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Development of RFID-based Reverse Logistics System

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ABSTRACT

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. 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 in reverse logistics. This paper proposes a genetic algorithm to determine such locations in order to maximize the coverage of customers. Also, the use of RFID is suggested to count the quantities of collected items in collection points and send the signal to the central return center. This can facilitate the vehicle scheduling for transferring the items from collection points to the return center. The significance of this research is the proposal of RFID-based reverse logistics framework and optimization of locations of collection points which allow economically and ecologically reasonable recycling. Simulation results indicated that the genetic algorithm is able to produce good-quality solutions in terms of coverage of collection points by choosing suitable locations for collection points and RFID can help detect the quantity of returned products so as to increase efficiency of logistics operations.

1. Introduction

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. The concerns about energy saving, green legislation and the rise of electronic retaining are increasing. Also, the emergence of e-bay advocates product reuse. Online shoppers typically return items such as papers, aluminum cans, and plastic bottles whose consumption and return rates are high. Although most companies realize that the total processing cost of returned products is higher than the total manufacturing cost, it is found that strategic collections of returned products can lead to repetitive purchases and reduce the risk of fluctuating the material demand and cost. For instance, the Body Shop utilizes an anti-animal test and a green marketing strategy. The customers can obtain a refund at any retail shop after returning their used cosmetic containers. This can indirectly attract them to patronize again.

With ever-rising needs of reverse logistics, firms possessing optimal planning of return routes, inventory and warehouse layouts for returned products are more competitive than the others. Thus, it is important for companies to equip with such a strategy. Typically, used products are collected and consolidated at designated regional distribution centers, retail collection points before shipping to the centralized return center. In addition, the activities of reverse logistics include collection, sorting, disassembly, repair and disposal for achieving product recovery. Distribution and inventory management are the main concerns for those activities. For distribution management, distribution network design and facility location allocation can be handled by optimization techniques. For inventory management, it is required to consider how the value of returned products can be retained and to realize the difficulties of predicting the uncertain quantities of recovery products. This leads researchers to shift their research direction from forecasting to responsive scheduling. Although distribution and

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inventory management are involved in both forward and reverse logistics, they are not exactly the same.

Reverse logistics is not the symmetrically opposite of forward logistics. The difference between reverse and forward logistics can be interpreted in form of various attributes such as quantity, category, cycle time, stock keeping unit and distribution paths. Returned products are usually small in quantity and have many different types. The cycle time of collecting returned products is uncertain that provokes some research on stochastic lead times (Lieckens & Vandaele, 2007). Also, the stock keeping unit used in forward logistics can be boxes or pallets while that in reverse logistics can be a weight unit. For example, box may be adopted as a stock keeping unit for drinks while kilograms as a unit for returned aluminum cans sold to the collection center. Regarding distribution paths, the routing and scheduling of reverse logistics are more complex than those of forward logistics. The routing of reverse logistics starts from the designated regional distribution center to the centralized return center and then to manufacturers for remanufacturing or to manufacturers directly without passing through the centralized return center. Due to the uncertainty of return quantities, the physical flow channel is more complicated than that in forward logistics. Since different areas have various product returning rates, the locations of collection points can significantly affect the efficiency of recycling. Accordingly, this paper proposes to employ artificial intelligence techniques to determine appropriate locations of collection points for maximizing their coverage.

This paper is organized as follows. Section 2 gives a literature review of optimization in reverse logistics. Section 3 presents the framework of reverse logistics and the roles of multi-echelon in the closed-loop supply chain. Section 4 introduces the RFID-based Reverse Logistics System which incorporates genetic algorithms into RFID systems to acquire responsive and effective return flows. Sections 5 and 6 provide the operations of genetic algorithm for determining suitable facility locations, and the daily application and results respectively. Section 7 concludes the findings together with the contribution of this research.

