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MODELS AND METHODOLOGIES IN REVERSE SUPPLY CHAIN: A REVIEW AND REFLECTION

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ABSTRACT

Environmental and economic issues have significant impacts on reverse supply chain management and are thought to form one of the developmental cornerstones of sustainable supply chains.
The objectives of this paper are to: report and review various perspectives on design and development of reverse SC, planning and control issues, coordination issues, product remanufacturing and recovery strategies, understand and appreciate various mechanisms available for efficient management of reverse supply chains and identify the gaps existing in the literature.

Keywords: Reverse Supply Chain management, Recycling, Reverse logistics. Design and development of reverse supply chain.

1. INTRODUCTION

Reverse logistics, which is the management or return flow due to product recovery, goods return, or overstock, form a closed-loop supply chain. The success of the closed-loop supply chain depends on actions of both manufacturers and customers. Now, manufacturers require producing products which are easy for disassembly, reuse and remanufacturing owing to the law of environmental protection. On the other hand, the number of customers supporting environmental protection by delivering their used products to collection points is increasing [1]. According to the findings, the total cost spent in reverse logistics is huge. In order to minimize the total reverse logistics cost and high utilization rate of collection points, selecting appropriate locations for collection points is critical issues in RSC/reverse logistics. Reverse logistics receive increasing attention from both the academic world and industries in recent years. There are a number of reasons for its attention. According to the findings of Rogers and Tibben-Lembke (1998), the total logistics cost amounted to $862 billion in 1997 and the total cost spent in reverse logistics is enormous that amounted to approximately $35 billion which is around 4% of the total logistics cost in the same year. However, efforts to synthesize the research in an integrated broad-based body of knowledge have been limited [9]. Most research focuses only on a small area of RL systems, such as network design, production planning or environmental issues. Fleischmann et al. [2] studied RL from the perspectives of distribution planning, inventory control and production planning. Carter and Ellram [3] focused on the transportation and packaging, purchasing and environmental aspects in their review of RL literature. Linton et al. [4] studied the interactions between sustainability and supply chains by considering environmental issues regarding product design, product life extension and product recovery at end-of-life. Realff et al. [5] have also reviewed the literature on RL 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. To consider the stock of the past research, Fleischmann et al. [6] and Fleischmann [7] their literature review suggested seven opportunities for further research.

First, they proposed the use of closed-loop network design and the integration of facilities between forward and backward flow. Second, they suggested including more comprehensive facility location models to examine the impact of uncertainty on reverse logistics network design via scenario and parametric analysis. Third, they suggested the development of stochastic model for reverse logistics network on real time basis. Fourth, they recommended the assessment of the impact of product recovery network on transportation. Fifth, they also suggested the analysis of

multi-agent characters in a reverse logistics network by revealing the underlying incentives of collectors, intermediaries and processors. Sixth, they proposed to investigate the impact of inventory management techniques such as risk-pooling and postponement on reverse logistics network design. Finally, they suggested investigating the impact of global supply chain issues such as taxation and cross-border waste transportation on the design of product recovery network.

The need for more complex objective functions; reverse logistics network and robust stochastic models have also been suggested in the literature by many authors.

The main objective of this paper is to review literature addressing various issues related to reverse logistics/closed loop supply chain during the period 1990-2009 and then to identify future research opportunities. This paper specifically identifies and reviews papers which addressed the research opportunities suggested by Fleischmann et al. [6] and [7]. Chanintrakul et al, [8] and Pokharel and Mutha [9]. Altogether we found more than 100 papers published during the period 1990-2009. For each paper we identify the applied modeling method and assumptions, i.e., time period, commodity-product flow, network level, open or close-loop structure, objective function, uncertainty type and other model constraints. The paper ends with frame of research and some thoughts on further research.

