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Scatter search algorithm for supplier selection and order lot sizing under multiple price discount environment

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ABSTRACT

Supplier selection is one the most important elements of supply chain management. This function involves evaluation of many factors such as, cost of parts/materials, size of order, quality, and delivery performance. Therefore, this problem is categorized as multi-criteria decision making problems. Different approaches have been applied in order to assess and select the suppliers when suppliers offer discount on the unit price. In practical conditions, buyers may face a situation where different types of discount may be offered by candidate suppliers. None of the previous studies have considered different discount schemes simultaneously. In this article a mathematical model is introduced which consider different types of discount (all-unit cost, incremental discount, and total business volume discount) through multi-objective formulation for single item purchasing problem. In addition, constraints such as suppliers' capacity and demand are taken into consideration in the model. Due to the complexity of the problem a proposed scatter search algorithm (SSA) is presented to solve this problem. Finally several sample problems have been solved by the proposed SSA and the exact (branch and bound) method. The results illustrate slight relative errors to compare with reasonable saving in computational times.

1. Introduction

Supplier selection is one the most important components of production and logistics management in the competitive environment of the global market. As organizations become more dependent on their suppliers the direct and indirect consequences of poor decisions become more severe [4]. Such decisions involve the selection of individual suppliers to employ and the determination of order quantities to be placed with the selected suppliers. Practitioners need to follow strategies to achieve higher quality, reduced costs and shorter lead times to be able to compete in the global market. Within new strategies for purchasing and manufacturing, suppliers play a key role in achieving corporate competition [1,9,27].

Many attributes affect a supplier's performance. Dickson [8] identified 23 criteria that have been considered by purchasing managers in various supplier selection problems. Also Weber et al. [26] found that 47 out of 76 articles which they reviewed, addressed more than one criterion for supplier selection decision making. Hence supplier selection problem is a multiple criteria decision making (MCDM) problem and it is necessary to make a trade off between conflicting quantitative and qualitative criteria to select the best suppliers.

Suppliers sometimes offer discounts. The motivation for using discount schemes stems from the fact that it tends to encourage buyers to procure larger quantities and to obtain operating advantages (such as economies of scale or reducing the cost of transportation) for the buyer. From a coordination perspective, it has been shown that both the buyer and the supplier can realize higher overall profits if discounting schemes are used to set transfer prices [25]. Various kinds of discount schemes which are usually offered by suppliers are discussed in relevant studies. So, the multi-objective supplier selection problem in presence of discount schemes becomes more complicated. Usually, two types of discounts—all-units discount and incremental discount—are used for cost reduction [3]. All-units model divides the range of possible order quantities into intervals with progressively lower unit costs. The unit cost corresponding to the size of a particular order is applied to every unit in the order. Dolan [10] and others argue, however, that the supplier is often better served by the incremental discount model, which applies a lower unit price only to those units purchased in excess of each successive breakpoint [21]. Finally total business volume discount model, described by Xia and Wu [28], is usually used when more than one item is to be purchased.

In this paper we propose a mathematical model for a single item purchasing problem considering various discount schemes simultaneously. Considering both qualitative and quantitative

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criteria in this model and in addition, permitting various types of discount schemes by suppliers, make this model more practical in comparison with other previous studies.

The remainder of this paper is organized as follows. In Section 2, some previous studies and researches on supplier selection problem in presence of discount offers are reviewed. In Section 3, the developed model of supplier selection problem when suppliers may offer various discount models is presented. In this model qualitative criteria are considered as well as quantitative criteria. In Section 4, the complexity of the problem is discussed and then a scatter search algorithm is proposed and in Section 5 the described problem and the impacts of varying situations on both formulation and optimum results are analyzed through some examples. In Section 6 the performance of the proposed SSA is evaluated by solving some sample problems. Finally in Section 7, conclusions achieved from this research are discussed.

2. Literature review

Relevant studies in the literature of the subject have been divided into two major categories. First category of studies includes the papers which consider just one criterion, usually the cost of the procurement for supplier selection problem while suppliers offer discounts on the quantity of materials being purchased.