2. Literature review

The five principal processes in the flow of reverse logistics are collection, storage, transportation, inspection and reduction. In the flow of reverse logistics, products are delivered through three transaction points which are Point of Sale (POS), Point of Return (POR) and Point of Exit (POE). POS is the place at which it is easy for providers to distribute products to consumers. POR is the place at which customers can dispose or return used products. POE is the end node of a logistics network. The latter two were covered in most research. A number of studies have studied various location allocation problems of those points. The three possible techniques to solve these problems are exact algorithms, heuristics and meta-heuristics.

The following studies utilized the former two approaches to tackle various location allocation problems. Caruso, Colorni, and Paruccini (1993) proposed a multiple objective mixed integer program and a heuristic solution procedure for solving the location allocation of waste service users, processing plant and sanitary landfill for the regional urban solid waste management system. The objective function was to minimize the overall cost (i.e. the investment and management expense and transportation cost), the waste of resources within the system in the time unit and the environmental factors. Srivastava (2008) suggested an integrated holistic conceptual framework combining descriptive modeling with mixed integer linear programming techniques to determine the location allocation and capacity decisions for facilities, and disposition decision for various grades of different products simultaneously for a reverse logistics network. Pati, Vrat, and Kumar (2008) dealt with the multi-item, multi-echelon and multi-facility decision making problem involved the facility location, route and flow of different varieties of recyclable wastepaper in paper recycling system by using mixed integer goal programming technique. Barros, Dekker, and Scholten (1998) tackled the location allocation problem of regional depots and treatment facilities for the sand recycling network by using heuristic procedures.

The work adopted meta-heuristics is discussed as follows. Min, Chang, and Hyun (2006) proposed a nonlinear mixed integer nonlinear programming model for a closed-loop supply chain network and employed a genetic algorithm to determine the number and locations of initial collection points, and the exact length of holding time at the collection points by considering the total reverse logistics cost. Bautista and Pereira (2006) used a genetic algorithm and greedy randomized adaptive search procedures heuristic to solve the problem of locating collection areas for urban waste management in Barcelona. He, Yang, and Ren (2007) suggested a combination of a fuzzy multi-objective programming and a genetic algorithm to determine the optimal locations and numbers of treatment facilities and transfer stations for municipal solid wastes. Chi, Hsu, and Lin (2007) solved the problem of selecting proper collection sites and refurbishing sites on a 1000×1000 squared area for minimizing the total transportation cost by using a genetic algorithm with the help of multiple overlapped fitness functions.

According to the findings of Fleischmann et al. (1997), the main recovery option can be classified as directly reusable network, remanufacturing network, repair service network and recycling network. Lu and Bostel (2007) formulated a 0–1 mixed integer programming model based on Lagrangian heuristics which considered both forward and reverse flows simultaneously for remanufacturing. A two-stage heuristic algorithm was proposed by Lee and Dong (2008) to decompose the integrated design of a logistic network for end-of-lease products recovery into a location allocation problem. In the problem, the network flow conservation constraints and capacity constraints were considered. The locations were randomly chosen and then the optimal solution for forward logistics and the initial solution of returned product were obtained by simplex algorithm.

The previous studies related to selection of location points and network design of reverse logistics has been discussed above. Researchers tried to use different mathematical models and artificial intelligence techniques such as genetic algorithms to select the optimal locations by minimizing the total cost and satisfying different constraints. They used only forecasting and simulation methods but lacked for real-time information. Since forecast is not always the same as the real situation, real-time data collection is needed to confirm the amount of returned products. Accordingly, RFID is suggested to be applied in reverse logistics so as to reflect the quantity collected in collection points. RFID tags help identify the category of collected products by installing RFID readers at various collection points. As a result, logistics practitioners can schedule the return shipment in order to minimize the loss of value of the returned goods.

3. Framework of reverse logistics

Reverse logistics is the collection and transportation of used products and packages. Fig. 1 shows the framework of forward and reverse logistics. In forward logistics, suppliers offer raw materials to manufacturers. These manufacturers deliver finished products to distributors who finally distribute them to customers. In reverse logistics, collectors and recyclers play important roles for