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A multi-product multi-echelon inventory control model with joint replenishment strategy

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ABSTRACT

On the basis of analyzing the shortages of present studies on multi-echelon inventory control, and considering some restrictions, this paper applies the joint replenishment strategy into the inventory system and builds a multi-product multi-echelon inventory control model. Then, an algorithm designed by Genetic Algorithm (GA) is used for solving the model. Finally, we respectively simulate the model under three different ordering strategies. The simulation result shows that the established model and the algorithm designed by GA have obvious superiority on reducing the total cost of the multi-product multi-echelon inventory system. Moreover, it illustrates the feasibility and the effectiveness of the model and the GA method.

1. Introduction

A supply chain is a network of nodes cooperating to satisfy customers' demands, and the nodes are arranged in echelons. In the network, each node's position is corresponding to its relative position in reality. The nodes are interconnected through supply–demand relationships. These nodes serve external demand which generates orders to the downstream echelon, and they are served by external supply which responds to the orders of the upstream echelon.

The problem of multi-echelon inventory control has been investigated as early as the 1950s by researchers such as Arrow et al. [1] and Love [2]. The main challenge in these problems is to control the inventory levels by determining the size of the orders for each echelon during each period so as to optimize a given objective function.

Many researchers have studied how to reduce the inventory cost of either suppliers or distributors, or have considered either the distribution system or the production system. Burns and Sivazlian [3] investigated the dynamic response of a multi-echelon supply chain to various demands placed upon the system by a final consumer. Van Beek [4] carried out a model in order to compare several alternatives for the way in which goods are forwarded from factory, via stores to the customers. Zijm [5] presented a framework for the planning and control of the materials flow in a multi-item production system. The prime objective was to meet a presanctified customer service level at minimum overall costs. Van der Heijden [6] determined a simple inventory control rule for multi-echelon distribution systems under periodic review without lot sizing. Yoo et al. [7] proposed an improved DRP method to schedule multi-echelon distribution network. Diks and Kok [8] considered a divergent multi-echelon inventory system, such as a distribution system or a production system. Andersson and Melchiors [9] considered a one warehouse several retailers' inventory system, assuming lost sales at the retailers. Huang et al. [10]

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considered a one-warehouse multi-retailer system under constant and deterministic demand, which is subjected to transportation capacity for every delivery period. Lagodimos and Koukoumialos [11] developed closed-form customer service models.

And many researchers have modeled an inventory system of only two-echelon or two-layer. Gupta and Albright [12] modeled a two-echelon multi-indentured repairable-item inventory system. Axsäter and Zhang [13] considered a two-level inventory system with a central warehouse and a number of identical retailers. Axsäter [14] considered a two-echelon distribution inventory system with stochastic demand. Chen et al. [15] considered a two-level inventory system in which there are one supplier and multiple retailers. Tee and Rossetti [16] developed a simulation model to explore the model's ability to predict system performance for a two-echelon one-warehouse, multiple retailer system. Seferlis and Giannelos [17] developed a new two-layered optimization-based control approach for multi-product, multi-echelon supply chain networks. Hill et al. [18] considered a single-item, two-echelon, continuous-review inventory model. Al-Rifai and Rossetti [19] presented a two-echelon non-repairable spare parts inventory system. Mitra [20] considered a two echelon system with returns under more generalized conditions, and developed a deterministic model as well as a stochastic model under continuous review for the system.

There are also many researches on multi-echelon inventory control, considering either the distribution system or the supply system. Choi et al. [21] evaluated conventional lot-sizing rules in a multi-echelon coalescence MRP system. Chikán and Vastag [22] described a multi-echelon production inventory system and developed a heuristic suggestion. Bregman et al. [23] introduced a heuristic algorithm for managing inventory in a multi-echelon environment. Van der Vorst et al. [24] presented a method for modeling the dynamic behavior of multi-echelon food supply chains and evaluating alternative designs of the supply chain by applying discrete-event simulation. The model considered a producer, a distribution center and 2 retailer outlets. Iida [25] studied a dynamic multi-echelon inventory problem with nonstationary demands. Lau and Lau [26] applied different demand-curve functions to a simple inventory/pricing model. Routroy and Kodali [27] developed a three-echelon inventory model for single product, which consists of single manufacturer, single warehouse and single retailer. Dong and Lee [28] considered a multi-echelon serial periodic review inventory system and 3 echelons for numerical example. The system extended the approximation to the time correlated demand process of Clark and Scarf [29], and studied in particular for an auto-regressive demand model the impact of leadtimes and auto-correlation on the performance of the serial inventory system. Gumus and Guneri [30] structured an inventory management framework and deterministic/stochastic-neurofuzzy cost models within the context of this framework for effective multi-echelon supply chains under stochastic and fuzzy environments. Caggiano et al. [31] described and validated a practical method for computing channel fill rates in a multi-item, multi-echelon service parts distribution system. Yang and Lin [32] provided a serial multi-echelon integrated just-in-time (JIT) model based on uncertain delivery lead time and quality unreliability considerations. Gumus et al. [33] structured an inventory management framework and deterministic/ stochastic-neuro-fuzzy cost models within the context of the framework. Then, a numerical application in a three-echelon tree-structure chain is presented to show the applicability and performance of proposed framework. The model only handled one product type.

Only one other paper we are aware of addresses a problem similar to ours and consideres inventory optimization in a multi-echelon system, considering both the distribution system and the supply system. Rau et al. [34] developed a multi-echelon inventory model for a deteriorating item and to derive an optimal joint total cost from an integrated perspective among the supplier, the producer, and the buyer. The model considered the single supplier, single producer and single buyer. The basic difference between our model and Rau et al. [34] is that our model considers multiple suppliers, one producer, and multiple distributors and buyers. Additionally, an algorithm designed by Genetic Algorithm (GA) is used for solving the model, and we apply the joint replenishment strategy into the model.

The remainder of this paper is organized as follows: In Section 2, the various assumptions are made and the multi-product multi-echelon inventory control model is developed. In Section 3, GA is used for solving the model and the algorithm based on GA is designed. Then, we simulate the model under three different ordering strategies, respectively. In Section 4, conclusions and limitations in this research are presented.

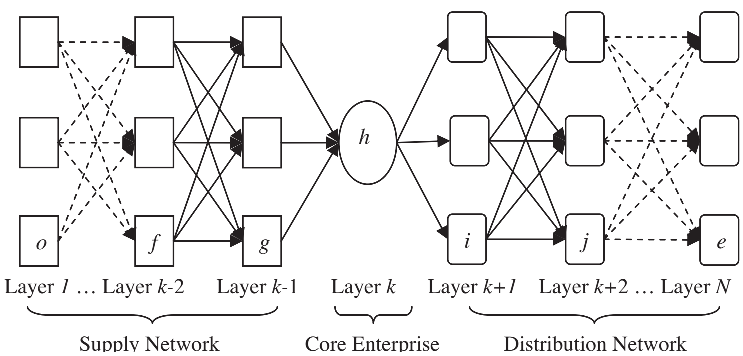

Fig. 1. The multi-product multi-echelon inventory control model.