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# A bibliometric analysis of reverse logistics research (1992-2015) and opportunities for future research

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## Abstract

**Purpose** – Interest in reverse logistics (RL) as a critical component of supply chain management (SCM) is gaining more traction with both practitioners and academics. Because of RL's growing strategic importance, it is imperative to conduct a timely and comprehensive literature review and to identify associated opportunities for future research.

**Design/methodology/approach** – In this paper, the researchers conduct an extensive bibliometric analysis of published academic articles on reverse logistics (RL) for the period of 1992-2015. Specifically, the CiteSpace software is utilized to conduct document co-citation analysis and burst detection analysis on 912 selected RL articles and their 22,642 references.

**Findings** – This research identifies the most influential RL research publications/citations in each of the five periods and their research contribution. Using co-citation analysis, we are able to identify and illustrate major research themes, knowledge groups, and future research opportunities in the RL field.

**Originality/value** – In contrast to existing literature review studies in the logistics field, our study uses impact factor as a key article selection criterion. The influential articles identified in this process well represent the core literature and RL body of knowledge and have important implications for future research.



**Keywords**: reverse logistics, returns management, product recovery, closed-loop supply chain, bibliometric analysis, co-citation analysis, burst detection

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## Introduction

Reverse logistics (RL) is a critical part of supply chain management (SCM). The scope of RL has broadened significantly since its early introduction. One of the earliest descriptions of RL was given by Lambert and Stock (1982) as product "going the wrong way down a one-way street because the great majority of product shipments flow in one direction" (p. 19). Later on, scholars modified the definition of RL to include more specific functions and processes (e.g. Carter and Ellram, 1998; Kopicki et al., 1993; Murphy, 1986; Murphy and Poist, 1989; Stock, 1992, 1998). The Council of Supply Chain Management Professionals (CSCMP) provides the following popular RL definition: "reverse logistics is a specialized segment of logistics focusing on the movement and management of products and resources after the sale and after delivery to the customer. Includes product returns for repair and/or credit". However, we believe the CSCMP definition has a somewhat narrow scope. Therefore, we opt to use the more comprehensive RL definition provided by Rogers and Tibben-Lembke (1999):

> "Reverse logistics is 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 or creating value or proper disposal" (p. 2).

The unique characteristics of RL versus forward logistics have drawn great interest from business researchers (Tibben-Lembke and Rogers, 2002). A rich body of knowledge on RL has developed over the last few decades, as evidenced by the rapid growth in the number of RL studies published in recent years (Huscroft et al., 2013), including several literature review articles. Carter and Ellram (1998) developed an insightful RL framework based on their review of the rather limited literature available at the time. Srivastava (2007) conducted a larger scale

literature view on green SCM, including RL as one theme. Srivastava also limited the number of publications by excluding empirical papers focused on firm-level or specific operational issues and technical work on topics (such as life-cycle assessment, inventory, etc.). Huscroft et al. (2013) took a unique perspective and compared their RL literature content analysis results with industry expert inputs to identify meaningful research areas. Rubio et al. (2008) may be the most comprehensive RL review study to date, using journal citation indices to identify 26 journals and 186 articles; but they but do not consider individual articles' research impact.

While the above studies make important contributions to help researchers better understand RL literature, they each have important limitations such as the limited number of articles available for analysis at the time of publication (Carter and Ellram, 1998), restricted scope and article selection approach used (Huscroft et al., 2013; Srivastava, 2007), omission of research impacts of individual publications (e.g. Rubio et al., 2008), and sometimes biased expert panel selection (i.e. heavy representation from government and military logisticians) for identifying key RL issues (Huscroft et al., 2013).

A literature review can be a beneficial means to identify the conceptual content of a research field and provide guidance for future research (Raghuram et al., 2010), but identifying the most relevant and influential articles is critical to a literature review's contribution. To date, literature review articles in the logistics field (including RL) generally utilize article selection methods that require a significant amount of researchers' subjective judgment. For example, the journals and articles included in a review study are usually pre-determined by the researcher without considering their research impact. Such approaches may omit some relevant and influential works and result in less meaningful results. The current study extends literature

review methods from other disciplines to conduct a bibliometric analysis of RL literature using the CiteSpace software to delineate the intellectual structure and advances in the area.

## Methodology and data

### *Research methodology*

Boundaries of traditional literature reviews are often framed based on the researchers' own knowledge, experience, and opinions. For example, many extant literature review studies rely on manually selecting and categorizing articles or citations. In contrast, the current study employs bibliometric analysis, which relies on using quantitative methods to examine written documents to uncover knowledge structure and development of research fields (Pritchard, 1969). Bibliometric analysis often utilizes information system tools to conduct a comprehensive search of relevant articles that appear in multiple databases and quantitative methods to probe various aspects of scientific communication (Pritchard, 1969). In addition to expanding the scope of the review (Raghuram et al., 2010), bibliometric analysis focuses on publications that are heavily cited by others over time, because only these publications can be considered as foundations of the discipline (González-Benito et al., 2013; Samiee and Chabowski, 2012). Therefore, bibliometric analysis can provide more objective and comprehensive results than typical author-scoped literature reviews. (Ramos-Rodriguez and Ruiz-Navarro, 2004). In the current study, we followed the 9-step guide for conducting bibliometric analysis offered by Chen et al. (2008).

Citation and co-citation analyses are effective means of conducting bibliometric reviews (Pilkington and Meredith, 2009; Ramos-Rodriguez and Ruiz-Navarro, 2004), because they can identify underlying patterns of relationships between articles based on references they cite (Osareh, 1996). Citation analysis is based on the premise that heavily cited articles are likely to

have exerted a greater influence on the subject than those less frequently referenced (Culnan, 1986; Sharplin and Mabry, 1985), and thus are indicators of activity or importance to the field (Garfield et al., 1979; Pilkington and Meredith, 2009). Because citation analysis screens all references used in selected articles without being constrained by researchers' subjective views, it is therefore possible to obtain a sufficiently large sample and provide useful insights into which journals, articles, and authors are influential. Co-citation analysis is a specific type of citation analysis used to identify clusters of references "co-cited" by subsequent articles (Small, 1973). When two or more references co-occur in the reference lists of articles, a link is established between these co-cited references (Raghuram et al., 2010). Essentially, by co-citing references in the same article, the authors establish connections between these references – because these references are part of the same research cluster or their foci are similar (Garfield et al., 1983; Peters et al., 1995). The identification of connections across a large number of articles based on their references makes it possible to generate graphic illustrations, which will help us understand the relationships inherent in the intellectual structure of the field (Pilkington and Meredith, 2009; Raghuram et al., 2010; White, 1990). This approach is particularly well suited to gaining an understanding of a research trajectory by studying relationships that exist across prior work (Leydesdorff and Vaughan, 2006; Raghuram et al., 2010).

Specifically, we apply two emerging bibliometric methods in the current study: document co-citation analysis and burst detection analysis. Document co-citation analysis (DCA) is generally used to interpret the similarity of content between two documents by counting the number of articles in which both articles have been cited in pair (Garfield, 1979). Its underlying rationale is that bibliographic references of a scientific paper can be viewed as the theoretical and empirical foundation of the study because these references are important in the research

development and signal the influences of the cited work (Ramos-Rodriguez and Ruiz-Navarro, 2004). Our DCA analysis is assisted with CiteSpace software, which is a freely available Java application for analyzing and visualizing emerging trends and citation patterns in scientific literature (Chen, 2006; Chen et al., 2008). CiteSpace can help users to identify some special classes of papers in terms of landmarks by citation popularity, hotspots by abrupt citation increase received, and pivotal papers that are strategically positioned in co-citation networks.

