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A genetic algorithm for vendor managed inventory control system of multi-product multi-constraint economic order quantity model

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ABSTRACT

In this research, an economic order quantity (EOQ) model is first developed for a two-level supply chain system consisting of several products, one supplier and one-retailer, in which shortages are backordered, the supplier's warehouse has limited capacity and there is an upper bound on the number of orders. In this system, the supplier utilizes the retailer's information in decision making on the replenishments and supplies orders to the retailer according to the well known (R, Q) policy. Since the model of the problem is of a non-linear integer-programming type, a genetic algorithm is then proposed to find the order quantities and the maximum backorder levels such that the total inventory cost of the supply chain is minimized. At the end, a numerical example is given to demonstrate the applicability of the proposed methodology and to evaluate and compare its performances to the ones of a penalty policy approach that is taken to evaluate the fitness function of the genetic algorithm.

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1. Introduction

The globalization of economy and liberalization of marketplace at an increasingly rapid pace has intensified the need for incorporating the resulting operational uncertainties and financial risks into the firms' production and inventory control decisions (Mohebbi, 2008).

Inventory control has been studied for several decades for cost savings of enterprises who have tried to maintain appropriate inventory levels to cope with stochastic customer demands and to boost their image through customer satisfaction (Axsäter, 2000, 2001; Moinzadeh, 2002; Zipkin, 2000). One of the key factors to improve service levels of the enterprises is to efficiently manage the inventory level of each participant within supply chains (Kwak, Choi, Kim, & Kwon, 2009).

A supply chain (SC) is a network of firms that produce, sell and deliver a product or service to a predetermined market segment (Chopra & Meindl, 2001). It not only includes the manufacturers and suppliers, but also transporters, warehouses, retailers and customers themselves. The term supply chain conjures up images of a product or a supply moving from suppliers to manufacturers then distributors to retailers and then customers along a chain (Chopra, 2003). Customers and their needs are the origin of the SC. The main objective of the supply chain management is to minimize system-wide costs while satisfying service level requirements (Tyana & Wee, 2003).

One of the well-known concepts utilized in supply chains is the vendor managed inventory (VMI) models (see for example Cheung & Lee, 2002; Disney & Towill, 2003) and many successful businesses have demonstrated the benefits of VMI, e.g., Wal-Mart and JC Penney (Cetinkaya & Lee, 2000; Dong & Xu, 2002). In these models, the retailer provides the supplier with information on its sales and inventory level and the supplier determine the replenishment quantity at each period based on this information. In other words, the supplier with regard to his own inventory cost that equals to the total inventory cost of the supply chain determines the timing and the quantity of replenishment in every cycle (Dong & Xu, 2002; Kaipia, Holmstrom, & Tanskanen, 2002; Lee, So, & Tang, 2000). Not only VMI has some advantages for both the retailer and the supplier, but also the customer service levels may increase in terms of the reliability of product availability. Since the supplier can use the information collected on the inventory levels at the retailers, future demands are better anticipated and the deliveries are better coordinated (for example, by delaying and advancing deliveries according to the inventory situations at the retailers and the transportation considerations) (Kleywegt, Nori, & Savelsbergh, 2004; Waller, Johnson, & Davis, 1999).

One of the most important problems in companies that utilize suppliers to provide raw materials, components, and finished products is to determine the order quantity and the points to place

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orders. Various models in production and inventory control field have been proposed and devoted to solve this problem in different scenarios. Two of the models that have been extensively employed are the economic order quantity (EOQ) and economic production quantity (EPQ) models (Silver, Pyke, & Peterson, 1998; Tersine, 1994). The economic order quantity (EOQ) is one of the most popular and successful optimization models in supply chain management, due to its simplicity of use, simplicity of concept, and robustness (Teng, 2008). However, these models are constructed based on some assumptions and conditions that bound their applicability in real-world situations.

In this research, a multi-product EOQ model is proposed in which not only the storage capacity, but also the number of orders is limited. Furthermore, in order to broaden the applicability of the proposed model in real-world inventory control systems, we consider shortage to be backordered and let the model act in a supply chain environment under the VMI condition. The objective is to find the order quantities and the maximum backorder level of the products in a cycle such that the total inventory cost of the supply chain is minimized. Under these conditions, the problem is first formulated as a non-linear integer-programming (NIP) model and then a genetic algorithm (GA) is proposed to solve it. At the end, a numerical example is presented to demonstrate the application of the proposed methodology and to compare its performance to the one of the penalty policy approach that is employed as another way to evaluate the fitness function the GA chromosome.

The remainder of the paper is organized as follows: a review of the literature is presented in Section 2. We define and model the problem in Sections 3 and 4, respectively. In Section 5, a genetic algorithm is developed to solve the problem. In order to demonstrate the application of the proposed methodology, we provide a numerical example in Section 6. Finally, conclusions and recommendations for future research are provided in Section 7.

