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Optimizing a bi-objective inventory model of a three-echelon supply chain using a tuned hybrid bat algorithm

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ABSTRACT

This paper presents a bi-objective VMI problem in a single manufacturer-single vendor multi-retailer (SM-SV-MR) supply chain, which a redundancy allocation problem is incorporated. In the hybridized problem, a manufacturer produces a single item using several machines that work in series, and stores it in a warehouse to replenish one vendor who delivers it to several retailers using the shortest possible route. A novel meta-heuristic, called hybrid bat algorithm (HBA), with calibrated parameters is utilized to find a near-optimum solution. To show the efficiency of HBA, the results are compared to the ones using the traditional BA and a genetic algorithm.

1. Introduction

Flexibility and integration in supply chain management (SCM) have important roles to reduce total cost and to improve performance. SCM is a set of approaches to efficiently integrate suppliers, manufactures, warehouses and stores, so that merchandises are produced and distributed in right quantities, to right locations, at right times, in order to minimize system-wide costs while satisfying service level requirements (Simchi-Levi et al., 2007). Inventory management is one of the important scopes in SCM, for which many academic communities presented various strategies.

In inventory management, the vendor managed inventory (VMI) approach is one of the most important and popular policies in retailer-supplier partnerships compared to other alternatives such as continuous replenishment (CR), quick response (QR), advanced continuous replenishment (ACR), consignment stock (CS) (Simchi-Levi et al., 2007; Wanke, 2012). The VMI approach, sometimes vendor-managed replenishment (VMR), is a strategy based on which a vendor controls inventory levels for both vendor and retailer using retailer's sales and inventory information to prevent an undesirable inventory. In other words, the vendor is permitted to manage the inventory at retail locations with respect to information sharing (Yao and Dresner, 2008). In addition, compared to traditional policies, VMI decreases inventory costs (see for example Yao et al., 2007 and Sari, 2007) and that its high service level coordination improves profitability for the whole supply chain (Heydari, 2014). Thus, reducing total inventory costs and improving customer service levels are the possible benefits of the VMI policy that has been implemented by many successful retailers such as Wal-Mart and Kmart (Simchi-Levi et al.,

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2007). The results obtained by Dong et al., 2007 surveying 137 firms showed that VMI was the most often employed strategy for the cooperative relationship between a vendor and a retailer. In addition, the SPC company consisting of more than 80 subsidiaries, one of the largest producer and supplier of petrochemical products in China, took advantages of VMI policy to reduce the cost of the system significantly (Zhao et al., 2010).

Elvander et al. (2007) presented a framework to evaluate establishing a VMI system. Afterwards, Sari (2007) elaborated the benefits of the VMI implementation under different SC scenarios such as different levels of outside supply capacity, demand uncertainty, and lead-time. Moreover, Disney et al. (2003) illustrated the transportation cost reduction in a supply chain using VMI policy. For a good review of the VMI implementation until 2010, interested readers are referred to Marquès et al. (2010).

1.1. VMI models

One of the key issues in modeling VMI is when and how many items to dispatch, which is similar to two well-known policies in inventory models called economic order quantity (EOQ) and economic production quantity (EPQ). While Pentico and Drake (2011) introduced a good review on the deterministic EOQ and EPQ models over the past 40 years, many VMI related research works are developed based on these two models. The next four subsections are devoted for a brief review on these works.

1.1.1. Vendor acting as a manufacturer

This case is similar to the EPQ policy in which a vendor (or supplier or manufacturer) produces items at a production rate and delivers them to retailers (or buyers). In a production environment, one of the first work is due to Goyal (1988) who modeled a one vendor-one buyer problem. Then, Goyal (1995) extended the model to include several buyers in which the average inventory was obtained ignoring the effect of the production rate. Next, Hill and Omar (2006) developed an integrated production-inventory model in which a vendor delivers a single item to a buyer.

Based on the consignment stock (CS) policy, Braglia and Zavanella (2003) extended an inventory model consisting of a single-vendor and single-buyer. CS considers stock legally owned by the supplier, but held by the retailer. In other words, ownership in CS is passed only when the stock is sold. Consequently, remaining stock may be returned to the vendor. Chan and Kingsman (2007) presented a single vendor-multiple buyer model for a two-echelon supply chain problem while production and delivery cycles were synchronized. Later, Zavanella and Zanoni (2009) modeled an integrated production-inventory problem with a single vendor and multiple buyers based on the CS approach. Under a cooperative game setting, Chen et al. (2010) studied a profit-maximization problem in a two-echelon SCM modeled by a Stackelberg game between the decision-makers at the distribution centers that use VMI and the consignment contractual arrangements. Das et al. (2014) optimized an integrated production model using a heuristic to find the optimal transportation and business cycles. Lee and Fu (2014) developed a production model for a producer–buyer supply chain problem with delivery cost fitted as a power function to reduce operating cost in practice.

1.1.2. Vendor acting as a supplier

Instead of producing items, in this case, a vendor orders products from outside suppliers to replenish retailers such that the VMI strategy can be modeled based on the EOQ model (Dong and Xu, 2002). To name a few works in this category, Yao et al. (2007) modeled a VMI–SC problem based on the EOQ approach and showed decreases in the total system cost obtained by implementation of the VMI strategy. While a vendor used common carriage for outbound dispatches, Mutlu and Çetinkaya (2010) presented a heuristic to minimize the cost function including the dispatch cost, inventory holding cost, replenishment cost, and customer waiting cost. Besides, Darwish and Odah (2010) proposed a single vendor-multiple retailer VMI problem in which the vendor would impose a penalty cost if number of items exceeded definite bounds. They presented an algorithm with a significant reduction in computational efforts to provide the optimal solution.

Considering quantity discount policies, Duan et al. (2010) investigated an inventory problem consisting of one vendor and one buyer in SC for a fixed lifetime product. Afterwards, Yu et al. (2012) considered perishable goods or spoilable products and raw materials in a VMI model. They presented a search algorithm to solve the problem. Moreover, Yu et al. (2011) took advantage of mixing a GA and Newton–Raphson method to optimize a VMI problem in which a vendor replenishes retailers with a deteriorating product. In addition, Yu et al. (2013) extended the VMI model of Yu et al. (2011) for a retailer selection problem and combined a GA with a dynamic programming algorithm to solve it.

Cárdenas-Barrón et al. (2012) improved the VMI model presented by Pasandideh et al. (2011). They used an available inventory to formulate the problem and presented a better heuristic for solution. However, they did not consider the replenishment frequency; one of the main factors of the VMI strategy. Consequently, Sadeghi et al. (2011) proposed an integer non-linear programming (INLP) model that took into account the replenishment frequency and proposed a parameter-tuned genetic algorithm (GA) to solve it. Besides, Sadeghi et al. (2013) presented a model for a multiple vendor-multiple retailer single-warehouse (MV-MR-SW) SC in a VMI framework and used an improved PSO to solve it.

1.1.3. Transportation cost in VMI strategy

Transportation cost is one of the factors that has not been considered in many VMI systems. The works that take into account the transportation cost in the VMI literature are due to Yu et al. (2011) and Kiesmüller and Broekmeulen (2010).