of end-of-life products’ is in an intermediate position between the quantitative and qualitative methodologies, which could point to a more homogeneous development of this research topic, insofar as it analyses the strategic aspects by means of qualitative methodologies (56.52%) and the tactical and operational decisions utilizing quantitative techniques and methods.

Table 5. Research topic and Methodology

	METHODOLOGY					TOTAL
	CASE STUDY	LITERATURE REVIEW	MATHEMATICAL MODEL	SURVEY	WHOLLY THEORETICAL	
MANAGEMENT OF THE RECOVERY AND DISTRIBUTION OF EOL PRODUCTS	52.17%	4.35%	39.13%	4.35%	0.00%	12.37%
PRODUCTION PLANNING AND INVENTORY MANAGEMENT	6.67%	0.95%	92.38%	0.00%	0.00%	56.45%
SUPPLY CHAIN MANAGEMENT ISSUES IN REVERSE LOGISTICS	36.21%	6.90%	25.86%	13.79%	17.24%	31.18%
TOTAL	21.51%	3.23%	65.05%	4.84%	5.38%	

When studying the main techniques employed for the data analysis (table 6), we find that mathematical programming techniques are the most used in the group of articles as a whole (18.58%), these mainly been used for the analysis of the problems arising in the ‘management of the recovery and distribution of end-of-life products’. We should bear in mind that this topic includes problems of allocation and localization – traditionally formulated and solved using linear programming. For their part, the works dealing with ‘supply chain management issues in reverse logistics’ prefer to employ descriptive analysis and the case study, in coherence with the qualitative methodology that predominates in these studies. Finally, we observe that simulation, together with mathematical programming, optimization and queueing, are the most common analytical techniques within the topic ‘production planning and inventory management’, as would be expected in these works that analyse the effect that the reverse flow of EOL products has on models of inventory management.

Table 6. Techniques employed for the data analysis

RESEARCH TOPIC	TECHNIQUE OF ANALYSIS							
	Case Analysis	Control Theory	Descriptive Analysis	Mathematical Programming	Optimization	Queueing and Markov Process	Simulation	Others
Management of the recovery and distribution of EOL products	30.43%	0.00%	8.70%	43.48%	4.35%	0.00%	4.35%	8.70%
Product planning and inventory management	4.76%	9.52%	1.90%	16.19%	16.19%	16.19%	20.95%	14.29%
Supply chain management issues in Reverse Logistics	27.59%	0.00%	29.31%	12.07%	3.45%	1.72%	6.90%	18.97%
TOTAL	15.30%	5.46%	11.48%	18.58%	10.93%	9.84%	14.75%	13.66%

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5 As far as the number of authors of each article is concerned, we observe that
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7 collaboration between researchers is predominant, since 83.87% of the works have two or
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9 more authors: specifically, 37.10% of the articles are signed by two, 35.48% by three and
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11 11.29% by four or more authors.
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15 With regards to the origin of the publications analysed, these are mostly
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17 concentrated in just three countries: USA (31.72%), the Netherlands (16.67%) and
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19 Germany (11.29%). In addition, 22.58% of the works have authors of different origins,
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21 although in 64.29% of these cases the first signer belongs to a research centre located in
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23 one of the three above-mentioned countries. Thus, we can say that research on reverse
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25 logistics is concentrated in research centres of these countries, or at least we observe a clear
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27 influence of them in work on this topic.
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33 We find that 93.7% of the works are authored by members of the academic
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35 community, while the remaining 4.3% have authors who are professionals in the business
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37 or industrial world. However, these works are fundamentally collaborations between firms
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39 and the university, and only two of the articles analysed (Maslennikova and Foley 2000,
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41 Fassoula 2005) are authored exclusively by researchers with no links to a university. With
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43 respect to the articles with university origins, we find that the Erasmus University
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45 Rotterdam (the Netherlands) is the main focus of research, since 15.59% of the analysed
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47 articles have a member of this university as first signer. In fact we find 57 instances of
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49 authors connected to this university in the total number of articles selected. At a significant
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51 distance comes the Duquesne University (USA), Air Force Institute of Technology (USA)
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53 and Otto-von-Guericke University (Germany), each of which has 3.76% of the first signers.
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Finally, we should point out that the Erasmus University Rotterdam is the main research centre in the reverse logistics field also from the point of view of the three research topics analysed, since scholars connected to this university first-signed 26.09% of the articles on ‘management of the recovery and distribution of end-of-life products’, 17.14% of the works analysing ‘production planning and inventory management’ and 8.62% of the articles on ‘supply chain management issues in reverse logistics’.

4. CONCLUSIONS

Throughout this work, we have analysed the development of research on reverse logistics over the recent years, by examining the scientific articles appearing in the main international specialized journals in the field of production and operations management. Our main goal has been to analyse the evolution and basic characteristics of the research on this topic, so that we could observe the path followed up to the present time, describe the current situation of the research and provide ideas about where it could be directed in the future. In accordance with our findings, we can point out the following conclusions:

- Although there were some earlier works focusing on issues related to reverse logistics, this current of research is very recent – its origins can effectively be dated to 1995. Since then, researchers have become increasingly interested in the field, as demonstrated by the progressive growth in the number of articles on the topic published (especially from 2000) and the appearance of numerous monographs in the journals. In general terms, the data on the number of publications confirms the growing interest of both the academic and professional communities in the relations

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4 between the firm and the environment (Hoffman and Ehrenfeld 1998, Burgos and
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6 Céspedes 2001).

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- The majority of articles centre on the study of tactical and operational aspects like production planning and inventory management, deriving from the implementation of a reverse logistics system. However, we observe that issues regarding closed-loop supply chain management have received the preferred attention of researchers in recent years, although we consider that more research on strategic factors (marketing, competition, technology) seems necessary in order to develop a theoretical framework for research.
 - In our analysis of the association between topic and the methodology and research techniques used, we find a 'typical profile' for articles and research topic. Research on 'management of the recovery and distribution of end-of-life products' is characterized by using indistinctively both quantitative and qualitative techniques, applying mathematical models and the case study as main methodologies. Research on 'production planning and inventory management', in accord with its quantitative profile, tends to be analytical in content and favours techniques such as simulation, optimization and mathematical programming. Regarding research on 'supply chain management issues in reverse logistics', this was characterized by being mainly theoretical and qualitative, largely using the case study, although a quantitative trend has been detected in recent years.
 - Research on reverse logistics has been led by scholars from the Netherlands, Germany and the USA. The first two of these countries have a strong environmental

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4 tradition, both in legislative terms and with respect to the concerns of their societies,
5 while the US is characterized by its liberal returns policy. Both features have
6 provided an incentive for the research on reverse logistics, thereby contributing to
7 its development. Nevertheless, it would be necessary to expand the research to the
8 supply chains of others countries, especially the emerging and transition economies
9 which will play a leading role in the global supply chain in the next years.
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20 To conclude, we should stress again that our initial intention was to analyse the
21 main characteristics of the research in the reverse logistics field, an ambitious task
22 interacting with many other fields of research within business management, engineering
23 and the environmental sciences. The problems have extensive ramifications; there are
24 various ways of approaching them and many aspects to clarify. All of these will have to be
25 analysed in future works. In this respect, we feel that research on reverse logistics should
26 now be directed at analysing strategic aspects and developing organizational theories,
27 allowing us to establish an appropriate framework of reference within which the tactical
28 and operational aspects that have been analysed in recent years can be developed
29 efficiently.
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