Burst detection analysis (BDA) is a technique based on a burst detection algorithm developed by Kleinberg (2002). This algorithm aims to analyze a set of terms or documents to find characteristics that have high intensity over finite durations of time periods. By extracting meaningful structures from document streams, this method can generate a ranked list of the most significant word bursts along with the intervals of time in which they occurred. Burst analysis can be used to identify the evolution and decay of research topics and themes (Chen et al., 2009; Chen et al., 2010). A high burst value associated with a word or citation signals the fast-growing interests among researchers. CiteSpace software was again used to conduct this analysis. A keyword or reference with a burst score of 3.0 or above is considered a burst keyword or burst reference (Chen et al., 2008). The higher the burst score, the more significant increase of research interest a keyword or reference is generating.

*Data collection*

We use ISI Web of Science (WoS) as the data source of this study, and the specific databases used are Science Citation Index Expanded (SCIE) and Social Sciences Citation Index (SSCI). Although not listed in Chen et al.'s (2008) 9-step guide for bibliometric analysis, we added procedures to reduce the possibility of drawing a too narrow search boundary (Chen, 2006). Specifically, we conducted interviews with a panel of RL experts to help the key search word

identification. This panel included three well-published RL academics and five experienced RL professionals. Interviewees were first asked to describe their understanding of RL definition and processes, and then each was asked to provide a list of appropriate search words. The interview results were analyzed, compared, and consolidated into a set of search words with the objective of being both succinct and comprehensive. This set of search words was returned to the panel for their confirmation. Our queries resulted in the following search words: "reverse logistics", "remanufacturing", "closed-loop logistics/supply chain", "recycling", "returns management", "product recovery/returns", and "end-of-life management". We considered all original research articles and literature review articles from the SCIE and SSCI containing at least one of the search terms in their titles, abstract, or keywords, but we excluded notes, proceedings papers, letters, book chapters, book reviews, editorial materials, news items.

The starting point of our literature search period is 1992, because it was the time when Stock's (1992) white paper on RL was published and when RL research started to experience substantial developments. Starting our search in 1992 is also consistent with the RL literature review study conducted by Huscroft et al. (2013). Our search result shows that there are 4,288 records published in the field of management, business, operations research and management science. Because several of the search terms used have broad meanings (such as "recycling" or "returns management"), many of the records are not actually related to RL. To ensure data accuracy and relevancy, all the 4,288 records' titles and abstracts were carefully screened by the authors. Each of the authors conducted his/her own screening independently, and then the results were compared and consolidated to ensure inter-rater reliability. After removing irrelevant articles from the dataset, we identified 912 RL related articles between 1992 and 2015. Figure 1

shows the yearly distribution of the bibliographic records of RL articles over the twenty-four-year period, and with rapid growth beginning in the mid-2000s.

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Insert Figure 1 about here

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For our citation analysis, we downloaded five topic fields in each article's bibliographic record from the databases – title, abstract, descriptors, identifiers, and references. Because an article's references are important building blocks of its intellectual structure, we also included all 912 articles' references (a total of 22,642) in our analysis. This critical and necessary step allows us to detect important and influential works (both journal articles and books) that are not included in SCIE and SSCI citation indices. This article selection approach is an improvement over existing literature review techniques used in the logistics and RL fields because the final list used in this current study is much more comprehensive as it incorporates a means to identify otherwise overlooked but important works in different publication outlets.

Before creating the intellectual map for RL, the bibliographic records were standardized and cleaned through a laborious process of manually checking and rechecking terms in citation indices generated from the data and using complex search routines. These checks corrected different spellings of the same author, journal, and keyword. For example, Harvard Business Review and Harvard Bus Rev were replaced with Harvard Bus Rev, reverse-logistics and reverse logistics were standardized as reverse logistics. Then, the entire time interval of 1992 to 2015 was divided into five periods: four five-year periods and the four-year period of 2012-2015 to facilitate meaningful analysis of RL literature. As indicated in Figure 1, the number of published RL articles has been growing rapidly in recent years. Using ten-year periods is too long to meaningfully capture trends and developmental details of RL literature and may therefore result

in very imbalanced analysis. However, using any periods of shorter than five years may create too fine a lens to identify patterns through our analysis. CiteSpace software was used to facilitate analysis of important topics or themes during each period by examining the corresponding references and observing research developments over time with the help of a series of visualization maps. The five corresponding networks were subsequently merged into one panoramic network to depict the changes in dominating research issues over the entire 24-year time span.

## Data analysis and results

### *Descriptive information of reverse logistics research*

While Figure 1 clearly delineates the growing trend of RL literature, we believe it is also interesting and meaningful to identify the leading authors and institutions and most cited authors and journals in the RL field. Table I provides such rankings based on our analysis. The author publication and institution rankings include the top 10 authors and top 10 affiliated institutions that published the most articles among our selected 912 articles. Both rankings are not limited to single-author articles and first authors. Instead, our analysis included all authors and institutions affiliated with the published articles. The author and journal citation rankings, on the other hand, considered all the reference entries in the 912 selected articles. In other words, these rankings are based on the total appearances that an author or a journal had in the total of 22,642 references.

**Table I:** Descriptive rankings in reverse logistics research

| Rank | Papers | Authors | | Rank | Citations | Authors | | Rank | Papers | Institution |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 32 | Guide VDR | | 1 | 451 | Guide VDR | | 1 | 34 | Erasmus University (Netherlands) |
| 2 | 23 | Van Wassenhove | | 2 | 436 | Fleischmann M | | 2 | 22 | Aristotle University of Thessaloniki (Greece) |
| 3 | 22 | van der Laan E | | 3 | 214 | Thierry MC | | 2 | 21 | INSEAD (France) |
| 4 | 16 | Xu BS | | 4 | 192 | Ferrer G | | 4 | 20 | Northeastern University (USA) |
| 5 | 14 | Srivastava R | | 5 | 169 | Inderfurth K | | 5 | 18 | Pennsylvania State University (USA) |
| 6 | 13 | Jayaraman V | | 6 | 161 | Rogers DS | | 5 | 18 | National Key Lab for Remanufacturing（China） |
| 7 | 12 | Fleischmann M | | 7 | 154 | Jayaraman V | | 7 | 16 | Georgia Institute of Technology (USA) |
| 7 | 12 | Li YJ | | 8 | 147 | van der Laan E | | 8 | 15 | Linköping University（Sweden） |
| 9 | 11 | Dekker R | | 9 | 139 | Krikke HR | | 9 | 13 | Chongqing University（China） |
| 9 | 11 | Tang O | | 10 | 136 | Teunter RH | | 9 | 13 | Hong Kong Polytechnic University（China） |

Compared to traditional bibliometric analysis methods, CiteSpace software represents a much more effective and powerful analytical tool. Using a diverse range of visual attributes, CiteSpace enables users to find salient patterns of a transient body of scientific papers and capture the dynamics in the research development of a scientific field (Chen et al., 2008). In order to gain a better understanding of relationships among the key researchers in the RL field, we used CiteSpace software to generate a co-authorship network of 1147 authors and 705 coauthoring links based on 912 bibliographic records for the period of 1992-2015. While it is impossible to include a visual presentation of this entire network in the paper, Figure 2 demonstrates the largest connected component of the RL co-authorship network that emerged in our analysis. The size of a node is proportional to the number of RL articles that one author has published, and the links represent co-authorships (Chen et al., 2008). The cluster of researchers led by Guide and Van Wassenhove in particular has generated a significant number of research publications that focus primarily on the economics and planning of remanufacturing. Most of the authors in this connected network are from Europe, and they produced the largest portion of the most cited RL publications. Research on remanufacturing is a predominant RL topic, with a well-established body of knowledge. Scholars who are interested in this topic should closely monitor and follow the publications produced by this group of influential authors. Given that remanufacturing is just one aspect of RL, the non-proportional emphasis on remanufacturing to date also suggests that many other key areas in RL have been understudied and warrant additional research effort.

