Computers & Industrial Engineering 85 (2015) 1–12

Contents lists available at ScienceDirect

Computers & Industrial Engineering

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

A two stage approach for supplier selection problem in multi-item/multi-supplier environment with quantity discounts

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ARTICLE INFO

Article history:
Received 10 July 2014
Received in revised form 25 February 2015
Accepted 26 February 2015
Available online 6 March 2015

Keywords:
Supplier selection
Multi-item/multi-supplier
Quantity discounts
F-AHP
MILP

ABSTRACT

Supplier selection, which is the basic process of finding the best supplier/suppliers to procure the items regarding various criteria, is an important decision problem to be studied. It becomes more complicated if there are various items and any supplier cannot provide all types of items individually. Such situations are called multi-item, multi-supplier environments and rarely studied in the literature. In addition, when quantity discounts are also considered, it gets more sophisticated. Although there are several studies dealing with these aspects separately, to the best knowledge of the authors, this study is the first candidate attempting to solve this type of problem with an integrated approach including Fuzzy Analytical Hierarchy Process (F-AHP) and Mixed Integer Linear Programming (MILP) model.

This study mainly operates in two stages. In the first stage, the relative weights of each criterion for each type of item are determined via F-AHP technique. In the second stage, these outputs are used as inputs in the MILP model to determine the suppliers and the quantities to be provided. In order to validate the model, an application is performed in a gear motor company and numerical results of the problem are revealed to select the best suppliers among 6 alternatives, for the procurement of 5 items regarding 4 criteria, namely, price, quality, delivery time performance, and after sales performance, in case of quantity discounts.

1. Introduction

Supplier selection is defined as the process of finding the right suppliers, at the right price, at the right time, in the right quantities, and with the right quality (Ayhan, 2013b). It is recorded that, purchasing cost of materials corresponds to more than 60% of total sales (Krajewsld & Ritzman, 1996). These purchasing costs may be more than 70% and 80% of total revenue, for automotive industry and high technology industry, respectively (Weber, Current, & Benton, 1991). Also, it is claimed that 70% of total production cost is composed by the purchases of goods and services (Ghodsypour & O'Brien, 1998). Hence, selecting the right supplier will result in reducing operational costs, increasing profitability and quality of products, improving competitiveness in the market and responding to customers' demands rapidly (Abdollahi, Arvan, & Razmi, 2015; Önüt, Kara, & Işık, 2009). Moreover, customer satisfaction is also enhanced by determining the best supplier (Amin & Razmi, 2009). In order to select the right supplier, various criteria should be specified and evaluated with respect to different suppliers' attributes. Therefore, this problem can be considered as a multiple criteria decision making (MCDM) problem. In this problem type, there is a set of multiple and usually conflicting criteria which are supposed to be ranked in order to select the best favorable supplier by evaluating the criteria among various candidates (Yu, Xu, & Liu, 2013).

As an initial step to solve this problem, numerous quantitative or qualitative criteria can be taken into account. Being one of the first studies about the supplier selection problem, Dickson (1966) noted 23 different criteria including quality, delivery, performance history, warranties, price, technical capability, financial position, and geographical situation (Razmi, Rafiei, & Hashemi, 2009). In following years, various studies have been performed to specify the factors affecting a supplier's performance. Ellram (1990), Roa and Kiser (1980), and Stamm and Golhar (1993) identified 60, 18, and 13 criteria for supplier selection, respectively (Ghodsypour & O'Brien, 1998). Similarly, Wang, Cheng, and Cheng (2009) adopted 12 performance metrics to assess the supplier's performance.

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http://dx.doi.org/10.1016/j.cie.2015.02.026
0360-8352/

Although there are many different criteria used in various studies, Weber et al. (1991) determined that the most popular three criteria are net price, delivery and quality.

