A Flexible Integrated Forward/Reverse Logistics Network Design

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Supply chain management (SCM) describes the dis-cipline of optimizing the delivery of goods, services and information from supplier to customer. Logistics network design is one of the most important fields of SCM and a major strategic issue due to its impact on the efficiency and responsiveness of the supply chain such as reducing cost and improving service quality.

Nowadays, extended producer responsibility is be-coming increasingly common around the globe. Also, due to the implementation of government legislation, social responsibility, environmental concern, economic benefits and customer awareness of the industries are under a pressure to not only provide environmentally friendly products, but also to take back a product after its use. In order to overcome these issues, it is necessary to setup a logistics network for the flow of goods from end users to manufactures. One way of doing so is through the utilization of returned products, which extends their useful life cycle. In addition, industries are using remanufacturing for expensive products such as turbines used in airplanes and electricity generation systems. Yet, most of logistic networks are not equipped to handle the returned products in reverse channels. Moreover, the significance of transportation cost and customer satisfaction spurs an interest to develop a flexible network design model with different delivery paths.

Problem Definition

The forward supply chain involves the movement of products from the upstream supplier to the downstream customer. The reverse supply chain focuses on the backward flow of materials from customer to supplier for possible recycling and reuse. In order to avoid sub-optimality of a solution derived by the separated design of the forward and reverse network, the forward and reverse supply chain should be integrated. Fig. 1 illustrates the general model of a closed loop supply chain network. Previous research in the area of forward, reverse and integrated logistics network design is often limited to analyze the flow between two consecutive stages. Nevertheless, considering flows between facilities which are not sequential will increase the logistics network efficiency and flexibility. Within this research a flexible model for single period, single product, multistage integrated forward/reverse logistics network design including supplier, production, distribution, collection/inspection is described, that could support both recovery and disposal activities with limited capacity.

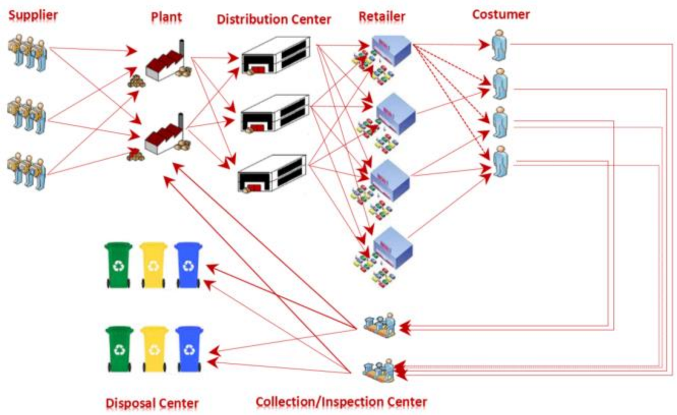

Fig. 1. Framework of the closed loop logistics network model

From literature, it is understood that the integrated forward/reverse logistics problems are different from traditional logistics models. Due to their size, these problems are more complex and require more effort to analyze. As illustrated in Fig. 1, in the forward flow, new products are shipped from plant to customer zones through distribution and retailer centers in a pull manner to meet the demand of each customer. Customer locations are assumed to be predetermined and fixed. In the reverse flow, returned products are collected by collection/inspection centers and, after inspection, the recoverable products are shipped to recovery facilities, and scrapped products are shipped to disposal centers in a push manner. Also three kinds of shipment are used in the proposed network to enhance

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the logistic network efficiency and flexibility by increasing customer satisfaction, reducing transportation cost and decreasing lead time, cf. Fig. 2.

- Normal Delivery: with this method, products are delivered from one echelon to another.
- Direct Shipment: with this method, products are transported from plants to customers directly.
- Direct Delivery: with this approach, products are transported from DCs to customers or via plants to retailers directly.

The model is enriched by different delivery paths which allow for skipping stages. It is clear that applying such a logistics model improves the flexibility and efficiency of a supply chain network. Using the new delivery routes makes the problem more complex. Hence, obtaining an accurate and efficient algorithm to tackle these NP-hard problems is necessary.

Objective

The objective of this research is to develop a mathematical model to minimize the total cost including transportation and processing of supply chain networks considering different types of delivery paths. The main issue addressed by this study is to determine both the optimal number and capacity of plants, distribution, retailer, collection/inspection and disposal centers, as well as the product flow between the facilities.

Since network design problems belong to the class of NP-hard problems, developing an efficient solution method is still a critical need. To achieve this objective, the future contribution of this work will be developing a practical solution based on the previously developed methods.

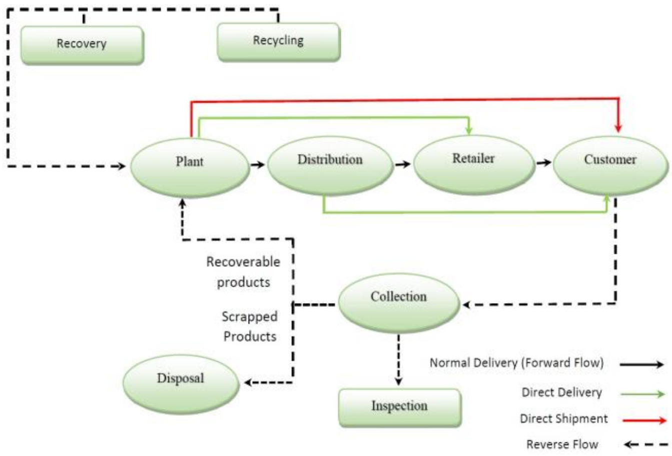

Fig. 2. Framework of the flexible integrated forward/reverse logistics

Solution Approach

There are three main approaches to tackle NP-hard problems: probabilistic algorithms, approximation algorithms and metaheuristic algorithms. Due to reducing the space search and increasing the quality of the solution, we consider metaheuristic algorithms as an approach. Among those, genetic algorithms (GAs) are an appropriate approach for closed loop supply chain model. The basic feature of GAs is a multidirectional and global search by maintaining a population of solutions from generation to generation. However, pure GAs often lack the capability of sufficient search intensification. Moscato and Norman first defined a memetic algorithm (MA) to integrate local search in GAs to improve the intensification of the search. MAs are population-based heuristic search approaches (like GA) for optimization problems, which have shown practical success in a variety of problem domains, and in particular for the approximate solution of NP-hard optimization problems. Hence, both GA and MA algorithm are appropriate solution methods, particularly in the large scale case. Comparing respective solutions can be considered as a good method to show the efficiency of these algorithms in closed loop supply chains. Moreover, small test problems can be solved via LINGO, GAMS or CPLEX optimization software to test the accuracy of the proposed MA and GA.