Goossens et al. [13] discussed the procurement problem of buying multiple items from a set of suppliers considering just the minimization of purchasing cost function so other affecting criteria are not included in their linear mathematical model. In their study authors assume that all suppliers offer just all-unit discount scheme. They argue that not only this problem is NP-hard but also there exists no polynomial-time approximation algorithm with a constant ratio. Burke et al. [5] analyze the impact of supplier pricing schemes and supplier capacity limitations on the optimal sourcing policy for a single buyer. They consider the situation where the total quantity to be procured for a single period is known by the firm and communicated to all suppliers. Each supplier quotes a price and capacity limit as a maximum quantity that can supply to the buyer. According to this information, the buyer makes a decision for quantity allocation among the suppliers and consequently a subset of suppliers is selected for order allocation. A variety of supplier pricing schemes from the constituent group of suppliers is analyzed. Kothari et al. [14] describe procurement auction with marginal decreasing piece wise-constant supply curves. All-unit discount is allowed by this auction. They present fully polynomial-time approximation schemes for the winner determination problem and the computation of the corresponding payments of this auction. Benton [2] uses Lagrangian relaxation to evaluate a purchasing manager's resource constrained order quantity decisions given alternative pricing schedules from multiple suppliers. The author assumes that the decision maker has a limited budget and storage space for ten items offered by three suppliers, each quoting three all-units discount intervals for each item. The objective is to minimize total acquisition and inventory costs. The manager must choose a single supplier for all items. Crama et al. [6] describe the purchasing decisions faced by a multi-plant company. The suppliers of this company offer discount schedules based on the total quantity of materials purchased. The schedules simultaneously account both for corporate purchases and for purchases at the individual plant level. The complexity of the purchasing decisions is further increased due to the existence of alternative production recipes for each final product. They formulate the corresponding cost-minimization problem as a non-linear mixed 0–1 programming problem. The above articles study the purchasing problem under only one discount offer by the suppliers. In addition, their models consider just one objective (usually purchasing cost) which cannot be applied for the real cases.

Considering the importance of criteria such as quality of products and services provided by suppliers and also direct and indirect impact of suppliers' performance on organizations' performance, persuade organizations to consider other affective criteria in suppliers' evaluation as well as cost. So the second category of papers discussing supplier selection under discount environment declares that supplier selection problem is a multi-objective decision making problem.

Rosenthal et al. [20] developed a mixed integer programming model for supplier selection with bundling, in which a buyer needs to buy various items from several vendors with limited capacity and also with different quality and delivery performances which offer bundled products at discounted prices. They applied single objective programming in their model. Ghodsypour and O'Brien [11] proposed an integrated AHP and linear programming model to help managers consider both qualitative and quantitative factors in their purchasing activity in a systematic approach. In their model, price of the product has been offered in a discount scheme and buyer's limitations on budget, quality, and service have been taken into account.

Amid et al. [1] consider a weighted additive fuzzy multi-objective model for the supplier selection problem under all-unit price discounts. They formulate the problem in such a way as to simultaneously consider the imprecision of information and determine the order quantities to each supplier based on price breaks. The problem includes the three objective functions: minimizing the cost, minimizing the rejected items and late deliveries, while satisfying capacity and demand requirement constraints. They argue, in practice, for supplier selection problems, most of the input information is not known precisely, so they use the fuzzy optimization theory to deal with this vagueness. A fuzzy weighted additive and mixed integer linear programming is developed.

Dahel [7] presents a multi-objective mixed integer programming approach to simultaneously determine the number of suppliers to employ and the order quantities to allocate to these suppliers in a multi-product, multi-supplier competitive sourcing environment. The objectives to be optimized are: cost, delivery and quality subject to the capacity constraints of suppliers. In their selection problem the discount on the total business volume is considered. Similar to the study of Dahel [7], Xia and Wu [28] discuss the multi-objective supplier selection problem under total business volume discount environment. They propose an integrated approach of analytical hierarchy process improved by rough sets theory and multi-objective mixed integer programming to simultaneously determine the number of suppliers to employ and the order quantity allocated to these suppliers while purchasing multiple products from a set of suppliers with multiple criteria. In this study, they assume that suppliers offer price discount on total business volume. The above papers consider multiple objective problems; however, their model cannot deal with multiple discount schemes simultaneously.

It is obvious that in practical situation buyers face with multiple sourcing in which suppliers may offer different price discount schemes. As it has been described above, there is need to develop a model to consider various discount schemes simultaneously. In this paper we intend to develop a mathematical model to consider three discount schemes (all-unit discount, incremental discount and total business volume discount) and some affecting factors in a multi-objective, single-item supplier selection problem.

3. Description of the proposed model

Various criteria are proposed for evaluation of suppliers. Dickson [8] identified 23 criteria that have been considered by purchasing managers in various supplier selection problems. Tracy [24]