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Supplier selection and order allocation problem using a two-phase fuzzy multi-objective linear programming

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ABSTRACT

The aim of this paper is to solve a supplier selection problem under multi-price level and multi-product using interactive two-phase fuzzy multi-objective linear programming (FMOLP) model. The proposed model attempts to simultaneously minimize total purchasing and ordering costs, a number of defective units, and late delivered units ordered from suppliers. The piecewise linear membership functions are applied to represent the decision maker's fuzzy goals for the supplier selection and order allocation problem, and can be resulted in more flexibility via an interactive decision-making process. To demonstrate effectiveness of the proposed model, results of applying the proposed model are shown by a numerical example. The analytical results show that the proposed approach is effective in uncertain environments and provide a reliable decision tool for integrated multi-objective supplier selection problems.

1. Introduction

In today's competitiveness world, most organizations attempt to meet demand, increase quality, and decrease cost. In most industries, the cost of raw materials and component parts forms the major part of production cost, e.g. up to 70% [1]. According to Weber et al. [2], the raw material cost may increase to 80% of total cost in hi-tech production environment. Generally, the costs of raw materials and components comprise the main quota of the final cost of a product. Selecting a proper supplier can significantly reduce purchasing costs, decrease production lead time, increase customer satisfaction, and strengthen corporate competitiveness [3].

In the supply chain scope, organizations should select the most appropriate suppliers for considerable products based on production capacity of available suppliers during the planning horizon. In a value chain, suppliers have a potential capability to increase customers' satisfaction. Hence, the supplier selection problem (SSP) is one of critical activity of the purchasing department in an organization and it can intensively affect other processes within organization. In this problem, the number and type of supplier, and the order quantities allocated to these suppliers should simultaneously be determined. Indeed, selection of suppliers and allocation of orders' quantity to each selected supplier are strategic purchasing decisions [4].

Regarding how many suppliers can be considered to supply the required materials, the supplier selection problem can be categorized into two types as follows [5]:

- Selecting the best supplier from the pool of available suppliers that can satisfy all buyer's requirements such as demand, quality, and delivery, etc. (single sourcing).

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- Selecting two or more suppliers to meet demands as none of suppliers can individually meet all buyers' requirements (multiple sourcing). In such situation, we face order allocation problem where the best suppliers should be selected and the optimal order quantities should be assigned to each of them.

Deciding on the order allocation is a strategic purchasing decision that will impact the firm's relationship with suppliers [4]. In multiple sourcing, the buyer has an opportunity to receive lower prices and shipping costs from a multiple-sourcing strategy [6]. Selecting suppliers provide the lowest price in a given industry is a challenge for purchasing managers, specifically when suppliers offer multiple products and volume-based discount pricing schedules [7]. In such case, the supplier offers discounts on the total quantity of sales volume in a given period of time. In general, purchasing multiple items from a supplier [8] and quantity discounts [9] represent a standard business practice.

Since different criteria can be considered during the decision making process for Supplier selection decision, this problem is a more complex in presence of volume discounts and multiple items. These criteria include qualitative and quantitative factors. Therefore, this problem is important for purchasing managers and they should determine the trade-off among the several factors. Improper selection of suppliers may unfavorably affect the company's competiveness strategy. Thus, this problem is naturally a multi-objective decision-making problem with several conflicting factors such as cost, quality, and delivery. Mathematical programming techniques can be applied to determine the optimal solutions of this problem where the criteria are formulated as the objective functions or constraints.

In practice, decision-making in SSP includes a high degree of different types of fuzziness [10]. In real-world SSPs, the input information (e.g. demand, quality, and cost) and the objective function are often uncertain or fuzzy since most of the input information is not precisely known or complete or achievable. The fuzzy set theory is one of the best tools to handle uncertainty and vagueness. Obviously, traditional mathematical programming cannot handle the fuzzy programming problems. The supplier selection model of the present paper under multiple products and multiple price levels represents the role of fuzzy theory where information, objective functions and parameters are imprecise.

The fuzzy sets theory was initially introduced by Zadeh [11]. Zimmermann [12,13], first extended his fuzzy linear programming (FLP) approach to a conventional multi-objective linear programming (MOLP) problem. For each objective functions of this problem, assume that the decision maker (DM) has a fuzzy goal such as 'the objective functions should be essentially less than or equal to some value'. Then, the corresponding linear membership function is defined and the minimum operator proposed by Bellman and Zadeh [14] is applied to combine all the objective functions. By introducing auxiliary variables, this problem can be transformed into an equivalent conventional LP problem and can easily be solved by the simplex method. Subsequent works on fuzzy goal programming (FGP) include Hannan [15], Leberling [16], Luhandjula [17], and Shanker and Vrat [18].

Due to the inherent conflict among the three objectives total purchasing and ordering costs, the number of defective units and late delivered units ordered from suppliers, a fuzzy goal programming approach is proposed in the current research to solve an extended mathematical model of a SSP under multi-price level and multi-product.

The present paper aims to develop an interactive fuzzy multi-objective linear programming (FMOLP) model to solve the multi-objective SSP under multi-price level and multi-product in the fuzzy environment. To do so, an MOLP model of a multi-objective SSP under multi-price level and multi-product is firstly constructed. The model attempts to minimize the total purchasing and ordering costs, the numbers of defective units and late delivered units ordered from suppliers. Then, the model is converted into an FMOLP model by an integration fuzzy sets concept and multiple objective programming approaches.

The remaining of the current paper is structured as follows: Section 2 describes the literature review related to supplier selection and order allocation problem. In Section 3, the MOLP mathematical formulation model of SSP under multi-price level and multi-product is presented. In Section 4, Interactive two-phase FMOLP mathematical models are developed to generate optimal solutions in the fuzzy environment of the problem. Section 5 presents a numerical example and reports the results of computational experiments to demonstrate the efficiency of the proposed interactive two-phase FMOLP model for supplier selection and order allocation problem under multi-price level and multi-product. Finally, conclusion part of the present paper is presented in Section 6.

2. Literature review

Researchers have introduced and examined different criteria for the supplier selection problem since 1960s. Dickson [19] identified 23 criteria based on a survey of 170 purchasing managers involved in various SSPs. The criteria such as price, delivery performance, and quality were the most important criteria in evaluating suppliers. Weber et al. [2] reviewed 74 articles to catch supplier selection criteria. They also concluded that the important criteria are quality, delivery performance and cost. They stressed that supplier selection not only depend on the criterion cost, but also it would depend on other criteria such as quality and delivery performance.

Many papers in the literature have investigated supplier selection and evaluation methods [20]. De Boer et al. [21] and Ho et al. [22] conducted a comprehensive survey of methods used for solving SSP. In this section, direction of literature review will essentially be conducted in the mathematical programming models used for supplier selection and order allocation decisions.