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A Genetic Algorithm-based optimization model for supporting green transportation operations

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ABSTRACT

Green Logistics (GL) has emerged as a trend in the management of the distribution of goods and the collection of end-of-life products. With its focus on maximizing the economic and environmental value by means of recycling and emission control, GL contributes to the sustainable development of industry but also requires a more comprehensive transportation scheme when conducting logistics services. This study is motivated by the practice of delivering and collecting water carboys. In this paper, a Genetic Algorithm-based optimization model (GOM) is proposed for designing a green transportation scheme of economic and environmental cost efficiency in forward and reverse logistics. Two vehicle routing models with simultaneous delivery and pickup (full or partial pickup) are formulated and solved by a Genetic Algorithm. A cost generation engine is designed to perform a comprehensive cost comparison and analysis based on a set of economic and environmental cost factors, so as to examine the impact of the two models and to suggest optimal transportation schemes. The computational experiments show that the overall cost is evidently lower in the full pickup model. Notably, the impact of product cost after recycling and reusing empty carboys on total cost is more significant than the impact of transportation cost and CO_2 emission cost. In summary, the proposed GOM is capable of suggesting a guidance for the logistics service providers, who deal with green operations, to adopt a beneficial transportation scheme so as to eventually achieve a low economic and environmental cost.

1. Introduction

Managing both the delivery of finished goods and the pickup of end-of-life products has become increasingly important to modern companies due to regulations by the government, the need for protecting the environment and of meeting environmental requirements, and value-added customer service for enhancing competitiveness. Reverse logistics, which has recently received close attention, influence a company's performance in both economic and environmental way. Published research has proposed possible frameworks of reverse logistics to maximize the efficiency and effectiveness of deliveries and pickups, but responding to environmental issues continues to be one of the major challenges in logistics and supply chain management. If both the distribution process and transporting re-usable packaging and goods in the reverse direction are performed simultaneously at the customers' locations by a fleet of vehicles, the economic and environmental impact of conducting logistics services can be jointly considered and examined in a more systematic and comprehensive manner.

Our study was motivated by the practice of delivering and collecting water carboys (Fig. 1). We believe that by designing a green transportation scheme of both deliveries and pickups the management of the procedures involved can be improved. In the plastic container industry which has a relatively low profit margin, logistics cost may have great impact on the overall profitability. The importance of recyclability of the used plastic products is also emphasized by the government and environmentalists. Thus it is both beneficial and necessary to find a transportation scheme with the best balance between economic and environmental cost efficiency.

The problem examined in this paper can be described as a Capacitated Vehicle Routing Problem with Simultaneous Delivery and Pickup (VRPSDP) of plastic carboys in order to minimize both economic and environmental costs. A reverse logistics transportation scheme was examined by conducting a comparative analysis between two models with different pickup strategies, VRP with Simultaneous Delivery and Full Pickup (VRPSDFP) and VRP with Simultaneous Delivery and Partial Pickup (VRPSDPP), for different customer sizes. VRPSDFP satisfies all the pickup requirements for recycling all the returned products when designing the routing plan, while VRPSDPP refers to the situation where the number of returned products picked up is exactly limited to the available vehicle loading space en route. The experiment uses filled plastic carboys as the goods to be distributed and empty carboys as the goods to be collected in the reverse process in the VRPSDP model. To be more

