Knowledge-Based Systems 50 (2013) 159–170

Contents lists available at SciVerse ScienceDirect

Knowledge-Based Systems

journal homepage: www.elsevier.com/locate/knosys

Optimizing a multi-vendor multi-retailer vendor managed inventory problem: Two tuned meta-heuristic algorithms

Javad Sadeghi [a], Seyed Mohsen Mousavi [b], Seyed Taghi Akhavan Niaki [c,*], Saeid Sadeghi [d]

[a] Young Researchers and Elite Club, Islamic Azad University, Qazvin Branch, Qazvin, Iran
[b] Faculty of Industrial and Mechanical Engineering, Islamic Azad University, Qazvin Branch, Qazvin, Iran
[c] Department of Industrial Engineering, Sharif University of Technology, Tehran, Iran
[d] Faculty of Industrial Engineering, Islamic Azad University, South Tehran Branch, Tehran, Iran

ARTICLE INFO

Article history:
Received 27 August 2012
Received in revised form 5 June 2013
Accepted 13 June 2013
Available online 25 June 2013

Keywords:
Multi-vendor
Multi-retailer
Vendor managed inventory model
Meta-heuristic
Taguchi method

ABSTRACT

The vendor-managed inventory (VMI) is a common policy in supply chain management (SCM) to reduce bullwhip effects. Although different applications of VMI have been proposed in the literature, the multi-vendor multi-retailer single-warehouse (MV-MR-SW) case has not been investigated yet. This paper develops a constrained MV-MR-SW supply chain, in which both the space and the annual number of orders of the central warehouse are limited. The goal is to find the order quantities along with the number of shipments received by retailers and vendors such that the total inventory cost of the chain is minimized. Since the problem is formulated into an integer nonlinear programming model, the meta-heuristic algorithm of particle swarm optimization (PSO) is presented to find an approximate optimum solution of the problem. In the proposed PSO algorithm, a genetic algorithm (GA) with an improved operator, namely the boundary operator, is employed as a local searcher to turn it to a hybrid PSO. In addition, since no benchmark is available in the literature, the GA with the boundary operator is proposed as well to solve the problem and to verify the solution. After employing the Taguchi method to calibrate the parameters of both algorithms, their performances in solving some test problems are compared in terms of the solution quality.

1. Introduction

In today's global markets, supply chain management (SCM) plays an important role to integrate different parts of organizations and companies in order to achieve better performances. SCM is a set of approaches used to efficiently integrate suppliers, manufactures, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and the right time, in order to minimize system-wide costs while satisfying service level requirements [44].

Inventory is one of the key factors in SCM. In a supply chain, undesirable or fluctuating inventory, referred to the bullwhip effect, may even make companies to go near bankruptcy [9,44]. Although there are several strategies in retailer–supplier partnerships such as quick response, continuous partnerships, and advanced continuous replenishments, the vendor-managed inventory (VMI) policy has shown to have the best performances in many companies [8,44]. VMI is a strategy based on which suppliers (or vendors) manage buyers' (or retailers') inventory level such that the chain total inventory cost is minimized.

Information technology is required in VMI to share retailers' sales and inventory information with vendors. The obtained information is used to schedule deliveries, program production, and determine the amount of the orders and inventory levels such that total inventory cost is minimized. The possible benefits of the VMI models include reduction of inventory costs for the supplier and the retailer and improvement of customers' service levels [1]. Wal-Mart, Kmart, and JC-Penny are just a few examples of successful companies that took advantage of the VMI policy [43].

Although the classical economic order quantity (EOQ) and economic production quantity (EPQ) [2,48] due to their simple and easy to understand natures have been the most employed inventory model in VMI implementation, some researchers extended them in order to bring the models closer to reality based on real-world constraints. While there are several constraints in an inventory system, in this research, the number of orders and the warehouse capacity in a multi-vendor multi-retailer VMI problem are assumed limited. In other words, a supply chain problem consisting of several vendors and several retailers with a single constrained-capacity central warehouse is investigated in which the number of orders is limited. The objective is to determine the order quantity and number of shipments received by retailers

* Corresponding author. Tel.: +98 21 66165740; fax: +98 21 66022792.
E-mail addresses: sadeqi@qiau.ac.ir (J. Sadeghi), mousavi.mohsen8@gmail.com (S.M. Mousavi), niaki@Sharif.edu (S.T.A. Niaki), saeed.sadeghi.85@gmail.com (S. Sadeghi).

0950-7051/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.knosys.2013.06.006

and vendors in a cycle so as the total inventory cost of the chain is minimized. Since the proposed model of the problem is shown to be of an integer nonlinear programming (INLP) type and is difficult to be solved by exact methods, a particle swarm optimization (PSO) is presented for an approximate optimum solution. Moreover, a genetic algorithm (GA) is employed as well to evaluate and verify the solution. In order to have better solutions, the parameters of both algorithms are tuned by the Taguchi method. Furthermore, in order to improve the performances of the employed meta-heuristics, a new operator, namely the boundary operator, is added to the GA; while the improved GA is employed as a local searcher for the PSO called the hybrid PSO.

The structure of the rest of the paper is organized as follows. The next section illustrates the application, the motivation, and the contribution of the paper. A review of the literatures and the notations used to model the problem are presented in Sections 3 and 4, respectively. The problem along with its assumptions is introduced in Section 5. The mathematical model of the problem is developed in Section 6 and the solution methodologies are described in Section 7. Subsequently, the Taguchi method is employed in Section 8 to calibrate the parameters of the solution methods. The performances of the meta-heuristic algorithms and their improvements are compared in Section 9 using some illustrative examples. Finally, conclusions and recommendations for future research are given in the last section.

