Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2014, 6(7):1916-1921

ISSN : 0975-7384
CODEN(USA) : JCPRC5

Reverse logistics network: A literature review

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ABSTRACT

The purpose of this article is to conduct a review of the reverse logistics network literatures, especially those published ever since 2000. We hope to find out characteristics in the research and possible opportunities for further research. Content analysis is applied in this article to review the published literatures in books and conference proceedings, and articles obtained from electronic sources. Most research focuses only on a small area of reverse logistics network. Many literatures in reverse logistics network design focus on case study, especially on electrical and electronic equipment recycling. Many quantitative models have been developed for reverse logistics network design. Reverse logistics network models can be classified as closed-loop network model, generic model, stochastic model and 3PLs model. Researchers focus on case study, quantity model and closed-loop network model. In particular, closed-loop network model has been receiving much more attention from 2000. However, the researches on models for 3PLs are relatively little.

Key words: Reverse logistics network, Case study, Quantitative model

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INTRODUCTION

Sustainability has become a major concern in the development of human society. Sustainability requires to solve some complex issues involving social, technical and legislative factors, such as how to prevent the environmental deterioration caused by the generation of wastes, how to minimize the generation of wastes and how to enhance the value recovery from the wastes. Reverse logistics network is helpful to meet this requirement because its main task is to collect and transport used products and packages based on the balance of cost and environment. It can take place through the original forward channel, a separate reverse channel and combinations of the forward and the reverse channel. On the other side, good reverse logistics network is important for firms to gain more profit. Integration and optimization of reverse logistics network has become an effective way to keep and improve competitive advantage for HP, GE and IBM [1].

The purpose of this article is to provide a review of the research of reverse logistics network ever since 2000. The rest of the article is organized as follows. In the second section research methodology is discussed. In the third section, the result of review is presented and this section is divided further into subsections to highlight various factors that are important to the research. In the last section conclusions with some thoughts on further research are made.

EXPERIMENTAL SECTION

The method of content analysis is applied in this literature review. As an observational research method, content analysis is often used to systematically evaluate the symbolic content of all forms of recorded communication. This method is also helpful to identify the literature in terms of various categories for creating research opportunities. Al-Mashari and Zairi used it to analyze the implementation of SAP R/3 for re-engineering the supply chain using enterprise resource systems [2]. It was also used by Byrd and Davidson to examine the impact of information technology on supply chain and by Marasco in a review of literature on third party logistics [3].

The review is based on the published literatures in books and conference proceedings, and articles obtained from electronic sources including Google Scholar, Science Direct, Emerald Insight, and Inderscience databases. Keywords such as “reverse logistics network”, “reverse logistics”, “recycling”, “remanufacturing”, “product returns”, “product recovery”, “end-of-life products”, ”closed-loop supply chains” and “green supply chain” were used to find related literatures.

LITERATURE REVIEW

3.1 Overview

According to the widely accepted definition of reverse logistics made by Fleischmann “reverse logistics network is the process of planning, implementing and controlling the efficient, effective inbound flow and storage of secondary goods and related information, opposite to the traditional supply chain directions for the purpose of recovering value and proper disposal”, reverse logistics network can be regarded as the configuration of nodes and the arrangement of lines in reverse logistics system, reverse logistics network covers three main sub-fields——distribution planning, inventory control, and production planning [4-6].

Research on reverse logistics network has been growing since the 1970s. Most research about the strategies and models on reverse logistics network can be seen in the publications in and after the 1980s. However, efforts to synthesize the research in an integrated body of knowledge seem comparatively limited. Most research focuses only on a small area of reverse logistics network, such as network design, production planning or environmental issues. For instance, a study was carried out from the perspectives of distribution planning, inventory control and production planning [4]. Another study, as a review of reverse logistics network literature, focused on the transportation and packaging, purchasing and environmental aspects [7]. The interactions between sustainability and supply chains was studied by considering environmental issues regarding product design, product life extension and product recovery at end-of-life [8]. More studies can be found in the literature review on reverse logistics network published between 1995 and 2005 by focusing on management of the recovery, distribution of end-of-life products, production planning and inventory management and supply chain management issues [9].

