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Network design for reverse logistics ☆

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Abstract

Collection and recycling of product returns is gaining interest in business and research worldwide. Growing green concerns and advancement of green supply chain management (GrSCM) concepts and practices make it all the more relevant. Inputs from literature and informal interviews with 84 stakeholders are used to develop a conceptual model for simultaneous location–allocation of facilities for a cost effective and efficient reverse logistics (RL) network. We cover costs and operations across a wide domain and our proposed RL network consists of collection centers and two types of rework facilities set up by original equipment manufacturers (OEMs) or their consortia for a few categories of product returns under various strategic, operational and customer service constraints in the Indian context.

In this paper, we provide an integrated holistic conceptual framework that combines descriptive modeling with optimization techniques at the methodological level. We also provide detailed solutions for network configuration and design at the topological level, by carrying out experimentation with our conceptual model. Our findings provide useful insights to various stakeholders and suggest avenues for further research.
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1. Introduction

Green supply chain management (GrSCM) is gaining increasing interest among researchers and practitioners of operations and supply chain management. Three drivers (economic, regulatory and consumer pressure) drive GrSCM worldwide. It integrates sound environmental management choices with the decision-making process for the conversion of resources into usable products. GrSCM has its roots in 'environmental management orientation of supply chains'. Producing environmentally friendly products has become an important marketing element that has stimulated a number of companies to explore options for product take-back and value recovery [1].

Managers have been giving increasing importance to the environmental issues, their impact on operations and potential synergies [2,3] since the early 1990s. Earlier literature is generally restricted to the plant or firm level focusing on green purchasing, industrial ecology, industrial ecosystems and corporate environment strategies [3]. Gradually, environmental management aroused increased interest in the field of supply chain management resulting in a growing literature on green supply chains [4–6].

For the purpose of this paper, we consider GrSCM as defined by Srivastava [4]. He defines GrSCM as

"Integrating environmental thinking into supply chain management including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life". An interesting and significant trend in GrSCM has been the recognition of the strategic importance of reverse logistics (RL) as evident from classification and categorization of the existing GrSCM literature by Srivastava [4] shown in Fig. 1.

RL shall become vital as service management activities and take-back for products such as automobiles, refrigerators and other white goods, cellular handsets, lead-acid batteries, televisions, personal computers (PCs), etc. increase in future. A well-managed RL network cannot only provide important cost savings in procurement, recovery, disposal, inventory holding and transportation but also help in customer retention. Since RL operations and the supply chains they support are significantly more complex than traditional manufacturing supply chains, an organization that succeeds in meeting the challenges presents a formidable advantage not easily replicable by its competitors [7].

Today, India is the fourth largest country in terms of purchasing power parity (PPP) and constitutes one of the fastest growing markets in the world [5]. However, RL is yet to receive the desired attention and is generally carried out by the unorganized sector for some recyclable materials such as paper and aluminum. Some companies in consumer durables and automobile sectors have introduced exchange offers to tap customers who already own such products. The returned products are sold either *as it is* or after refurbishment by third parties.

Successful exchange offers have been marketing focused and no original equipment manufacturer (OEM) has come up with repair and refurbishing or remanufacturing facilities for the returned products and their sale. A summary of product–market characteristics for the wide category of products covered in our study is presented in Table 1. The cumulative annual growth rate (CAGR) shown is for the sales in the past decade and the expected demand in the next decade.

We cover the literature on GrSCM, primarily focusing on 'RL'. We do not consider literature and practices related to green logistics as the issues are more of operational rather than strategic nature and may not be significant in the RL network design per se. We also do not focus in detail on literature on corporate environmental behavior, green purchasing, industrial ecology and industrial ecosystems as it is generally either regulatory-driven or firm-specific. We rather focus more on RL

from resource-based viewpoint as establishment of efficient and effective RL and value recovery networks is a pre-requisite for efficient and profitable recycling and remanufacturing. This has received less attention in the GrSCM literature so far.

This paper is further organized as follows. In Section 2, we describe briefly our methodology in light of our objective. This is followed by contextual literature review in Section 3. To address some of the research issues and gaps related to designing RL networks for product returns, we develop a conceptual model in Section 4. The development of the corresponding mathematical model formulation for optimizing the decision-making is described in Section 5. Data collection in the Indian context is described in Section 6. Experimentation results for a few scenarios for decision-making using our model are discussed in Section 7. In Section 8, we conclude by describing the contributions as well as the limitations of our work and also suggest directions for further research.

2. Methodology

Our methodology consists of a theoretical part (literature review and conceptual model development) and an applied part (maximizing profits for various scenarios in practical settings using a hierarchical optimization model and drawing useful managerial insights and implications). A focused literature review seems to be a valid approach, as it is a necessary step in structuring a research field and forms an integral part of any research conducted. We focus mainly on RL literature deriving from related areas like natural resource based view of the firm, GrSCM, supply chain risk, etc. to maintain the theoretical roots and linkages. We identify a few issues and gaps as well as challenges and opportunities. Our endeavor is to highlight the importance of RL and develop a more formal framework for analyzing the RL and value recovery network design. To achieve this, we develop a bi-level optimization model; use secondary data for product returns for a period of 10 years; conduct informal interviews with 84 stakeholders to gauge and estimate various costs and other parameters; and finally derive important strategic and operational implications for various stakeholders.

3. Literature review

The resource-based-view of the firm draws primarily from Hart [8] who proposes a theory of competitive advantage based upon the firm's relationship to the natural environment. He provides a conceptual framework