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Insert Figure 2 about here

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*A dynamic view of reverse logistics research*

Citation count and burst detection methods available through Citespace offer a dynamic view (Pilkington and Meredith, 2009; Raghuram et al., 2010), allowing us to identify the most critical RL references in the five periods over a twenty-four year span. A high citation count of a reference usually indicates the influence of this reference to the research in that particular period. A high burst value indicates fast growing research interest on a certain reference, and it is thus reasonable to use this reference as an indicator of the research trends and evolving directions in a specific timeframe. Within each period, we identified the most influential references that have both the highest citation counts and the highest burst values (as shown in Table II). By combining these two criteria, some widely-cited references can be excluded from our list. However, although these popular references generated a large number of citations in a steady pace over the years, they have less value in terms of understanding the evolution of RL focus and interests.

**Table II:** Most influential references with both high citation count and high burst score (Burst score shown in parentheses)

| | |
|---|---|
| **1992-1996** | |
| (9.26) Muckstadt and Isaac, 1981, NRL | |
| **1997-2001** | |
| (25.53) Fleischmann et al., 1997, EJOR | (6.40) Ferrer, 1997, RCR |
| (20.38) Thierry et al., 1995, CMR | (6.21) Inderfurth, 1997, ORS |
| (12.89) van der Laan and Salomon, 1997, EJOR | (3.32) Spengler et al., 1997, EJOR |
| (9.21) Simpson, 1978, OR | |
| **2002-2006** | |
| (11.99) Fleischmann and Krikke, 2000, OMEGA | (5.90) Jayaraman et al., 2003, EJOR |
| (10.59) Guide, et al. 2000, Interfaces | (5.21) Guide and Van Wassenhove, 2001, P&OM |
| (9.62) Guide et al., 2003, M&SOM | (4.67) Stock, 1998, Book |
| (9.42) Jayaraman and Guide, 1999, JORS | (4.21) Krikke et al., 1999, ORS |
| (8.48) Barros et al., 1998, EJOR | (4.34) Debo et al., 2005, MS |
| (7.98) Toktay et al., 2000, MS | (3.64) Rogers and Tibben-Lembke, 1999, Book. |

| | |
|---|---|
| (6.29) Carter and Ellram, 1998, JBL | (3.51) Majumder and Groenevelt, 2001, P&OM |
| **2007-2011** | |
| (16.55) Srivastava, 2007, IJMR | (4.56) Rogers and Tibben-Lembke, 2001, JBL |
| (7.69) Ferguson and Toktay, 2006, P&OM | (4.52) Debo et al., 2005, MS |
| (6.63) Ferrer and Swaminathan, 2006, MS | (3.79) Srivastava, 2008, OMEGA |
| (6.36) Guide and Van Wassenhove, 2001, P&OM | (3.73) Sheu et al., 2005, TRPE |
| (5.91) Ferrer and Ketzenberg, 2004, IIET | (3.23) Majumder and Groenevelt, 2001, P&OM |
| (4.87) Zhu and Sarkis, 2004, JOM | |
| **2012-2015** | |
| (12.04) Guide and Van Wassenhove, 2009, OR | (4.87) Ferguson et al., 2009, P&OM |
| (11.09) Atasu and Van Wassenhove, 2008, MS | (4.86) Daugherty et al., 2001, JBL |
| (7.65) Pokharel and Mutha, 2009, RCR | (4.27) Rogers et al., 2002, IJLM |
| (5.91) Ferrer and Swaminathan, 2010, EJOR | (3.96) Stock et al., 2006, MITSMR |
| (5.47) Atasu et al., 2010, CMR | (3.27) Daugherty et al., 2005, TRPE |

CMR: *California Management Review*; EJOR: *European Journal of Operational Research*; IIET: *IIE Transactions*; IJAMT: *International Journal of Advanced Manufacturing Technology;* IJLM: *International Journal of Logistics Management*; IJMR: *International Journal of Management Reviews*; IJPDLM: *International Journal of Physical Distribution & Logistics Management;* IJPE: *International Journal of Production Economics;* IJPR: *International Journal of Production Research*; IMM: *Industrial Marketing Management;* Interfaces: *Interfaces*; JBL: *Journal of Business Logistics*; JOM: *Journal of Operations Management*; JORS: *Journal of the Operational Research Society*; MITSMR: *MIT Sloan Management Review*; MS: *Management Science*; M&SOM: *Manufacturing & Service Operations Management*; NRL: *Naval Research Logistics*; OMEGA: *The International Journal of Management Science* OR: *Operations Research*; ORS: *OR Spektrum*; P&OM: *Production and Operations Management*; RCR: *Resources, Conservation and Recycling*; TRPE: *Transportation Research Part E*

In Figure 3, we present a Citespace generated graphical illustration of the growth pattern of RL literature. Figure 3a-3e provides a dynamic growth view of the intellectual structure development in RL research of the field. The nodes in Figure 3 are influential references (publications) that emerged from our analysis, and the links in Figure 3 represent the co-citation relationships among these references. It is evident that these key references appear in other articles simultaneously. This approach clearly links all five periods into a coherent body of knowledge by identifying the influential references at the interfaces of different periods. More specifically, the references identified on the right side in Figure 3a–3e represent influential studies in their own period as well as being closely related to (i.e. having co-citation relationships with) some of the most influential studies in the following periods. In other words, these are the crucial references that have laid the foundation for subsequent

RL research. Therefore, understanding the essence of these important articles facilitates a grasp of the key developments in RL literature. Next, we provide a brief discussion of key RL research trends in each of these periods based on the identified references.

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Insert Figure 3 about here

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Influential RL references and trends in 1992-1996

As shown in Table II, our analysis of the literature in the period of 1992-1996 only identified one influential reference - Muckstadt and Isaac (1981) that had both the most citation count and the highest burst score. This is probably due to the very limited number of RL studies published in that period (as shown in Figure 1). Muckstadt and Isaac (1981) developed simple cost models to address issues in single-item inventory systems with returns. Although the study was published at a much earlier date, it still experienced significant citation increase more than ten years later. Our finding indicates that RL research in the 1992-1996 period had a rather narrow scope that primarily focused on certain specific tactical and operational issues (such as inventory management) of returns management, similar in level and nature of analysis to Muckstadt and Isaac (1981). It is also interesting to note that in Figure 3b Muckstadt and Isaac (1981) has co-citation relationships with multiple influential references in the following period (1997-2001). This clearly indicates that the impact of this study goes beyond the period of 1992-1996, and also contributed significantly to RL research development in the following years.

Influential RL references and trends in 1997-2001

In the period of 1997-2001, RL research grew significantly as indicated by the increasing number of influential references. Using the same criteria as above (citation counts and burst scores), seven references were identified as influential in this period (Table II). A closer look at these articles generates the following observations. First, from the perspective of authors' origins, European researchers played a dominant role in RL research. This is likely related to EU's implementation of many regulatory RL policies, which promoted the emphasis on RL from both companies and academics. Second, our analysis shows that RL research expanded in both the number of studies published and in the scope of topics covered in this period.

While RL researchers continued to address inventory issues related to returns during this period (e.g. Inderfurth, 1997; Simpson, 1978; van der Laan and Salomon, 1997), a broader perspective of RL started to develop. As an influential work, Fleischmann et al. (1997) took a comprehensive viewpoint and divided the field into three main areas in their review of quantitative models: distribution planning, inventory control, and production planning. The development of such a broad view of the RL process provided a useful framework to enable researchers to more effectively identify and address specific research questions. For example, van der Laan and Salomon (1997) applied the Push and Pull concepts into a strategic decision scenario regarding remanufacturing or disposal. The broadened research scope is also reflected in the emergence of RL related environmental topics. For example, Spengler et al. (1997) developed sophisticated models to address recycling of industrial by-products and dismantling and recycling of products at the end of their lifetime. Third, studies that emphasized the value of RL during this period gained a substantial amount of research attention. For example, Thierry et al. (1995) used case studies to argue for the

importance of product recovery strategy, and Ferrer (1997) used economic value analysis to support the strategic decision of remanufacturing tires. This recognition of RL's potential for adding value is a drastic departure from the view of RL as a cost center demonstrated in the emphasis on inventory issues.

