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A multi-objective quantity discount and joint optimization model for coordination of a single-buyer multi-vendor supply chain

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ABSTRACT

Supply chain management is concerned with the coordination of different parts of the production system. Companies have realized that they must closely collaborate with the suppliers of their strategic components or products. Recently, developing integrated inventory models for the supplier selection problem has attracted a significant amount of attention amongst researchers. In these models some incentives are required from the vendors to motivate the buyer to change his (her) policies to the policy which is optimal for the entire system. Quantity discount policies are used as common incentives in the literature. However, the literature on this problem does not incorporate quantity discount into the coordination model. This paper develops a multi-objective mixed integer nonlinear programming model to coordinate the system of a single buyer and multiple vendors under an all-unit quantity discount policy for the vendors. Due to the complexity of the problem two well known meta-heuristic algorithms are proposed to solve the problem. An illustrative example is given to show the behavior of the model. Results obtained from solving the sample problems show good performance of the proposed algorithms in finding the optimal solutions.

1. Introduction

In the last few years the procurement function has become more critical for companies because of the increase in the level of outsourcing. Companies have realized that to remain in control of their destiny they must focus on closely collaborating with the suppliers of their strategic components or products. In these cases effective strategies are required to coordinate the supply chain. There are many academic and industrial researchers who have contributed to the joint optimization of buyer(s) and supplier(s). They have strived to improve the overall performance of the supply chain by considering the benefits of both parts of the supply chain. Recently the topic of one buyer and multiple suppliers has attracted significant attention among the researchers. In this topic the buyer should consider the benefits of the suppliers in the process of supplier selection and allocates his (her) orders among the suppliers.

By optimizing the whole supply chain, the buyer's total cost increases when compared with independent optimization. In order to overcome this problem, encouraging policies such as discounts and revenue sharing can be used. Quantity discount usually is used as a coordination mechanism to reduce the total system costs or maximize the total system profits. This policy encourages the buyer to order larger quantities and applies a mechanism that leads to a balance between the discounts

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obtained due to larger purchasing quantities and inventory holding costs. Furthermore it has been shown that when a typical discount policy is used, both the buyer and the supplier can realize higher overall profits [1].

In the supply chain different members have different conflicting objectives. Various criteria have been proposed for evaluating the suppliers [2,3]. Some of these criteria such as price/cost, quality and delivery performances are quantitative and some others such as flexibility, background of relationship and reputation are qualitative. Furthermore, some criteria may conflict with each other, such as cost and quality or quality and on time delivery. Hence, it is necessary to make a tradeoff between conflicting quantitative and qualitative criteria to find the best suppliers.

This paper proposes a multi-objective supplier selection and order allocation model that tries to optimize the overall performance of a one-buyer and multiple-supplier supply chain by minimizing the total system cost including buyer's annual cost and vendors' annual cost, the total number of defective items and the total number of late delivered items. Furthermore, to incorporate the qualitative criteria in the model, maximizing the total purchasing value is also considered as another objective. In this model while the vendors benefit from the coordination by joint optimization, quantity discounts offered by the suppliers can guarantee that a buyer's total relevant cost of coordination will not increase when compared with independent optimization.

The remainder of the paper is organized as follows. Section 2 reviews some previous studies and researches. Section 3 states the problem specifications and presents a mathematical model. Section 4 discusses the procedures to solve the problem. In Section 5, a numerical example is presented to show the behavior of the model. In Section 6, the performance of the proposed algorithms is evaluated by solving some sample problems. Finally Section 7 is devoted to the conclusions achieved from this research.

2. Literature review

Corresponding to the topic of this paper there are two main research streams: buyer–vendor coordination models and the supplier selection problem. Excellent reviews on buyer–vendor coordination models can be found in Goyal and Gupta [4], and Ben-Daya et al. [5]. Furthermore Weber et al. [6], Aissaoui et al. [7], and Ho et al. [8] provided literature reviews on the supplier selection problem. In this paper we discuss the works that are important to our problem.

2.1. Buyer–vendor coordination models

Goyal [9] was one of the first researchers who contributed towards the buyer–vendor coordination models. He considered a system of a single buyer and a single vendor under the assumption of infinite production rate for the vendor and lot-for-lot policy for the shipments from the vendor to the buyer. Banerjee [10] studied the finite production rate for the vendor while retaining the lot-for-lot policy. Thus in his problem the vendor is assumed to be a manufacturer who produces to order for the buyer. Goyal [11] further generalized the problem by relaxing the lot-for-lot policy. He studied the problem wherein the production lot is shipped from the vendor to the buyer in a number of equal-sized shipments. The problem is further extended by considering more complex shipment policies between vendor and buyer. For example Goyal and Nebebe [12] discussed a shipment policy in which a small shipment is followed by a number of larger and equal-sized shipments.

Some researchers have studied the multiple buyer case. Joglekar and Tharthare [13] studied a system in which a vendor supplies a product to a group of identical buyers. Banerjee and Burton [14] generalized the model by considering a delivery cycle that must be followed by all the buyers to coordinate the supply chain. Chan et al. [15] proposed a delayed payment method for coordinating a single-vendor multi-buyer supply chain. Krichen et al. [16] extended the model of Chan et al. [15] by incorporating the quantity discount policy in the modeling of the problem. Sinha and Sarmah [17] also investigated the impact of stochastic demand and discount pricing scheme on the single-vendor multi-buyer integrated inventory model.

2.2. Supplier selection

Many researches have been paid attention to the supplier selection problem in recent years. Among them we will only review the quantitative models that closely concern the problem studied in this paper. These models mainly strive to answer the questions of which vendors to select and how to allocate the order quantity to the selected suppliers.

Goossens et al. [18] studied the problem of buying multiple items from a set of available suppliers where the suppliers offer all-unit quantity discount and try to minimize the total cost of purchasing. Burk et al. [19] assumed that the suppliers have capacity limitations and studied the impact of supplier pricing schemes on the optimal policy for the buyer. They showed that the problem is NP-hard and no polynomial-time approximation algorithm exists for it. Benton [20] discussed a situation where the buyer has a limited budget and storage space for ten items offered by three suppliers. The buyer must choose one supplier for all items by minimizing the total acquisition and inventory costs. In order to consider both qualitative and quantitative factors in the process of supplier selection and order allocation, Ghodsypour and O'Brien [21] developed an integrated AHP and linear programming model. They used the AHP method to calculate the overall score or weight of each supplier and incorporate these scores in a linear model. A weighted additive fuzzy multi-objective model for the supplier selection problem under all-unit price discounts was proposed by Amid et al. [22] where some input information is not known precisely and three objectives are considered. Dahel [23] discussed the problem in which a buyer wants to