2. Motivation and contribution

VMI is a common practice in production–distribution systems to both reduce bullwhip effects and to decrease costs. There are many successful companies such as JC-Penny and Wal-Mart that took advantage of VMI [43]. The retailer–supplier partnerships in the VMI can be classified into three classes of namely single-vendor single-retailer, single-vendor multi-retailer, and multi-vendor multi-retailer. Although different applications of VMI have been proposed in the literature, the multi-vendor multi-retailer (MV-MR) case has not been investigated yet. Indeed, it is quite possible to have a production–distribution system with several vendors and retailers. An appliance factory is just an example where its agencies and customers are called vendor and the retailer, respectively. In these cases, although a shared central warehouse can be an important part of a VMI problem, most of the research works in VMI models have not considered it yet (see Table 1). Therefore, in this research, a multi-vendor multi-retailer single warehouse (MV-MR-SW) supply chain problem in VMI environment is investigated in order to reduce the bullwhip effect and to minimize the total cost of the supply chain.

To be more specific, the first contribution of this paper is to consider a constrained MV-MR VMI problem with a central warehouse. The second novelty of this paper is to improve the performances of two different parameter-tuned meta-heuristic algorithms, namely particle swarm optimization (PSO) and genetic algorithm (GA), with a new local searcher and a new operator, respectively. These algorithms are employed in order to find a near optimum solution of the complex problem.

3. Literature review

The vendor-managed inventory is a well-known strategy in supply-chain inventory management in which there is retailer–supplier partnerships. Determination of when and how much to replenish is the key issue in the VMI model. Marqu's et al. [32] provided a good survey of literature on VMI. Goyal [16] first developed an inventory model for a single-vendor single-buyer production inventory system, in which the vendor's lot size was an integer multiple of the purchaser's order size. He then extended his model for single-vendor multi-buyer, where the effect of production rate in computing average inventory was ignored [17]. Moreover, Lu [30] presented a heuristic approach to solve a single-vendor multiple-buyer integrated inventory problem. Whereas Goyal [16,17] and Lu [30] considered the inventory models in which the shipment sizes all are equal, Hill [20] demonstrated an optimal policy if shipment sizes vary. Later, Hill and Omar [21] extend the model to the case where shipments sizes may differ. Based on the 'consignment stock' (CS) case, Braglia and Zavanella [3] extended Hill's [20] model to be applicable in supply chains consisting of a single-vendor and a single-buyer. In the CS case, the retailer pays the vendor for each item he sells. CS is a stock legally owned by the vendor, but held by the retailer. In other words, ownership of CS is passed only when the stock is sold. As a result, remaining stocks may be returned to the vendor. Using the CS case, Zavanella and Zanoni [54] extended Braglia and Zavanella's model [3] for the case of one-vendor multi-buyer production–distribution system.

Dong and Xu [11] employed the EOQ policy in a VMI environment based on deterministic demand and lead-times. The benefits of using the VMI approach in transportation cost savings of a supply chain were demonstrated by Disney et al. [10]. Yao et al. [51] studied a VMI model for one supplier and one buyer using the EOQ policy. Darwish and Odah [6] considered a VMI model for one-vendor multi-retailer supply chain problem in which the vendor incurs a penalty cost for items exceeding definite bounds. They provided a heuristic algorithm to find the optimal solution that would reduce the computational efforts significantly. Duan et al. [26] presented an inventory model for a one-vendor one-buyer supply chain problem with a fixed lifetime product in which the quantity discount policy was applied. Zammori et al. [53] defined a standard structure of a VMI agreement that can guide personnel involved in the initial definition of the agreement.

Pasandideh et al. [37] considered a supply chain, in which one supplier manages retailer's inventory for multi products. In this

Table 1
Some studies on vendor managed inventory problems.

Study	R	V	W	R F	S M	T P	Policy	Constraint
Goyal [15]	Single	Single	No	Yes	Heuristic	No	EOQ	No
Lu [29]	Multi	Single	No	Yes	Heuristic	No	EPQ	No
Hill [19]	Single	Single	No	Yes	Heuristic	No	EPQ	No
Yao et al. [50]	Single	Single	No	Yes	Optimal solution	No	EOQ	No
Zavanella and Zanoni [53]	Multi	Single	No	Yes	Optimal solution	No	EPQ	No
Darwish and Odah [6]	Multi	Single	No	Yes	Heuristic	No	EOQ	Over-stock penalty
Pasandideh et al. [36]	Single	Single	No	No	GA	No	EOQ	Storage, number of order
Sadeghi et al. [39]	Single	Single	No	Yes	GA	RSM	EOQ	Storage, number of order, budget, available inventory
Nachiappan and Jawahar [33]	Multi	Single	No	Yes	GA	No	EOQ	Storage, sales quantity
Sue-Ann et al. [45]	Multi	Single	No	Yes	GA, PSO, GA-AIS	No	EOQ	Storage, sales quantity
Proposed Model	Multi	Multi	Yes	Yes	Proposed GA, hybrid PSO	Taguchi	EOQ	Storage, number of order

R = retailer; V = vendor; W = warehouse; R F = replenishment frequency; S M = solution algorithm; T P = tuning parameters.