Influential RL references and trends in 2002-2006

In the period of 2002-2006, RL research continued to grow at a rapid pace. As shown in Table II, our analysis identified fourteen influential references. Not surprisingly, research in this period still continued to demonstrate some of the same patterns from the previous five years. For example, European researchers published the majority of these influential studies; researchers still showed a strong interest in inventory control of returned items, particularly in a remanufacturing context (e.g. Toktay et al., 2000); the value-creating potential of RL was still a key topic (Guide et al., 2003; Guide and Van Wassenhove, 2001), with continuing preponderance of quantitative modeling methods.

However, several new research themes did emerge in this period. First, multiple influential references were focused on the complexity and various specific aspects of remanufacturing (Guide et al., 2003; Guide and Van Wassenhove, 2001; Toktay et al., 2000), such as return product acquisition, location of remanufacturing/distribution facilities, transshipment, production, inventory, etc.

The second major development in RL literature in this period is the rising of the "network" concept. Krikke et al. (1999) utilized a mixed integer linear programming model to address the RL network re-design issue. Barros et al. (1998) developed a two-level

network model for sand recycling in the Netherlands. Jayaraman et al. (2003) used a heuristic expansion method to study the reverse distribution networks. Researchers' attention on the network concept signals the increasing understanding of the complexity that various RL processes involve.

Finally, Stock's (1998) and Rogers and Tibben-Lembke's (1999) books –are identified as influential references in our analysis. These books provide an overview of RL practices and the first comprehensive and in-depth overviews of RL industry and practices, respectively. Although these books would not appear in a traditionally conducted literature review, the research impact of these highly recognized and cited books should be recognized. They provide a broader, more in-depth, and process-oriented perspective of RL that provides a general understanding of RL issues rather than creating quantitative models to solve a specific problems.

Influential RL references and trends in 2007-2011

Our analysis of this five-year period resulted in eleven influential references (Table II). As in previous periods, the scope of RL research continued to expand in 2007-2011. Emerging trends in research themes and methodologies are summarized as follows. First, researchers are taking a broader approach to study RL, which is reflected in the increased attention and use of terms such as "supply chain" (e.g. Sheu et al., 2005; Srivastava, 2007 Zhu and Sarkis, 2004). Researchers also brought concepts from other management areas, such as "competition" and "market segmentation", into the RL context (e.g. Debo et al., 2005; Ferguson and Toktay, 2006; Majumder and Groenevelt, 2001). This broadened view is

critical for both academic research and managerial practices, because RL in essence is not an isolated function and it interacts with a firm's other business processes and functions, including forward logistics. Rogers and Tibben-Lembke's (2001) empirical study reported numerous barriers to executing RL, many of which can be addressed if RL is incorporated into a firm's overall supply chain strategy development and implementation. The term "closed-loop" vividly describes the focal firm's responsibility in developing its supply chain with RL as an important component.

Second, influential RL references became more diverse in terms of research methodology. While modeling was still the most prevalent research method in this period, other methodologies started to gain attention and recognition. Although studies utilizing non-modeling research methodologies are still relatively scarce, this is a very promising starting point. For example, Rogers and Tibben-Lembke's (2001) article was one of first empirical influential RL studies based on survey data and experienced significant citation increase.

Influential RL references and trends in 2012-2015

Although the final period included in our analysis only covers four years, we were still able to identify ten influential references with the same criteria. This is an indicator of substantially increased research activities in the RL field. Several research trends are apparent in this period.

Significantly, RL research methodology in the latest period has become more diverse than in previous periods. While modelling had been the dominant methodology in the past, empirical survey research has started to gain ground in the RL literature (e.g. Daugherty et al.,

2001; Daugherty et al., 2005). Different from modeling approaches, survey research has the ability to investigate managerial and behavioral perspectives of RL management. This represents important progress because the use of multiple scientific research methodologies contributes to the knowledge base development by providing insights to a phenomenon from different perspectives. Researchers have also started to reflect on extant RL literature and several review pieces have received significant citations, such as Guide and Van Wassenhove (2009) and Pokharel and Mutha (2009).

**Reverse logistics research trends in the near future**

A goal of this study is to assess the state of RL research and establish a valuable research agenda to help scholars advance scientific exploration in the RL area. In the preceding sections, we have identified research themes and findings that also reveal gaps in need of further exploration. Our analysis also highlights the most influential research, allowing us to identify potential research paths and future directions that build on key findings. We look first at the literature and then consider the data collection and analysis method used here.

*Implications from this study and future research*

Because 2012-2015 is the most current period, the influential references in this time frame will likely continue to impact RL research in the near future. Therefore, we provide details (including the burst occurrence years) of these references in Table III.

**Table III:** The burst of references between 2012 and 2015

| References | Burst |
|---|---|
| Guide, V.D.R. and Van Wassenhove, L.N. (2009), "The evolution of closed-loop supply chain research", *Operations Research*, Vol. 57 No. 1, pp. 10-18. | 12.04 |

| | |
|---|---|
| Atasu, A., Sarvary, M. and Van Wassenhove, L.N. (2008), "Remanufacturing as a Marketing Strategy", *Management Science*, Vol. 54 No. 10, pp. 1731-1746. | 11.09 |
| Pokharel, S. and Mutha, A. (2009), "Perspectives in reverse logistics: A review", *Resources Conservation and Recycling*, Vol. 53 No. 4, pp. 175-182. | 7.65 |
| Ferrer, G. and Swaminathan, J.M. (2010), "Managing new and differentiated remanufactured products", *European Journal of Operational Research*, Vol. 203 No. 2, pp. 370-379. | 5.91 |
| Atasu, S., Guide, V.D.R. and Van Wassenhove, L.N. (2010), "So what if remanufacturing cannibalizes my new product sales?" *California Management Review*, Vol. 52 No. 2, pp. 56-76. | 5.47 |
| Ferguson, M., Guide, V.D.J. and Koca, E. (2009), "The value of quality grading in remanufacturing", *Production and Operations Management*, Vol. 18 No. 3, pp. 300-314 | 8.87 |
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| Rogers, D.S., Douglas, M., Lambert, K.L., Croxton, S.J. and García, D. (2002), "The returns management process", *International Journal of Logistics Management*, Vol. 13 No. 2, pp. 1-18. | 4.27 |
| Stock, J., Speh, T. and Shear, H. (2006), "Managing product returns for competitive advantage", *MIT Sloan Management Review*, Vol. 48 No. 1, pp. 57-62. | 3.96 |
| Daugherty, P.J., Richey, R.G., Genchev, S.E. and Chen, H. (2005), "Reverse logistics: superior performance through focused resource commitments to information technology", *Transportation Research Part E-Logistics and Transportation Review*, Vol. 41 No. 2, pp. 77-92 | 3.27 |

In order to achieve more precise predictions of RL research development directions, we again used the ISI Web of Science database to identify additional important RL articles. Selection criteria include: (1) published in 2012-2015 period; (2) cited at least one of the references listed in Table III; (3) not a literature review article; and (4) generated immediate impact as indicated by the number of citations produced. These important articles are listed in Table IV as "Major citing papers". Combined with the influential references listed in Table III, we are able to identify major clusters of important studies. We believe that these articles possess a significant influence on RL research in the near future because of their popularity and impact in recently published articles.