2. RESEARCH ISSUES IN REVERSE SUPPLY CHAIN

The models in RSC are developed and proposed with one or more specific research issues in mind. Some of the relevant research issues in RSC are as follows:

Research Gaps in Reverse Logistics Network Design & Development
Remanufacturing Issues in Reverse Supply Chain
Research Gaps in the Literature Related to Remanufacturing Strategies
Application of Simulation for RL Network Design
Impact of Transportation on Product Recovery
Modeling of Dynamic Uncertaincy Systems

2.1 . Research Gaps in Reverse Logistics Network Design & Development

A very few authors presents the overview of the simulation models for reverse logistics network design appeared in literature during the last two decades. Overall, few simulation models were proposed to analyze the impact of various network design parameters on the operational performance of reverse logistics systems. The objective of the simulation models was to investigate which possible design variables are important for a reverse logistics network design.

Despite many profound contributions of the researchers, these papers (models) are still faced with some limitations:

- All of the proposed models considered few elements of return and/or demand uncertainty left out other elements of risk and uncertainty in terms of quantity, quality and timing.
- All of the proposed papers have not included more realistic assumptions, i.e., multi-objective, multi-period, multi-commodity flow, capacitated, closed-loop network structure into a single model
- Though a number of the heuristics solution methods were proposed, there is no computational time performance comparison between the proposed models and other heuristics solution methods.
- The models only investigated the element of return uncertainty in terms of quantity but ignored the risk and uncertainty in terms of quantity, quality and timing.
- All of the proposed models did not consider reverse logistics capacities and basic operations requirement

2.2 Remanufacturing Issues in Reverse Supply Chain

In this section, we identify the problems with current descriptions of remanufacturing and their planning and control issues. As observed by Volmann et al. [66], an aggregate production plan should provide as close a match as possible between the model and the real world. Management must clearly define key objectives in order to develop advanced manufacturing systems.

A complete review of this research stream is offered in both Fleischmann [21] and Guide and Jayaraman [32]. Further, the past work has been focused on producing operations research models and there have been a very limited number of attempts to structure the field.

2.3. Research Gaps in the Literature Related to Remanufacturing Strategies

The issue of forecasting for used product returns has proven to be a difficult challenge for the remanufacturing industry. Rogers and Tibben-Lembke [28] characterize good gate keeping as ,"the first critical factor in making the entire reverse flow manageable and profitable". Another important characteristic in the closed-loop supply chain is the need for a well-functioning reversed logistic network [27]. Remanufacturers are often categorized into three categories: original equipment remanufacturers, contracted remanufacturers and independent remanufacturers (IRs). Despite many profound contributions, literature in the segment having many gaps that needs to be addressed by the researchers and models are still faced with some limitations:

Although there are a lot of studies on various specific areas of remanufacturing, only a few research studies have focused on the development of a general framework and mathematical model about remanufacturing system

Absolute shortage of integrated models which includes remanufacturing with OEM. More research needed on integrated modes which include reverse and forward channels simultaneously.

Performance measurement system for the integrated manufacturing models which includes reverse and forward channels is still awaited.

2.4. Application of Simulation for RL Network Design:

A very few authors presents the overview of the simulation models for reverse logistics network design appeared in literature during the last two decades. Overall, few simulation models were proposed to analyze the impact of various network design parameters on the operational performance of reverse logistics systems. The objective of the simulation models was to investigate which possible design variables are important for a reverse logistics network design. For example, Biehl et al. [14] took potential design variables such as the number of collection centres, collection rates, type and set up of information technology for forecasting and control systems, recycling rates and return rates into account in order to assess how the US carpet industry would able to meet a 40% diversion from landfills by 2012. Regarding the model results, both simulation models were able to provide several crucial managerial recommendations for the improvement of reverse logistics network.

