Computers & Industrial Engineering 85 (2015) 33–43

Contents lists available at ScienceDirect

Computers & Industrial Engineering

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

A heuristic to solve the dynamic lot sizing problem with supplier selection and quantity discounts ☆

Mohammad Mahdavi Mazdeh [a,*], Mohsen Emadikhiav [b], Iman Parsa [a]

[a] Department of Industrial Engineering, Iran University of Science and Technology (IUST), Tehran, Iran
[b] Department of Management and Engineering, Linköping University, Linköping, Sweden

ARTICLE INFO

Article history:
Received 21 December 2012
Received in revised form 24 February 2015
Accepted 25 February 2015
Available online 12 March 2015

Keywords:
Lot sizing
Supplier selection
Inventory planning
Quantity discounts
Supply chain

ABSTRACT

In the present study, the single-item dynamic lot sizing problem with supplier selection is investigated. The problem is broken down into two different cases. In the first case, quantity discounts are not taken into account; in the second case, incremental and all-unit quantity discounts are considered. Due to the complexity of the problems, a new heuristic is developed, which is based on the Fordyce–Webster Algorithm (Fordyce and Webster, 1984). In order to solve the problem where multiple suppliers are considered, a third dimension is added to the matrices used in the Fordyce–Webster Algorithm. The solutions gained using the proposed algorithm are similar to those of Parsa, Khiav, Mazdeh, and Mehrani (2013) in terms of accuracy and computational time. However, the implementation of matrices makes this method easy to explain in comparison with other heuristics developed for similar problems.

1. Introduction

Of the various activities involved in supply chain management, purchasing is one of the most strategic because it provides opportunities to reduce costs and consequently increases profits (Mendoza & Ventura, 2010). Therefore, the problems of lot sizing and supplier selection, each having a grave impact on the supply chain, have attracted many researchers for many years. The main purpose is to determine which suppliers to procure from, the periods in which orders have to be placed, and to determine the lot sizes in order to meet the demands while minimizing the total cost.

In terms of lot sizing, on the one hand, the well-known Economic Order Quantity model (EOQ) and the Economic Lot Scheduling Problem (ELSP) are utilized for the infinite time horizon, continuous time scale and constant demand lot sizing problems. On the other hand, the form of planning generally known as dynamic lot sizing (DLS) is used for the finite time horizon, discrete time scale and dynamic demand lot sizing models. The DLS model is the subject of this paper. The paper presented by Glock, Grosse, and Ries (2014) reviews the literature in the area of lot sizing.

The dynamic inventory lot sizing problem was introduced by Wagner and Whitin (1958), considering only one item. They proposed a dynamic programming algorithm to gain optimal solutions to the problem. Fordyce and Webster (1984) presented a heuristic to solve the problem using suitably defined matrices to obtain the optimal cost and production or ordering sequence for different periods. The Fordyce–Webster Algorithm (FWA) also works when quantity discounts are considered. In this case, the solution obtained may be non-optimal. Furthermore, the matrices used in this algorithm make it much easier to explain than any other heuristic (Sumichrast, 1986).

Supplier selection is considered a very important issue in lot sizing problems because of the probable differences between the purchasing costs that may result from choosing different suppliers in each period. In addition, practitioners often face multiple suppliers and quantity discounts. When quantity discounts are considered and the order made by the buyer is large, the supplier reduces the unit purchase price according to a specified schedule. Suppliers often offers a number of price breaks, according to which the unit purchase price decreases as the order quantity increases (Lee, Kang, Lai, & Hong, 2013).

In this paper, the single-item dynamic lot sizing problem with supplier selection is considered, in which shortages are not allowed. This is the same problem considered in Parsa, Khiav, Mazdeh, and Mehrani (2013). Two different problems are discussed. In the first problem, named Problem A, quantity discounts

☆ This manuscript was processed by Area Editor Christoph H. Glock.

* Corresponding author. Tel.: +98 912 350 68 63.
E-mail addresses: mazdeh@iust.ac.ir (M.M. Mazdeh), mohsenemadi1989@yahoo.com (M. Emadikhiav), iman.prs@gmail.com (I. Parsa).

http://dx.doi.org/10.1016/j.cie.2015.02.027
0360-8352/

are not considered, while in Problem B, incremental and all-unit quantity discounts are taken into account. In this case, in which suppliers are free to choose their discount schemes, a mathematical model is formulated which is based on the model presented in Parsa et al. (2013). The complexity of this lot sizing problem has been studied in the literature. Lee et al. (2013) and Florian, Lenstra, and Kan (1980) claimed that this kind of problem is basically NP-hard. Therefore, a heuristic is provided to solve such a complicated problem, in which a third dimension is added to the Fordyce–Webster algorithm that is used to solve the supplier selection problem. In order to evaluate the accuracy of the proposed algorithm, a backward dynamic programming method is used to find the exact solutions. Results show that the accuracy and the speed of the algorithm are averagely high, like those of Parsa et al. (2013). However, the algorithm proposed in this paper is simpler and easier to be understood and explained.

This paper is organized as follows: Section 2 provides a literature review on the subject. In Section 3, the problem is described in detail. The mathematical model is presented in Section 4, and the proposed method is explained in Section 5. This explanation is followed by a numerical example in Section 6. The computational results are presented in Section 7. Finally, in Section 8, the conclusion of the paper is presented.