**Table IV:** Major clusters of influential references (2012-2015)

| **Reference** | **Guide and Van Wassenhove, 2009, OR** | **Atasu and Van Wassenhove, 2008, MS** |
|---|---|---|
| **Major citing papers** | Chen and Chang, 2012, TRPE<br>Rahman and Subramanian, 2012, IJPE<br>Wu, 2012, IJPE | Chen and Chang, 2012, TRPE<br>Das and Chowdhury, 2012, IJPE<br>Wu, 2012, IJPE |

| | | |
|---|---|---|
| | Cardoso et al., 2013, EJOR<br>Brandenburg et al., 2014, EJOR | Wu, 2013, OMEGA |
| **Reference** | **Pokharel and Mutha, 2009, RCR** | **Ferrer and Swaminathan, 2010, EJOR** |
| **Major citing papers** | Amin and Zhang, 2012, IJAMT<br>Das and Chowdhury, 2012, IJPE<br>Kannan et al. 2012, RCR<br>Rahman and Subramanian, 2102, IJPE | Chen and Chang, 2012, TRPE<br>Pokharel and Liang, 2012, IJPE<br>Choi et al., 2013, IJPE<br>Wu, 2013, OMEGA |
| **Reference** | **Atasu et al., 2010, CMR** | **Ferguson et al., 2009, P&OM** |
| **Major citing papers** | Choi et al., 2013, IJPE<br>Chen and Chang, 2012, TRPE<br>Chen and Chang, 2013, IJPE | Altekin and Akkan, 2012, IJPR<br>Hazen et al., 2012, IJPDLM<br>Hazen et al., 2012, IJPE<br>Robotis et al., 2012, IJPE |
| **Reference** | **Daugherty et al., 2001, JBL** | **Rogers et al., 2002, IJLM** |
| **Major citing papers** | Bell et al., 2013, IJPDLM<br>Ye et al., 2013, IJPE | Bell et al., 2013, IJPDLM<br>Hazen et al., 2012, IJPDLM |
| **Reference** | **Stock et al., 2006, MITSMR** | **Daugherty et al., 2005, TRPE** |
| **Major citing papers** | Turrisi et al., 2013, IJPDLM<br>Ye et al., 2013, IJPE<br>Garcia-Rodriguez et al., 2013, IJPE<br>Bernon et al., 2013, IJPDLM | Das and Chowdhury, 2012, IJPE<br>Hazen et al., 2012, IJPDLM<br>Lee and Lam, 2012, IMM<br>Rahman and Subramanian, 2012, IJPE |

See notes of Table II for journal names.

After a close and careful examination of the references in Table IV, we are able to identify some major RL research trends and opportunities from three aspects: research content, research methodology, and author base diversity. We summarize them in Figure 4 and provide discussion as follows.

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Insert Figure 4 about here

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Operational topics

First, the scope of RL research has grown in recent years and continues to expand. RL research started with a focus on costs and specific solutions to operational problems, and has

increasingly emphasized strategic issues. While researchers are studying a wider range of RL topics, efforts are still limited in many aspects. On the operational side, research has already demonstrated that operational RL encompasses multiple processes, including source reduction, product returns, reuse, recycle, disposal, repair, remanufacturing and resale (Carter and Ellram, 1998; Rogers and Tibben-Lembke, 1999; Stock, 1998). Clearly, there are many additional operational RL issues that warrant significant research effort. For example, both Carter and Ellram (1998) and Stock (1998) identified source reduction as a relevant RL process, which involves the activities that can prevent product returns and reduce materials used. While almost all existing studies examine how to effectively manage the reverse flow after it has occurred, advanced initiatives related to returns prevention has been largely overlooked (such as product/packaging design, customer communication, and return policies, etc.), but could have significant impacts on the magnitude and nature of the reverse flow. It's estimated that in the U.S. alone, returns cost retailers around $260 billion annually (Reagan, 2016). This is becoming an increasingly important issue with the growth in e-commerce, where returns are around 30% of sales, versus just under 9% for bricks and mortar stores (Rudolph, 2016). Handling e-commerce returns can also be more costly than regular retail returns due to shipping costs, unknown condition of items returned, and the need to transport returned items to be resold or otherwise disposed of. Research on reducing the rates of return and improving the disposition of returns could reduce environmental waste and save retailers billions of dollars annually. The e-commerce returns management process can become more complex and difficult to manage when online channels and traditional channels start to intertwine more deeply, such as Wal-Mart's pick-and-mix pricing (Weinswig, 2017) and

Amazon's purchase of Whole Foods (Whitten, 2017). These new developments certainly present great research opportunities for RL researchers to explore.

Another closely related and mostly overlooked process is resale or secondary markets. More and more companies are turning to secondary markets in different formats in order to capture more value (even profit) from the returns (Carter and Ellram, 1998; Rogers and Tibben-Lembke, 1999). Secondary markets provide "drains" for firms so that slow-moving, obsolete and returned products can be profitably dispositioned and sold through an alternative marketplace (Rogers et al., 2010), and these markets are fueled by the reverse logistics processes in a supply chain (Rogers and Tibben-Lembke, 1999).

Secondary markets are a huge opportunity, and continue to grow in part due to increased e-commerce returns and online access as an outlet to buy and sell returned and overstocked goods, growing at an estimated 31% from 2010 to 2014 (The Economist, 2016). It is estimated that the U.S. secondary market's size is approximately 3% of country's gross domestic product (GDP). Secondary markets not only give both consumers and sellers access to markets that they would not have otherwise, they also have important social impacts because of lower costs, increased access, and positive environmental benefits derived from longer product lives. However, our analysis revealed that research on resale or secondary markets is almost non-existent. Topics like this present great research opportunities because they represent important developments in practice that have been given relatively limited attention in extant literature. There are billions of dollars tied up in these markets, and these markets are very diverse in nature. Thus, it is likely that there are substantial opportunities to

study various RL-related aspects of secondary markets that could make important contributions to both theory and practice. These can be studied from a strategic standpoint as well as efficiency (cost-minimizing) and effectiveness (enhance revenue without cannibalizing sale of new products) standpoints.

Strategic topics

On the strategic side, researchers have moved beyond minimizing cost and improving efficiency as the sole objective of RL to study RL value, network design, and RL's interfaces with other management areas. Both practitioners and academics gradually realized the critical importance of effective RL and have argued it is really a value center (e.g. Guide et al., 2003). In fact, Atasu et al. (2008) and Atasu et al. (2010) explicitly suggest that remanufacturing should be considered a marketing strategy and be linked with new product sales. Future research in this area could be linked to value capture and secondary markets as well.

A network perspective recognizes the complexity of intertwined RL processes that are also connected to other business processes (e.g. Amin and Zhang, 2012; Das and Chowdhury, 2012; Kannan et al., 2012; Srivastava, 2008). For example, a RL inventory problem cannot be ideally solved if inventory management is isolated from other related processes. Researchers should take a broader perspective, such as the network view to gain more rigorous and relevant insights when designing a study or developing a RL model. In our literature review, most network research still remains bounded within the scope of direct RL activities, although network approaches have gained traction in other areas of research. This gap suggests that future RL research should be directed to a network with broader scope that

interacts with other processes and networks in supply chains. Potential examples include linking secondary market activities to primary market activities in terms of effectively transferring goods between markets, and the impacts of a robust secondary market on primary markets, or vice versa.

This is in line with our next identified trend in RL research – a supply chain perspective. Our analysis reveals that recent research uses RL in a supply chain context (e.g. Cardoso et al., 2013; Chen and Chang, 2012; Choi et al., 2013; Srivastava, 2008; Turrisi et al., 2013; Wu, 2012), and we expect this trend will continue in the coming years. This trend suggests that RL has become an integral component of companies' supply chain strategy. The supply chain perspective also calls for the integration of RL research and forward logistics research. While there are significant differences between them, RL and forward logistics should not be managed in total isolation. RL flows are often the results of forward logistics and may be redirected into forward logistics systems after proper processing. Therefore, efficient and effective synchronization of RL and forward logistics networks represents an area with abundant research opportunities.