2.5. Impact of Transportation on Product Recovery:

Though there are only three papers, they laid the foundations for the research of the impact of the transportation issues in terms of consolidation and channel selection decisions (direct and indirect shipment). Particularly, the proposed models have coped with products returned from online sales [27], products returned from online and retail sales [28] and mail catalog or online sales business via third-party logistics company [29]. De Brito and Dekker [20] mentioned that there are three main classifications of agents in reverse logistics and closed-loop supply chain as follows; forward supply chain actors (as supplier, manufacturer, wholesaler and retailer), specialized reverse chain actors (such as jobbers, recycling specialists, etc.) and opportunistic actors (such as charity organizations). Each of players within forward and/or reverse channels may have particular operations objectives and constraints. Moreover, each of them may have different competition and/or collaboration behaviors with other agents in the same or different tiers.

To analyze the behavior of agents in reverse logistics network, Nagurney and Toyasaki [26], Chen et al. [14] and Hammond and Beullens [16] proposed a network equilibrium model for reverse logistics recycling network by using the variational inequality (VI) approach. All proposed models addressed single-period and single-commodity flow problem for the recycling waste of electric and electronic equipment (WEE). The proposed models consider an open-loop system with four-tiered network comprised of four agents including the sources of electronic waste, the recyclers, the processors and demand markets (Nagurney and Toyasaki,[11]; Chen et al.,[22]) and a closed-loop system with a two-tiered network and two agents including manufacturers and consumer markets[63].

2.6. Modeling of Dynamic Uncertaincy Systems:

Furthermore, several authors began to investigate the impact of uncertainty on reverse logistics network design for large-scale problems solved by robust MILP models with exact algorithms, decomposition algorithms and heuristics algorithms and large-scale and dynamic problems solved by MINLP model with heuristics algorithms. Furthermore, many of the proposed models were applied in different industrial and product sectors, i.e., copier remanufacturing and paper recycling [12], end-of-life home appliances and computer (Shih 2001), refrigerator (Krikke et al., 2003), spent batteries (Schultmann et al., 2003), LPG-tanks (le Blanc et al., 2004), copier remanufacturing (Salema et al., 2006), office document company (Salema et al., 2007), paper recycling[44], carpet recycling (Realff et al., 2000, 2004), home appliances, computer, mobile phone and car (Srivastava, 2008), and end-of-lease computer products [1].

3. CRITICAL APPRAISALS OF THE EXISTING APPROACHES

This Pricing the remanufactured product for sale is a complex and challenging issue [85] due to stochastic returns and demands. This makes it difficult to determine the price of a re-manufactured product vis-à-vis new products.

3.1 Pricing and Competition:

Researchers have studied the relationship between markets for new and re-manufactured products and developed models to determine the optimum selling price for re-manufactured products and parts. The competition between original equipment manufacturers (OEMs) and local re-manufacturers not only affect the supply of used products but also the price of the re-manufactured product [16-17-18-19]. They found that OEMs are in a better position to offer re-manufactured. Products at a lower price than those offered by local re-manufacture.

3.2 Coordination Support:

The Coordination in RL is also discussed by the authors. Some authors have discussed the importance of communication to help in quick and early disposition of returned products and also assisting in re-manufacturing planning [13-15]. Some authors have suggested the use of information support systems to assist in coordination [16-17].

3.3. Customer Relation :

The benefits of RL on customer relationship such as improved customer retention and customer satisfaction through liberalized returns policies is analyzed by Fuller et al.[19], Turner et al.[99], Wise and Baumgartner [10], Sarkis et al.[11], and Mollenkopf et al.[12]. Amini and Retzalff-Roberts [13] suggest reduction in cycle time of providing refunds and exchanges to customers as a way of enhancing customer service quality

