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Lot-sizing in a serial distribution system with capacitated in-system production flow

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Abstract

In this paper, we focus on an N-stage serial production–distribution system with limited production capacity at the first stage. Our objective in such a system is to find inventory management policies that minimize the global logistic cost, including transportation and holding costs. We use myopic heuristics based on the breakdown of the system into local systems. One of these systems is a 2-stage system, and the second is a 3-stage system. They both can be solved with a very good performance guarantee. The successive optimizations of such systems provide quite good policies for the global system as asserted by the experimental results at the end of the paper.
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1. Introduction

Multi-echelon inventory management has strongly interested researchers as well as industry in the past decades. Over this period, enhanced competition between firms has forced them to be more attractive in terms of costs and delays. Thus, inventory related costs as well as all logistic costs had to be minimized. Moreover, inventories had to be managed in such a way that customer delays should also be kept to a minimum. The entrance into the 21st century enhanced these needs even more due to the rise of worldwide global markets, and thus worldwide competition. This is especially true when dealing with inventories in the distribution channel as distances from production to sales points are becoming ever greater. At the same time, the emergence of the supply chain concept showed the need for integrating firms and activities in a global management of the chain. In this field of supply chain integration, a wide range of studies can be found, from incitation mechanisms, to the integration of activities or multi-actors problems. A wide variety of such problems are presented in Tayur et al. (1998). In this context, the need for integrating activities such as distribution channel inventory management and production is of major interest as the optimization of local activities may lead to poor global performance.

This paper focuses on lot-sizing in a serial distribution system that integrates production constraints. The environment we consider here is

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deterministic and with continuous time. We are interested in finding high performing inventory management policies in a distribution system, taking into account a capacitated production at the start of the chain. We consider a constant and continuous demand that arises at the end of the chain (retailer's facility). Between the production facility and the retailer's, we have intermediate storage facilities. We focus on stationary policies: a stationary policy is a policy in which each facility orders a constant batch at regular intervals. The reasons for this choice are that stationary policies are easy to implement and to manage in practice and they lead to smooth product flows. Moreover, in a constant and continuous demand environment, they appear to be very natural.

The problem of determining policies in multi-echelon system in a constant and continuous context has been extensively studied but with two general assumptions (e.g. see Roundy, 1986; Federgruen et al., 1992; Graves et al., 1993; Williams, 1981): the first one is that the upstream stage is supplied by a perfect supplier (who can supply any quantity instantaneously); the second assumption states that the holding costs increase as products flow along the chain. Very recently, a one-warehouse-multiple-retailer model has been studied by Axsäter (2003), considering that the first stage of the chain orders from an external perfect supplier.

The first assumption makes sense when an external supplier, whose costs are not included in the optimization process, exists. This leads to policies such that the first storage facility quite rarely orders from this external supplier. Thus the supplier must either hold a large amount of inventory, or have a very high production capacity. Both solutions lead to high costs that are not considered in classical models.

The second assumption is quite clearly relevant in a production system, in which high value is added to the product at each step. In our distribution context, no value is added, and the inventory cost basically depends on the cost involved in handling and storing the products. Hence, this inventory cost strongly depends on the facility where it is stored, leading to non-monotone evolution. Consider for example that a product is manufactured in a big city in western Europe, shipped to a specialized logistics platform in China and sold in Singapore (as an example, Schneider Electric uses such a system for a range of products). Holding costs are expensive at the production facility, low in China (low salaries, well-equipped facility with cheap extensive space for storage) and again very expensive in Singapore.

In our integrated context, many interesting properties found in distribution systems such as the zero-inventory-ordering property or the last-minute ordering (see Roundy, 1986) are no longer dominant. These points that we have just examined show the need for new approaches in such systems. We propose methods to obtain efficient stationary policies in any type of serial production–distribution network with continuous demand. In Section 2, we present an overview of the literature related to inventory management and especially lot-sizing problems, and we explain our contribution in this context. In Section 3, we present our model and the general scheme of our heuristics, which are based on the study of local systems presented in Section 4. In Section 5, we detail the heuristics we have developed as well as their empirical performance. Section 6 concludes the paper.

2. Literature overview

Clark and Scarf (1960) studied an N-stage serial system on a finite time horizon with multiple periods and stochastic demand. Even if this paper deals with discrete time, this work is especially relevant in the field of continuous-time lot-sizing, since it introduces the concept of echelon inventory. The echelon inventory is the inventory level at stage i plus all inventories downstream. The cost associated with this inventory is the overcost induced by holding inventory at stage i instead of holding it at the upstream stage. This echelon inventory concept has been extensively used in inventory management and lot-sizing studies. However, it can be used for orders only if the echelon associated holding cost is positive, which leads to the assumption that holding costs increase along the chain.

The major contribution in continuous time distribution inventory management and lot-sizing was published by Roundy (1986). He studied a network with any particular physical structure, taking into account transportation costs and holding costs. Assuming constant and continuous demand, non-decreasing holding costs along the chain and a perfect external supplier at the beginning of the chain, he re-used the famous power-of-two policies he introduced for the one-warehouse-multiple-retailer problem (Roundy, 1985). Again, he proved that these policies are very efficient (98% efficient) and gave a quick algorithm

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