Sustainability, particularly green logistics, is also identified as an emerging trend in our analysis (Bell et al., 2013; Brandenburg et al., 2014; García-Rodríguez et al., 2013; Lee and Lam, 2012). While the economic sustainability aspect of RL is the most researched aspect of the triple-bottom line, there are still significant opportunities for understanding the holistic financial implications of RL, as indicated above, considering network design, value recovery and secondary markets. However, the relationship between RL and the social

aspects of sustainability has not been explored in significant ways. Therefore, we call for more comprehensive and in-depth investigations of the RL-sustainability interface that combine all three elements of the triple-bottom-line. We expect such research will greatly benefit companies' business practices and help them achieve long-term sustainable growth. For example, returns of used clothing in developed countries may appear to be a responsible act. However, these returns may be shipped to India, and may simultaneously create economic (reduced demand for new clothing), social (reduced manufacturing jobs in apparel) and environmental (disposal of excess clothing) duress for the Indian economy. This is a real and growing problem which demands attention (Bellman, 2016). From a supply chain perspective, this topic also relates to the area of effectively managing a product over its lifecycle. While designing a product for the environment is not a new idea, the RL aspect of product design has received limited attention in the influential literature identified in this paper.

The important references listed in Table IV are the most cited works in the period of 2012-2015 and should be very relevant to RL research in the near future. In order to help researchers with their research efforts on various current popular and emerging RL topics, we reorganize and group these references by topic and present them in Table V.

**Table V:** Important references for popular and emerging RL topics

| Key RL themes | Related important references |
|---|---|
| Green logistics/sustainability | Kannan et al. 2012, RCR; Lee and Lam, 2012, IMM; Rahman and Subramanian, 2102, IJPE; Robotis et al., 2012, IJPE; Bell et al., 2013, IJPDLM; Garcia-Rodriguez et al., 2013, IJPE; Brandenburg et al., 2014, EJOR |
| Product life cycle management | Guide and Van Wassenhove, 2009, OR; Altekin and Akkan, 2012, IJPR; Amin and Zhang, 2012, IJAMT; Chen and Chang, 2012, TRPE; Das and Chowdhury, 2012, IJPE; Hazen et al., 2012, IJPDLM; Rahman and Subramanian, 2102, IJPE; Chen and Chang, 2013, IJPE; Choi et al., 2013, IJPE |
| Product returns | Daugherty et al., 2001, JBL; Rogers et al., 2002, IJLM; Daugherty et al., 2005, TRPE; Stock et al., 2006, MITSMR; Bernon et al., 2013, IJPDLM |

| | |
|---|---|
| Remanufacturing | Atasu and Van Wassenhove, 2008, MS; Ferguson et al., 2009, P&OM; Pokharel and Liang, 2012, IJPE; Atasu et al., 2010, CMR; Ferrer and Swaminathan, 2010, EJOR; Chen and Chang, 2012, TRPE; Hazen et al., 2012, IJPE; Robotis et al., 2012, IJPE; Wu, 2012, IJPE; Chen and Chang, 2013, IJPE; Wu, 2013, OMEGA |
| RL interface with other areas | Daugherty et al., 2001, JBL; Daugherty et al., 2005, TRPE; Atasu and Van Wassenhove, 2008, MS; Atasu et al., 2010, CMR; Ferrer and Swaminathan, 2010, EJOR; Hazen et al., 2012, IJPE; Lee and Lam, 2012, IMM; Wu, 2012, IJPE; Choi et al., 2013, IJPE; Garcia-Rodriguez et al., 2013, IJPE; Turrisi et al., 2013, IJPDLM; Wu, 2013, OMEGA; Ye et al., 2013, IJPE |
| RL network | Pokharel and Mutha, 2009, RCR; Amin and Zhang, 2012, IJAMT; Das and Chowdhury, 2012, IJPE; Kannan et al. 2012, RCR; |
| RL and Supply chain | Guide and Van Wassenhove, 2009, OR; Pokharel and Mutha, 2009, RCR; Chen and Chang, 2012, TRPE; Rahman and Subramanian, 2102, IJPE; Wu, 2012, IJPE; Chen and Chang, 2013, IJPE; Bell et al., 2013, IJPDLM; Bernon et al., 2013, IJPDLM; Cardoso et al., 2013, EJOR; Choi et al., 2013, IJPE; Turrisi et al., 2013, IJPDLM; Brandenburg et al., 2014, EJOR |

See notes of Table II for journal names.

*RL research methods*

RL research methodology warrants some discussion and attention. After two decades of evolution, researchers have developed more sophisticated models to address different RL topics and examine more complex phenomena such as networks. RL modeling research has grown from mainly focusing on simple inventory and scheduling problems to addressing a wide range of topics such as facility location, network design, uncertainty management, etc. As highlighted by our literature review, such advances have certainly driven researchers to develop more complex models with additional variables and functions. However, the business environment is often more complex than even sophisticated mathematical models can capture. In general, the more sophisticated a model becomes, the more assumptions the researchers have to make. Therefore, we suggest researchers pay special attention to relevance and application when developing mathematical models related to RL (Rogers et al., 2012).

An important and exciting trend in RL research is the growth of diversity in research methodologies over the last few years, including empirical survey and qualitative research, as

reflected by the influential references identified for the period of 2012-2015 (e.g. Bell, et al., 2013; Daugherty et al., 2001; Daugherty et al., 2005; Hazen et al., 2012; Lee and Lam, 2012). Empirical research (such as surveys, interviews, case studies, content analysis, etc.) can generate highly meaningful, generalizable results that help companies improve their RL practices. For example, research topics such as top management's support for RL and empowerment of RL personnel are crucial in the development of effective RL programs, but they cannot be quantified and studied with typical modeling methods. Empirical studies have made huge contributions to the advancement of the general SCM discipline; we believe such research can have a similar effect on RL. We therefore call for more empirical research in RL to enhance the body of knowledge related to RL, including research that provides greater insight into the specific motivations for RL, perhaps using stakeholder, institutional or legitimacy theories as possible avenues for advancing RL theory and practice.

*Diversity of researchers engaged*

RL research's author base is becoming more diverse but still needs the active involvement of more researchers from different backgrounds. Our analysis indicates that RL research to date has been significantly impacted by a relatively small number of important author clusters. However, a limited number of key authors may limit the scope of research. Methods can be driven by authors' preference for a particular methodology or the nature of the problems they study. With a small set of prominent authors who may have a preference for certain methodologies or problems, findings and conclusions may be skewed toward the focus of those authors. Therefore, it is important that a much broader range of authors contribute to

the creation of the RL body of knowledge. In terms of RL authors' geographic locations European and North American scholars will continue to play an important role in RL research, but recent influential publications indicate that scholars from other regions will become more involved. The rise of RL scholars in emerging economies (most notably Chinese scholars) is particularly evident. These scholars' focus on RL topics is a promising indicator of the increasing awareness of RL within these countries.

*Viewing the literature a different way*

One of the contributions of this research is to apply the burst detection analysis technique in the supply chain area, where it has been limited, and in RL, where it has not been used to our knowledge. The burst detection analysis (BDA) technique used in this paper represents a different approach to conducting a literature review that provides insights into patterns and relationships. Depending on the goal of the literature review, this method has several advantages that might be of interest to SCM and logistics researchers. First, the burst detection method allows the researcher to focus only on the most influential articles. At a high level, this allows researchers to see the major ideas, people, and other patterns emerging at a given point in time. This is an excellent technique for seeing patterns over time. However, BDA downplays the importance of new ideas that simply have not yet gained traction.

Another unique aspect of the way that this literature review was conducted, is that after identifying all the relevant articles in the Web of Science database (912), CiteSpace software was used for co-citation analysis, encompassing 22,642 references. This is important

because we could detect influential references in various formats but not limited to journal articles. For example, this study surfaced two influential books that normally would not be considered in a literature review, although they provide key foundations for many RL authors. Determining and justifying the boundaries of a literature review is a subjective and often contentious task. Using an approach like this expands the domain to identify influential scholarly articles beyond a certain domain or pre-defined set of journals, but does not exclude influential books and managerial articles as well.