Design and optimization of reverse logistics network is a major focus in the recent years. This includes the network structure, the number of layers, the type of necessary facilities as well as the technology needed to be employed. The responsible parties need to decide the number of facilities required, their capacities and their most appropriate locations as well. In the design and optimization of a reverse logistics network several issues should be considered: actors in reverse logistic network, functions to be carried out and the relation between the forward and reverse logistic network. Some researchers have proposed several design principles for reverse logistic network [10-12]. However, these principles were limited in certain circumstance and cannot form a widely accepted criterion. Design principles were put forward for closed-loop logistic network according to characteristics of reverse logistics from the perspectives of economics, environment and logistics channel [13]. The principles include selection criterion of suppliers, production life cycle (PLC) analysis, product quality, and recovery percentage, and so on.

Table 1 Differences between reverse logistics network and forward logistic network

Reverse Logistics Network	Forward Logistics Network
through standard channel	driven by external force
definite destination	indefinite destination
clear disposal mode	uncertain disposal mode for recycles
uniform prices	prices influenced by many factors
speed is very important	speed is subordinate
uniform inventory	various inventories for various products
products exist in the easy-to-be-managed stages of the life cycle	recycled products exist in complicated stages
direct negotiations among participants of the supply chain	complex and variant negotiation process
real-time tracing for products being saled	difficult to trace how recycled products are treated
can be predicted uniformly	difficult to be predicted
transportation is unilateral to multilateral	transportation is multilateral to unilateral
homogenous quality of products	heterogenous quality of products
uniform packages of products	packages of products often damaged

3.2 Comparison between reverse logistics network and forward logistic network

Because of the higher supply uncertainty in quality, quantity, time and some other aspects, reverse logistics network is much more complicated than traditional forward logistic network. Regarding supply chain performance, Fleischmann pointed out the distinctions between reverse logistic network and forward logistic network, i.e. recovery products have to be inspected and classification in reverse logistics with higher uncertainty. The distinctions should be considered in designing and optimizing reverse logistics network [14]. More differences put forward by the researchers can be seen in Table 1 [15-18].

3.3 Case Studies for reverse logistics network

Many researchers have carried out case studies because a reverse logistics network is usually complicated. The cases were chosen from various industries or products such as battery recycling, paper recycling, electronic equipment, sand recycling and nuclear power. .

A vehicle routing approach was presented for the transport of end-of-life consumer electronic goods for recycling in South Korea to minimize the distance of transportation of end-of-life goods collected by local authorities and major manufacturers' distribution centers to four regional recycling centers located [19]. A linear multi-objective optimization model was used to optimize the operations of both the nuclear power generation and the corresponding induced waste reverse logistics in China [20]. A multi-period MILP model was established for carpet recycling in England to analyze a set of alternative scenarios identified by the decision maker and provided a near-optimal solution for network design [21]. A new MILP model was put forward to optimize the infrastructure design and the reverse network flow for the recovery of electrical appliances and computers in Taiwan, with computational results for the scenarios of different product return rates and operation conditions [22]. The reverse logistics network of an electronic equipment remanufacturing firm in America was analyzed, and a multi-product capacitated warehouse location MILP was presented and solved to obtain optimality for different supply and demand scenarios [23]. Another MILP model was established for the multi-echelon product recovery network design which focused on the remanufacturing of a certain type of copy photocopier [6]. In this study an LP solver was also used to get the optimal solution for the instances of small problem size. More case studies can be found in Table2.