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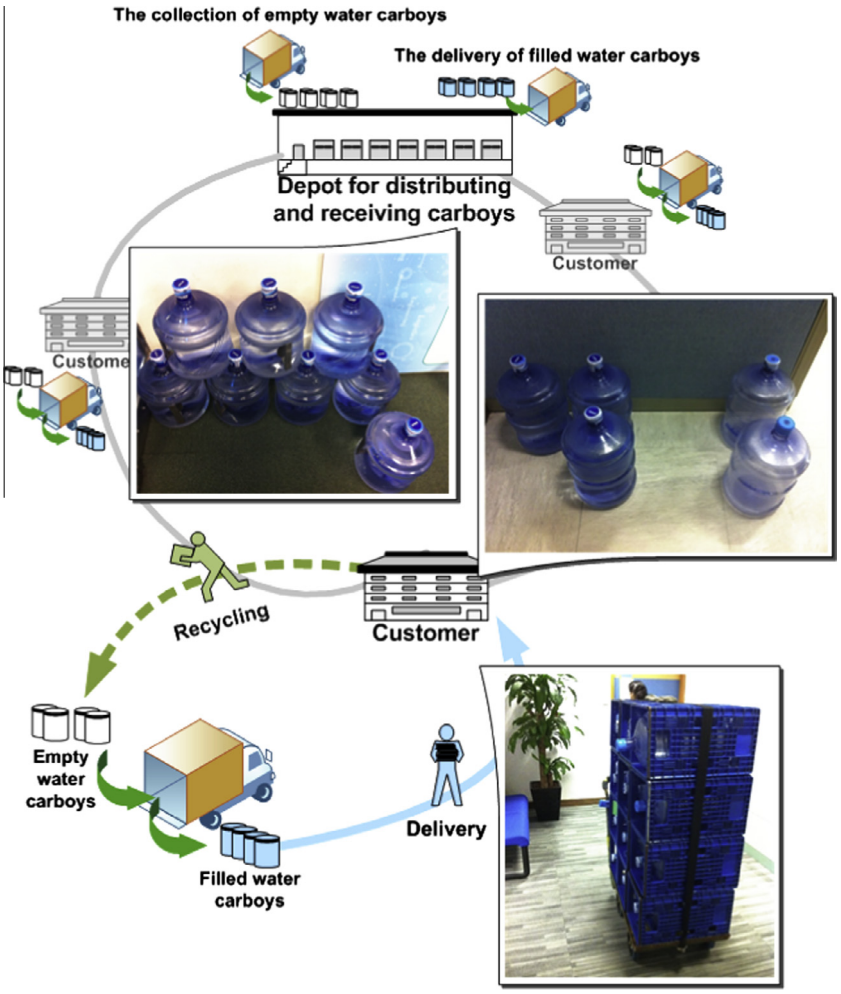

Fig. 1. Delivery and collection of water carboys.

specific, the model is capacity-constrained, that is, the routing design is constrained by the capacity of each vehicle. The VRPSDPP model may be more close to the real situation of recycling, since the number of returned products is usually unknown to the distributor. VRPSDFP assumes that all pickup amounts are known.

Both economic and environmental factors directly related to the logistics activities are taken into account in the cost efficiency calculations. Major economic costs include logistics costs such as fuel consumption costs and the labor costs of driving the fleet of vehicles. Other economic factors include product costs and the reduced production costs resulting from reusing empty carboys (in other words, monetary value gained from reusing empty carboys). For environmental factors, cost of CO_2 emission is calculated, which varies with the amount of fuel consumed by different vehicles with different curb and cargo weight. Although other environmental factors such as the environmental impact of reusing and recycling plastic end-of-life products may have a much greater impact on overall cost than CO_2 emissions, the exact monetary value of such intangible factors is difficult to define with limited resources and time. Thus the experimental computations only include CO_2 cost.

To sum up, the main objectives of this study are:

- To propose a Genetic Algorithm-based optimization model (GOM) that assists in designing a green transportation scheme and a pickup strategy of economic and environmental cost efficiency in forward and reverse logistics, notably in the case of plastic carboys.
- To examine the impact of forward and reverse logistics on total costs by comparing two pickup strategies (models), full pickup and partial pickup.
- To suggest appropriate transportation and pickup schemes for delivering and recycling goods.

The contributions of this study are outlined as follows:

- Two VRPSDP models with different pickup strategies, VRPSDFP and VRPSDPP, are proposed to formulate the commonly addressed logistics issues of delivering and collecting products. The two models attempt to compare the cost efficiency between full and partial pickup strategies for recycling end-of-life products, which frequently bothers logistics managers when making decisions on a cost-effective logistics plan.
- A comprehensive cost analysis, including economic cost (transportation) and environmental cost (the returned value of end-of-life products and the negative impact of greenhouse gas emission) is conducted, providing a framework for analyzing the economic and environmental impact of a reverse logistics strategy.
- Managerial implication based on the cost analysis of two pickup strategies is discussed to enable decision makers to consider the compromises or trade-offs of different economic and environmental cost indicators. Particularly, possible environmental influences, such as CO_2 pollution and recycle materials, can be evaluated so that different levels of green logistics strategies can be adopted.