4. FRAMEWORK OF RESEARCH

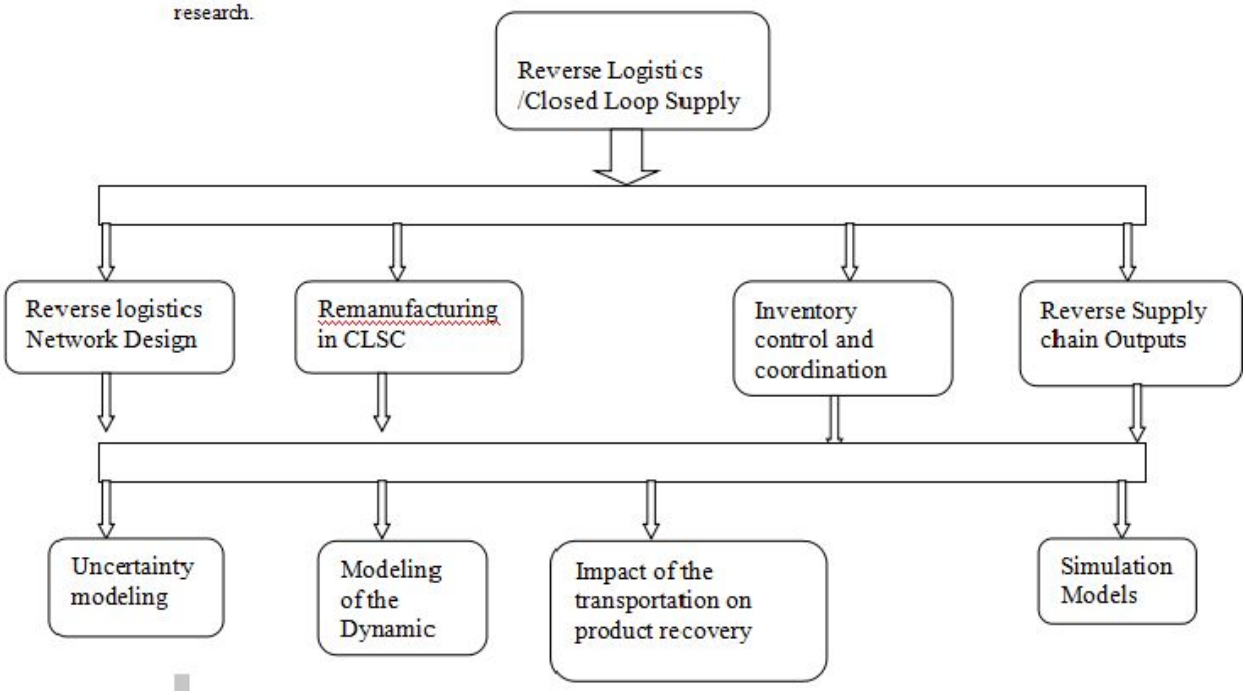
This paper gives a comprehensive literature review of the journal papers on reverse logistics/closed loop supply chain published in last two decades.

Figure 2 shows the eight major streams covered by our literature review with regards to the issues being addressed during the review period 1990-2009, the impact of design of reverse logistics network channel functions in isolation was most popular issue among the academician and practice , while the rest of the research issues received relatively less attentions. Particularly, we found a lot of contributions to the understanding of the impact of uncertainty on reverse logistics network design because return and demand uncertainty in terms of quantity, quality and timing have now been investigated [22]. The rest of the research issues, though received relatively less attention, have already given the foundations for future research.

The review presents reverse supply chain from a systems perspective. It can assist the decision maker in key operational and strategic decision making, for example, integrating manufacturing, distributors, remanufacturing operations and 3PL providers, evaluating end-of-life options for returned products, or setting up a returns policy. RL involves a paradigm shift in terms of product, that is, from “cradle-to-grave” to “cradle to cradle”. Arising from the above, we propose some important directions in RL research. We have found that the research can be strengthened in assessing the stochastic nature of supply and demand and the yield from a remanufacturing process. More generic models have to be developed to tackle this type of situation so that better networks can be designed to facilitate reverse logistics. The objective of this study was to encourage and provide researchers with future research directions in RSCM for which empirical research methods are appropriate.

Our review concludes that there have been a gradual increased of efforts in modeling of reverse supply chain/closed loop supply chain network but there is a need for incorporating more realistic and complicated assumptions in terms of time period, commodity-product flow, network level, open or close-loop structure, objective function, uncertainty type and other model constraints.

research.



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