Table 2 Case studies for reverse logistics network

Case	Literature
Battery recycling	[24]
Waste of electrical and electronic equipment	[5]
EOL electronic and electronic products	[25]
EOL vehicles	[10]
Original equipment manufacturers	[17]
Electronic goods	[19]
Paper recycling	[26]
EOL computer products	[27]
Nuclear power generation	[20]
Metal-mechanic company	[14]
Carpet recycling	[28]
Automotive industry	[29]
Sand recycling	[30]
Electronic waste	[31]
Waste of electrical and electronic equipment	[18]
Carpet recycling	[21]
Spent batteries	[32]
Computers and home appliances	[22]
Electronic equipment remanufacturing company	[23]
Photocopiers	[6]
Carpet materials	[33]
Sand recycling	[24]

3.4 Quantitative Models for reverse logistics network

Many quantitative models have been proposed for reverse logistics network design in the recent years, including mixed integer linear programming (MILP) model, mixed integer nonlinear programming (MINLP) model, mixed integer goal programming (MIGP) model and linear multi-objective programming (LMOP) model.

A multi-objective and multi-period MILP model was established for reverse logistic network design for modularized products which determines the number of existing forward flow facilities to be used and the number of dedicated facilities to be setup for handling return flows [34]. A mixed integer goal programming (MIGP) model was established to determine the facility location, route and flow of different varieties of recyclable wastepaper in the multi-item, multi-echelon and multi-facility environment [26]. A simulation model of a reverse logistics network was used to collect EOL appliances [16]. With temporal consolidation issues in a multiple planning horizon, Min and his colleagues put forward a nonlinear mixed integer programming model and a genetic algorithm to solve the reverse logistics problem involving product returns in other two articles [35]. A nonlinear integer program was proposed to solve the multi-echelon, multi commodity closed loop network design problem involving product returns in another article of the authors [36]. A linear multi-objective optimization model was presented to optimize the operations of both the nuclear power generation and the corresponding induced waste reverse logistics [37]. The author incorporated factors such as the operational dangers induced in both the power generation and reverse logistics processes in the model formulation. An MILP model was put forward to analyze the impact of product recovery on logistics network design and a heuristic algorithm was applied to obtain the solution for cases with large problem size [12]. More quantitative models can be found in Table 3.

Table 3 Quantitative models in reverse logistics network

Quantitative model	Literature
Linear multi-objective programming	[20], [37]
Mixed integer goal programming	[26]
Mixed integer linear programming	[38], [39], [25], [40], [11], [41], [42], [43], [44], [45], [30], [34], [21], [46], [4], [22], [23], [6]
Mixed integer nonlinear programming	[47], [35], [36]

A major issue in the reverse distribution is how to integrate forward channel and reverse channel [4]. The structure of reverse logistics network has a strong influence on the performance of forward logistics network and vice versa as they share a lot of resources such as transport and warehouse capacity. Separately designing forward logistics and reverse logistics results in sub-optimal designs with respect to costs, service levels and responsiveness, so the integration of forward and reverse logistics networks has drawn attention of many researchers. A closed-loop supply chain (CLSC) consists of both forward supply chain and reverse supply chain. Correspondingly, a closed-loop logistic network consists of both forward logistic network and reverse logistic network.

By studying a case of photocopier remanufacturing and a case of paper recycling, Fleischmann pointed out that there is possibility for cost savings if one undertook an integrated view rather than a sequential design of the forward and reverse distribution networks [4]. A hybrid method was developed to establish a closed-loop supply chain model for spent batteries. The model includes a two-stage facility location optimization problem and was applied under different scenarios for a steel making process [32]. A linear multi objective programming model was formulated to optimize the operations of both integrated logistics and corresponding used-product reverse logistics in a given green-supply chain, with the consideration of the used product return ratio and corresponding subsidies from governmental [37]. A generic stochastic model was presented for the design of networks comprising both supply and return channels in a closed loop system, which is solved by the integer L-shaped method [43]. A two (0, 1) level mixed integer programming model of an uncapacitated facility location was proposed, in which simultaneously forward and reverse flows and their mutual interactions were considered [44]. The logistics network design for end-of-lease computer products was discussed and a determined programming model for systematically managing forward and reverses logistics flows was developed [27]. An integrated model for supply chain management was proposed, where the operation of the reverse chain had been built based on the existing processes of the forward chain, and this model had been validated in a company from the metal-mechanic sector [14]. A facility location-allocation model for redesigning closed-loop service network of a computer manufacturer was developed. The model considered the possibility of the network spanning across several countries and multi-period planning horizons [48]. A closed loop mixed integer linear programming model was developed to determine raw material level, production level, distribution and inventory level, disposal level, and recycling level at different facilities with the objective of minimizing the total supply chain cost [38].