2. Literature review

The lot sizing problem can be divided into different groups according to the product levels and the resource constraints (Bahl, Ritzman, & Gupta, 1987). The present work in particular addresses the single-item dynamic lot sizing problem with unconstrained resources. This problem was first introduced by Wagner and Whitin (1958) proposing a dynamic programming algorithm. Despite providing an optimal solution, the Wagner–Whitin Algorithm (WWA) is considered to require a high computational effort. Consequently, researchers have attempted to overcome this burden by various methods; such as the heuristic provided in Silver and Meal (1973). Some researchers have tried to enhance the performance of the Wagner–Within model itself (Evans, 1985; Jacobs & Khumawala, 1987; Saydam & McKnew, 1987; Heady & Zhu, 1994). The main purpose of these attempts is to reduce the computational resource needed by establishing efficient data structures and control rules in order to scale down the search scope (Parsa et al., 2013). Wagelmans, van Hoesel, and Kolen (1992) investigated the worst-case performance of WWA and its variants. Lyu and Lee (2001) presented a parallel algorithm to solve the dynamic lot sizing problem efficiently.

The lot sizing problem has also been studied widely in terms of supplier selection during the last several decades. The main goal of the lot sizing problem with supplier selection is to decide which supplier(s) should be selected and how much should be ordered from the selected supplier(s) (Weber & Current, 1993). Aissaoui, Haouari, and Hassini (2007) presented a review paper of the supplier selection problem where inventory is also considered for different cases. Basnet and Leung (2005) solved the multi-item lot sizing problem with supplier selection using an enumerative search algorithm and a heuristic. Glock (2012) considered the single-item problem, where a single buyer needs to decide whether to meet its demands by buying the product from one or two suppliers. Moqri, Moshref Javadi, and Yazdian (2011) presented a dynamic programming approach for the single-item lot sizing problem with supplier selection. Ustun and Demirtas (2008) presented a paper considering supplier selection and lot sizing using the Analytical Network Process and Goal Programming. Rezaei and Davoodi (2011) developed two multi-objective mixed-integer non-linear models for lot sizing problems involving multiple products and multiple suppliers and applied a genetic algorithm to solve the models.

It is common to consider multiple suppliers and quantity discounts in lot sizing problems. In the case of quantity discounts, when the buyer places a large order, the supplier reduces the unit purchase price according to a schedule specified in advance. The literature on the lot sizing problem under different quantity discount schemes was reviewed by Benton and Park (1996) and a classification of the literature was provided. Lee et al. (2013) presented a mixed-integer programming approach and a genetic algorithm to solve the lot sizing problem with multiple suppliers, multiple periods and quantity discounts. Ebrahim, Razmi, and Haleh (2009) introduced a mathematical model for a single-item lot sizing problem with supplier selection which considered different types of discounts and capacity restrictions, and proposed a scatter search algorithm to solve the problem. Tempelmeier (2002) considered a single-item lot sizing problem and introduced a model formulation with discount rate, supplier-specific delivery periods and lead times along with a heuristic method for this problem. Parsa et al. (2013) solved the single-item lot sizing problem with quantity discounts with multiple suppliers using a heuristic dynamic programming method derived from the one presented by Moqri et al. (2011).

The problem considered in this paper is the single-item dynamic lot sizing problem with multiple suppliers and quantity discounts, which is the same as the problem addressed in Parsa et al. (2013). Then a new tabular approach is implemented to solve the problem. The proposed heuristic solves the problem in low computational times and solutions gained are of a good accuracy, on average. As mentioned in this section, there are a few papers which have addressed the lot sizing problem with supplier selection and quantity discounts. In comparison to the paper of Tempelmeier (2002), which makes similar assumptions, this study gives the suppliers the freedom to choose their discount policies. However, Tempelmeier (2002) considers supplier-specific delivery periods and lead times which are not included in this paper. Moreover, in terms of accuracy, this algorithm provides the same results as the dynamic programming algorithm presented by Parsa et al. (2013), since both algorithms eliminate same parts of the search space by implementing the same lemmas and theorems, which are presented in Section 5. In addition, the matrices used in different steps of this method make it much easier to explain and understand the method in comparison to the algorithms of Tempelmeier (2002) and Parsa et al. (2013).

3. Problem description

Consider Fig. 1 (Moqri et al., 2011), which illustrates a scenario where a company can purchase its required product from different suppliers. Each supplier has a different unit price with a different discount scheme for the product; in addition, each has a different fixed ordering cost which may vary from period to period. Each supplier may use one of the two possible discount schemes, incremental and all-unit, or may offer unit purchase prices without any

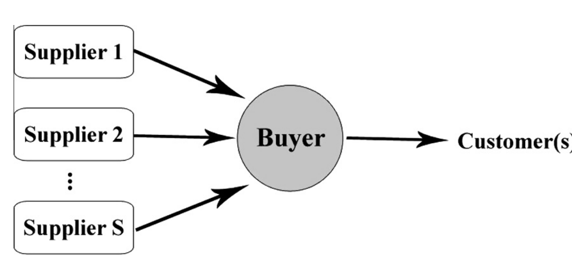

Fig. 1. The supply chain under consideration.