2. Literature review

The two basic questions any inventory control system must answer are when and how much to order. Over the years, hundreds of papers and books have been published presenting models for doing this under various conditions and assumptions (Pentico, Drake, & Toews, 2009). Economic lot size models have been studied extensively since Harris (1913) first presented the famous economic order quantity (EOQ) formula. Then, a variation of this formula, namely the economic production quantity (EPQ), was developed for manufacturing environments. Much of the literature on inventory theory contains the basic models of EOQ and EPQ with/without shortages (Cardenas-Barron, 2001).

Since the EOQ and EPQ are constructed based on some assumptions and conditions that bound their applicability in real-world situations, many scholars have strived to develop a formulated inventory model in a more realistic fashion. As some examples, Papachristos and Skouri (2003) generalized the work of Wee (1999) in which the demand rate is a convex decreasing function of the selling price and the backlogging rate is a time-dependent function. Biskup, Simons, and Jahnke (2003), Chung and Huang (2003) and Liao (2007) extended the Goyal (1985) EOQ model to the EPQ model under conditions of permissible delay in payments.

An early conceptual framework of VMI was described by Magee (1958) when discussing who should have authority over the control of inventories. However, interest in the concept has only really developed during the 1990s. Companies have looked to improve their supply chains as a way of generating a competitive advantage, with VMI often advocated. This strategy has been particularly popular in the grocery sector but has also been implemented in sectors as diverse as steel, books and petrochemicals (Disney & Towill, 2003). For example, the benefits of VMI implications have been realized by successful retailers and suppliers, most notably Wal–Mart and key suppliers like Proctor and Gamble (Cetinkaya & Lee, 2000).

Waller et al. (1999) indicated that the VMI method can improve inventory turnover and customer service levels at every stage of a supply chain. In a more in-depth analysis, Disney and Towill (2002) showed that the kernel goal of VMI chains, which is minimizing the channel cost while simultaneously satisfying some degree of customer service levels, is achieved primarily by sharing demand and inventory information. Furthermore, the studies by Lee, Chu, and Hung (2005) and Vergin and Barr (1999) conclude that VMI is becoming an effective approach for implementing the channel coordination initiative, which is critical and imperative to improve the entire chain's financial performance.

Xu, Dong, and Evers (2001) presented a study, in which they examined the impacts of electronic data interchange (EDI) and internet-based technologies on the practice of VMI. Moreover, a survey conducted by Tyana and Wee (2003) points out that aside from the computer technologies, the key of implementing VMI lies in the abilities of the related chain members to cooperate and to understand the flows and processes concerning their products or services delivery.

Jasemi (2006) developed a supply chain model with a single-supplier and n buyers and compared the performances of a VMI system with the ones of the traditional types. He also made a pricing system for profit sharing between parties. Furthermore, Sofifard et al. (2007) presented an analytical model for a single-buyer single-supplier model to explore the effects of collaborative supply chain initiatives such as vendor managed inventory (VMI) with the EPQ model.

Cetinkaya and Lee (2000) presented an analytical model for coordinating inventory and transportation decisions in VMI systems. Woo, Hsu, and Wu (2001) and Yu and Liang (2004) extended their two-echelon inventory supply chains to three-echelon ones where the supplier was a manufacturer and his raw materials' inventory was involved. Angulo, Nachtmann, and Waller (2004) evaluated the effects of information sharing on a VMI partnership. Incorporating the dynamic dimension, Jaruphongsa, Cetinkaya, and Lee (2004) provided a polynomial time algorithm to compute the optimal solutions for the replenishment the dispatching plans. Bertazzi, Paletta, and Speranza (2005) compared the order-up-to level policy and the fill-fill-dump policy of VMI. They showed that the fill-fill-dump policy leads to a lower average cost than the order-up-to level policy. Vigtil (2007) described a set of five case studies and showed that sales forecasts and inventory positions were the most valuable information provided to supplier by the retailers in a VMI relationship.

Dong and Xu (2002) presented an analytical model to evaluate the short-term and long-term impacts of VMI on supply chain profitability by analyzing the inventory systems of the parties involved. Several common assumptions that also were used in their inventory-channel coordination research were: the inventory system of the buyer can be described by an EOQ policy, the demands are deterministic, there are no stock-outs, and the lead-times are also deterministic. Yao, Evers, and Dresner (2007) using the same assumptions as Dong and Xu's (2002) along with an additional assumption (the order quantity for the supplier is likely to be an integer multiple of the buyer's replenishment quantity) presented an analytical model to determine how key logistics parameters, most notably ordering costs and inventory carrying charges, can affect the benefits to be derived from VMI. Van Der Vlist, Kuik, and Verheijen (2007) extended the Yao et al. (2007) model along with the costs of shipments from the supplier to the buyer.

Within the researches that employed genetic algorithms (GA) in supply chain environments, Moon, Kim, and Hur (2002) proposed a

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