Many reverse logistic network models have appeared in case studies, so they lack generality in different situations. Some researchers have tried to propose generalized models. A general quantitative model was presented for product recovery, in which repairing and remanufacturing were considered simultaneously [42]. Another generalized model of reverse logistics network was established as a mixed integer formulation, where capacity limits, multi-product management and uncertainty on product demands and returns were considered [45]. Fleischmann and his colleagues also put forward such a model for the design of reverse logistics networks, and presented a generalized facility location model (MILP) to integrate the forward and reverse chains with a balance constraint that the total return of each factory cannot exceed its total production [4].

Uncertainty is another important characteristic of product recovery because the quantity and the quality of used products are more difficult to control and estimate in reverse flow. Some researchers have addressed this issue under stochastic environment.

A periodic review model was established for product recovery in stochastic remanufacturing systems with multiple reuse options [49]. A stochastic programming approach was presented together with a determined location model for product recovery network design to deal with some uncertainties. However, this approach can only solve a small number of scenarios of the uncertain problem parameters [30]. A multi-period and multi-echelon forward-reverse logistics network design risk model was developed by El-Sayed and his colleagues. The model was formulated as a stochastic mixed integer linear programming (SMILP) decision making form. But it can only be used for single item and single product problems [11]. A two stage stochastic programming model was put forward by Lee and his colleagues. They integrated the sample average approximation method with a heuristic algorithm based on system analysis [50].

Some researchers have used quantitative models to study reverse network concerning third-party logistics (3PLs). The reason is probably that there are major advantages associated with 3PLs providers handling the reverse logistics for companies. First, the 3PLs providers have expertise, sophisticated logistic networks, IT technology and the capability to operate systems efficiently [51]. Second, the same assets (investment) of third-party providers can be used in various contractual relationships and thus provide economies of scale when employed [52]. Rupnow and other researchers showed the multiple benefits that companies using 3PLs service typically experience [1]. The most frequently mentioned advantages are cost reduction, improved expertise and access to data, improved operation and customer services and the ability to focus on core competencies and flexibility.

A mixed integer nonlinear programming model was applied for the design of a dynamic integrated distribution network for 3PLs. In order to handle the realistically sized problem, a genetic algorithm was presented [47]. A closed loop reverse logistics network problem was established in which manufacturers took advantage of a 3PL system for the post-sale service [40]. A mixed-integer programming model and a genetic algorithm were put forward to solve the reverse logistics problem involving the location and allocation of repair facilities for 3PLs [41].

CONCLUSION

This paper summarizes the research methodology for reverse logistics network as case study and quantity analysis, and classifies reverse logistics network models into four major categories: closed-loop, generic model, stochastic model and 3PLs. Our review shows that case study for reverse logistics network has kept a high proportion in the last decade while quantity model and closed-loop network have received growing attention. The product types covered in case study are still not extensive and limited in several similar products. It is a challenge to extend case study for reverse logistics network to most products. Moreover, the generality of model for reverse logistics network is not satisfactory as there are a lot of different situations in each logistic network. In addition, reverse logistics network design for 3PLs has not fully been addressed.

Acknowledgements
This research was financially supported by Research Start Project of Hangzhou Dianzi University (KYS035609044).

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