In considering future RL research, there are topics that span many disciplines that may nevertheless be viewed differently among those disciplines. For example, returns processing has different implications from a customer service or marketing perspective than it does from an environmental perspective or a supply chain perspective. An approach like the one used in this study could be used in future research to understand the key RL and other SCM themes across different disciplines, which can help identify common findings, areas for potential synergy, and opportunities for future research. One specific example is RL for electronics products. Electronics RL has received more attention in the sustainability than in the SCM literature. How can these bodies of knowledge inform each other? A cross-disciplinary perspective can create opportunities to conduct more meaningful studies and advance knowledge on various topics.

**Limitations**

In this study, we attempted to provide new perspectives of existing RL literature by using new bibliometric analysis methods. However, certain potential limitations warrant attention

when interpreting our research results and conducting future RL research. First, because our approach focused on identifying influential references with both high citation counts and high burst values in order to capture the dynamics of RL research development, the influential references generated in this study may not include some highly-cited references that have generated steady citations over time. Therefore, we suggest that RL scholars still consider such potentially important references when reviewing and synthesizing existing literature. Second, the fact that many of the logistics/SCM journals were not in ISI WoS until after 2010 could have contributed to the imbalanced representation of more established operations research journals in our analysis. At the same time, some scholars may have limited their RL literature searches to a small set of operations research journals, causing fewer citations for RL articles appearing in logistics/SCM journals.

**Conclusion**

Despite above mentioned limitations, we still believe our study contains important and valuable information for RL scholars. First of all, our study results indicate that the RL field has experienced tremendous developments in recent years. Rogers and Tibben-Lembke (2001) once concluded that "much of the world does not yet care about the reverse flow of product". Carter and Ellram (1998) found that "most of the literature dealing with reverse logistics is descriptive and anecdotal" and only examines relatively narrow aspects of RL. More than ten years later, our study shows that this is no longer the case. In this paper, we focus on identifying the most influential references in RL research and depicting RL research development trends. Using CiteSpace software as a bibliometric analysis tool, we were able

to conduct a comprehensive literature search that includes a wide range of articles. Unlike existing literature review studies in the logistics field, our study uses citation count as a key article selection criterion. The group of influential articles identified in this process well represents the core literature and knowledge body of RL. We also divide RL literature between 1992 and 2015 into five periods as shown in Figure 3, and our analysis clearly shows how RL research in each period grew and expanded on the basis of the previous period. It is evident that some of the key references played a crucial role in advancing RL literature. By carefully evaluating and synthesizing the influential references and related articles in the latest four-year period (2012-2015), we also identified some important RL research trends and opportunities. It is evident that many operational and strategic areas in RL demand much more research effort. Our analysis also indicates that enhanced diversity in terms of research methodology and author base is imperative for the future development of RL research. Since RL has become globally important, it can be expected that the boundaries of RL research will continue to expand and many more interesting problems and propositions will emerge.

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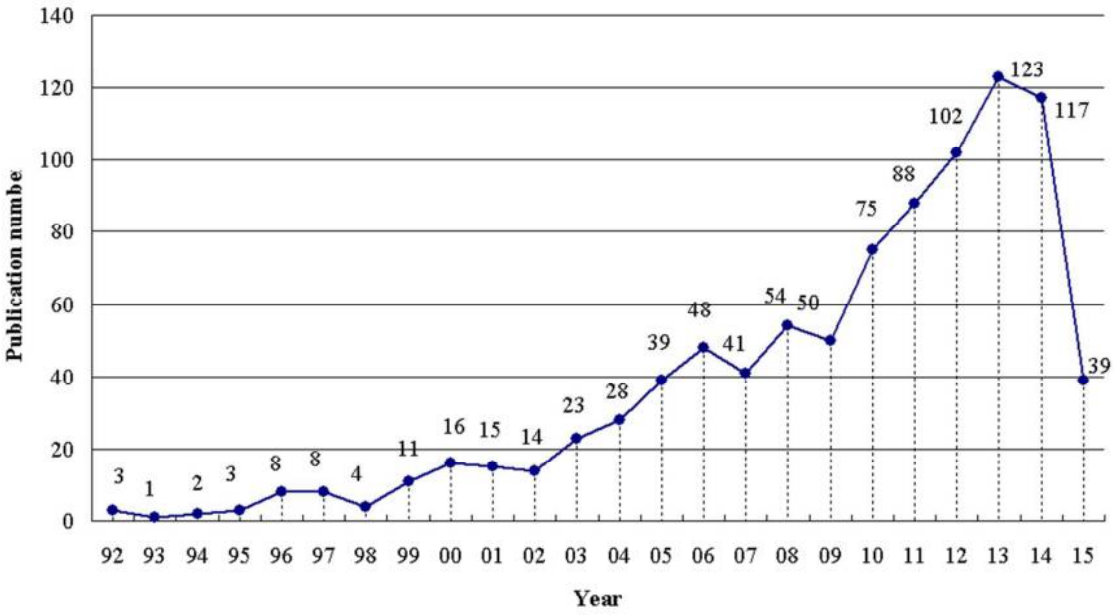



**Figure 1:** Distributions of Bibliographic Records of Reverse Logistics Papers (1992 to 03/31/2015)

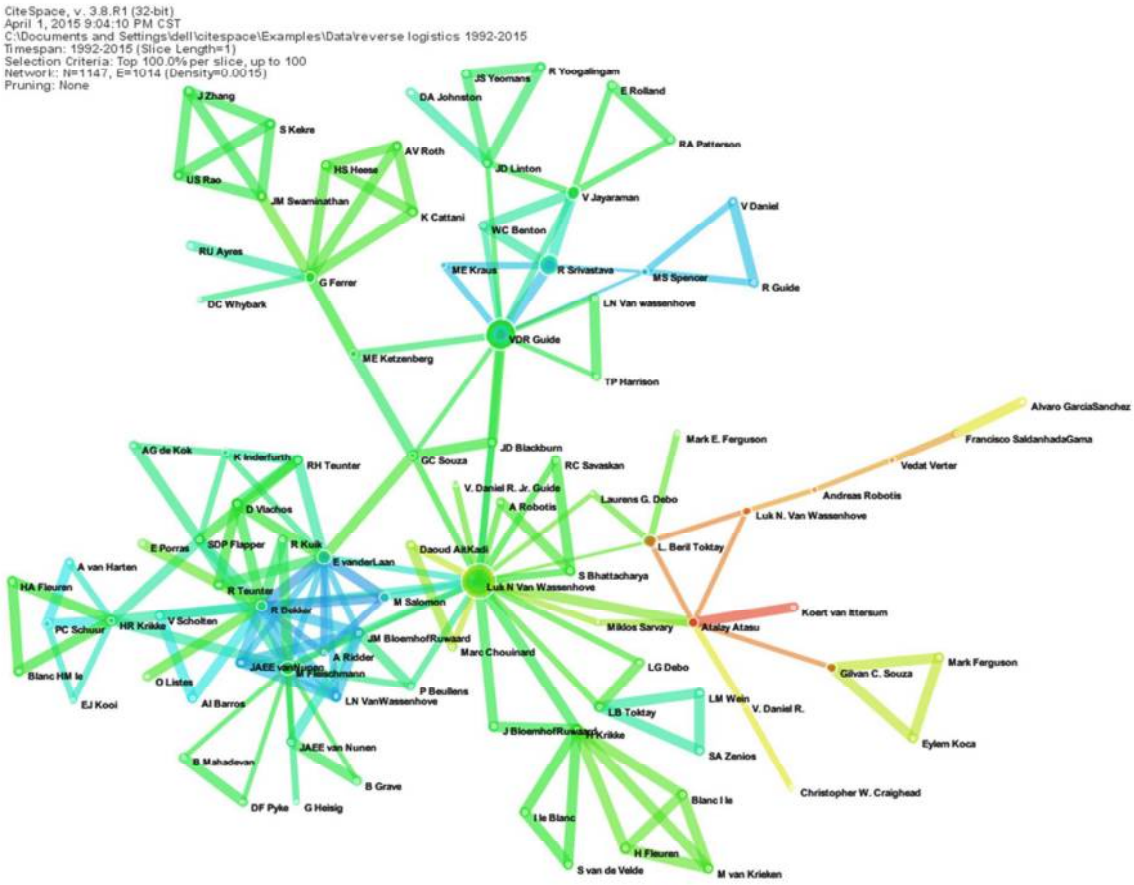
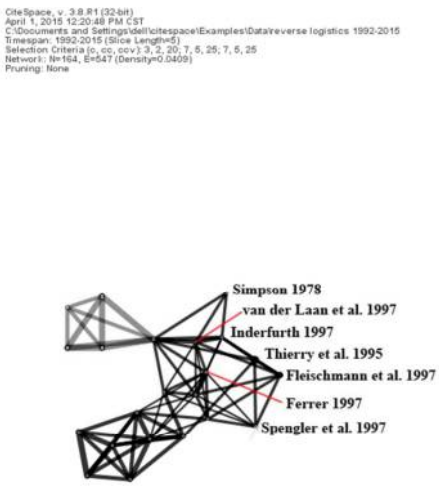
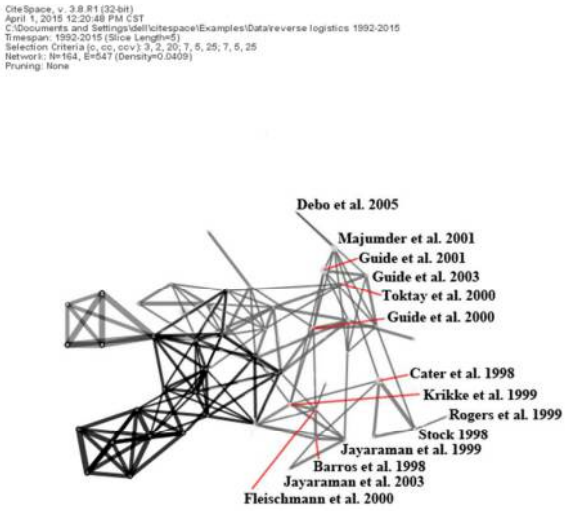



