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Replenishment routing problems between a single supplier and multiple retailers with direct delivery

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Abstract

We consider the replenishment routing problems of one supplier who can replenish only one of multiple retailers per period, while different retailers need different periodical replenishment. For simple cases satisfying certain conditions, we obtain the simple routing by which the supplier can replenish each retailer periodically so that shortage will not occur. For complicated cases, using number theory, especially the Chinese remainder theorem, we present an algorithm to calculate a feasible routing so that the supplier can replenish the selected retailers on the selected periods without shortages.

Keywords: Inventory; Replenishment; Routing; Chinese remainder theorem

1. Introduction

This paper considers a replenishment routing problem where the supplier has only one vehicle and can replenish only one retailer per period using the vehicle, while different retailers need different periodical replenishment. Given a set of retailers, the problem is that, whether and how the supplier can replenish all the retailers and shortages will not occur at each retailer.

In this problem, the replenishment of inventory at each retailer is controlled by the supplier, and the inventory are kept at independent retailers. Such cases are always considered to be vendor managed inventory (VMI) problems. In VMI systems, the supplier decides which retailers should be replenished at which times, and with how many items. Now, the use of VMI is becoming very popular because the benefits of VMI are made possible by the increased availability of relevant information for the decision maker, and by the increased coordination, and are well recognized by successful retail businesses. More and more advantages implementing VMI over using conventional inventory management are discovered at a very rapid pace,

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(see, for example, Çetinkaya and Lee, 2000, Kleywegt et al., 2002, 2004).

A notable issue is that VMI focuses on the coordination of inventory replenishment and transportation, so that VMI can reduce transportation costs by shipping a large load to several retailers instead of delivering small loads to each retailer, respectively. When implementing VMI, the core decision problem that often has to be addressed is that, how to determine optimal policies for the distribution of products from the supplier to the retailers, which is called the inventory routing problem (IRP).

In general terms, IRP supposes that the supplier controls a fleet of vehicles. Anily and Federgruen (1990) consider that all stock are distributed to the retailers by a fleet of capacitated vehicles. Barnes-Schuster and Bassok (1997) use $\frac{D}{q}$ trucks to replenish one retailer, where q is the truck capacity and D is the retailer's demand. Kleywegt et al. (2002, 2004) uses a fleet of M homogeneous vehicles. And in the example of Kleywegt et al. (2002), six instances that use 6, 8, 10, 12, 14, 16 vehicles, respectively are discussed.

It is worth noting that the existing literature discussing the IRP allows that one vehicle is used to replenish all the retailers or visit all the customers without time limit, or one vehicle can replenish more than one retailer and one retailer can be replenished by more than one vehicle. For example, Bertsimas (1992) studies two strategies. Under strategy (a) the vehicle visits all the customers in the same fixed sequence, but serves only customers requiring service that day. Strategy (b) is defined similarly to strategy (a) with the sole difference that the demand is known before the vehicle starts its route, and customers on the vehicle routing with no demand are simply skipped. Generally, such cases are always using the algorithms that are mostly used in the traveling salesman problems (TSP) (Lawler et al., 1985) to compute the visiting sequence that will minimize total traveling distance or total traveling time. Anily and Federgruen (1990) provide a model discussing a distribution system with a depot and many geographically dispersed retailers, each of which faces external demands occurring at constant, deterministic but retailer specific rates, and restrict themselves to a class of strategies in which each time one of the retailers in a given region receives a delivery, this delivery is made by a vehicle that visits all other retailers in the region as well.

A large variety of deterministic and stochastic models of inventory routing problems have been formulated, and a variety of heuristics and bounds have been produced. A classification of the inventory routing literature is given in Kleywegt et al. (2002). Even given conditions facilitating the analysis of a proposed policy, the general IRP is always hard to solve. Then, many researchers consider the special case of the IRP in which only one customer is visited on each vehicle route. The special case of the IRP is called the IRP with direct deliveries (IRPDD) (Kleywegt et al., 2002). Burns et al. (1985) analyze the direct shipping distribution strategy (i.e., shipping separate loads to each customer), and develop expressions for transportation and inventory costs per item. Supposing that each retailer sends goods via one or more trucks which leave the depot with the goods, deliver them to the retailer, and then return to the depot, Gallego and Simchi-Levi (1990) show that the effectiveness of full truck direct shipping over all inventory routing strategies is at least 94% whenever the economic lot size of each of the retailers is at least 71% of vehicle capacity. And the effectiveness deteriorates as the economic lot sizes become smaller. Barnes-Schuster and Bassok (1997) study the cost effectiveness of a particular direct delivery policy for the inventory routing problem, and show that simulation studies demonstrate that very good results can be achieved by a direct shipping policy. Reiman et al. (1999) find that direct shipping allowing backlogging is the most transportation-efficient routing scheme when the policy that achieves the lowest transportation cost is the one that delivers the largest amount per unit time traveled. And direct shipping will be preferred for cost-symmetric systems with sufficiently high backorder costs. Kleywegt et al. (2002) develop approximation methods to perform the computational tasks and to obtain good solutions for the inventory routing problem with direct deliveries.

When the demand of the retailer is deterministic, and shortage and backlogging are not allowed, the retailer should be replenished once per several periods. Gallego and Simchi-Levi (1990) require that the retailer i should be replenished once per Q^f/D_i time where Q^f is the economic lot size and D_i is the demand per unit time. When the demand of the retailer is stochastic, Dror and Ball (1987) convert this case to a deterministic one by approximating the stochastic demands by demands which are known, but different in each period. They assume