**Figure 2:** The Largest connected component of the RL co-authorship network

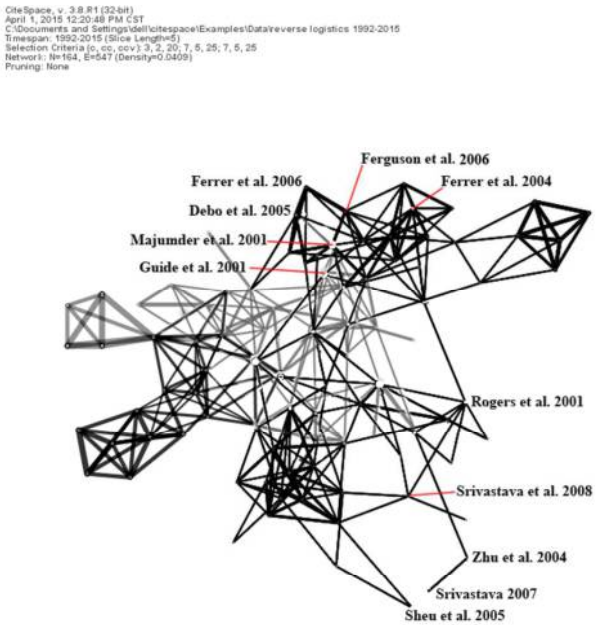

（a）1992-1996



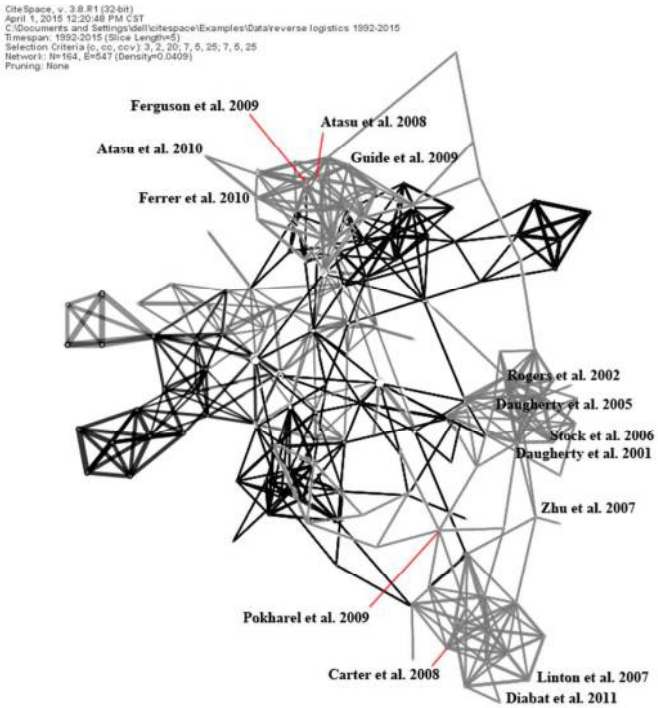

(b) 1997-2001




(c) 2002-2006




(d) 2007-2011




(e) 2012-2015

**Figure 3:** The Panorama View and Four Five-Year Snapshots of Documents Co-citation Network during the Entire Time Interval of the Dataset (1992–2015)

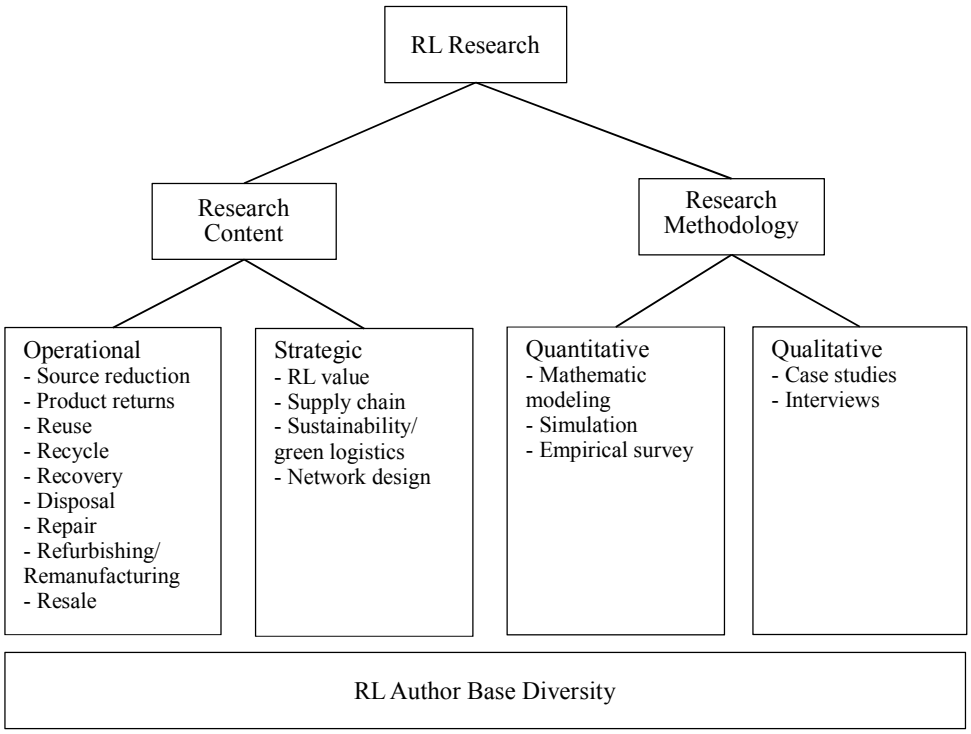



**Figure 4:** RL research trends summary framework