Depending on the selected criteria, various solution approaches can be used. With a thorough literature survey of 74 related articles, Weber et al. (1991) classified the solution approaches into three categories: linear weighting methods, mathematical programming models, and statistical approaches. Although most of them can be used singly, many of them are used with other techniques. Singly used techniques include but not limited with Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Data Envelopment Analysis (DEA), Mathematical Programming, Case Based Reasoning, Fuzzy Set Theory, Quality Function Deployment (QFD), etc. On the other side, hybrid techniques incorporate integrated AHP approaches, integrated F-AHP and cluster analysis, integrated fuzzy and genetic algorithm, integrated fuzzy and QFD, etc. (Kilic, 2013). Among the singly used techniques DEA, Mathematical Programming, and AHP are the most widely used ones. On the other hand, AHP aided Goal Programming (GP) is the most popular one within the integrated approaches (Ho, Xu, & Prasanta, 2010). According to one of the last classifications made by Sanayei, Mousavi, and Yazdankhak (2010), there are six main clusters for solution approaches. These are multi attribute decision making techniques (AHP, ANP, Technique for Order Preference by Similarity to Ideal Solution-TOPSIS), mathematical programming (Linear Programming-LP, Goal Programming-GP or Mixed Integer Programming-MIP), probabilistic approaches, intelligent approaches (neural networks, expert systems), hybrid approaches (AHP-LP, ANP-MIP) and others. Although the solution approaches can be grouped in various classes, it is more important to analyze the problem type and specify its requirements.

When the problem structure is investigated, De Boer, Labro, and Morlacchi (2001) identified four phases of supplier selection problem as definition of the problem, formulation of the criteria, qualification, and final selection (Boran, Genç, Kurt, & Akay, 2009). In general, supplier selection problems can be classified in two types. In single sourcing type, one supplier can satisfy all the needs of the buyer. In the multiple sourcing type, no supplier can satisfy all the requirements of the buyer (Ghodsypour & O'Brien, 1998). Hence, the management wants to split order quantities among different suppliers (Demirtas & Üstün, 2009). In another classification, if only one item is in interest, problem can be named as a single-item problem (Ghodsypour & O'Brien, 1998; Razmi & Rafiei, 2010) or a multi-item problem if more than one item is considered (Benton, 1991; Kilic, 2013). As expected, if it is a multi-item, multi-sourcing problem, it becomes more complicated. That is because; each supplier having different capacities for each item type cannot provide all the items. Moreover, as stated by Ho et al. (2010), if it is desired to provide long term partnership with fewer but reliable suppliers, problem gets more complicated and constrained by a maximum number of suppliers.

Besides the other problem types such as stochastic demands (Dogan & Aydin, 2011; Hu & Motwani, 2014; Zhang & Zhang, 2011), multi objective problems (Amid, Ghodsypour, & O'Brien, 2011; Choudhary & Shankar, 2014; Deng, Aydin, Kwong, & Huang, 2014), and etc., supplier selection problem is also studied regarding the case of quantity discounts (Amid, Ghodsypour, & O'Brien, 2009; Benton, 1991; Burke, Carrillo, & Vakharia, 2008; Dahel, 2003; Ebrahim, Razmi, & Haleh, 2009; Kokangul & Susuz, 2009; Lee, Kang, Lai, & Hong, 2013; Mansini, Savelsbergh, & Tocchella, 2012; Razmi & Maghool, 2010; Xia & Wu, 2007; Wang & Yang, 2009). In the quantity discounts case, as the order size increases, the unit price charged by the supplier is reduced according to a predetermined pricing scheme. There are three major types of quantity discounts such as incremental quantity discount, business volume discount, and all-unit discount. For incremental quantity discount, the reduced price is applied to the units inside the price break quantity. Different prices are applied to the units belonging to different price breaks. In business volume discount, price discounts are respective to total sales value (Ebrahim et al., 2009). For all-unit quantity discount, if the order size belongs to a specified quantity level, the reduced price is applied to all units starting from the first unit (Lee et al., 2013). Since the last one is more proper in real life, all-unit quantity discount models are more prominent in the literature. However, most of the studies deal with the problem when there is a single item. Although Benton (1991) tries to solve the multi-item multi-sourcing problem with different alternative discount schedules, the single aim is to minimize the total cost. That is, the other criteria, which can be used while determining the best suppliers, such as quality, and delivery performances, are not considered at all. Therefore, to the best knowledge of the authors, there is a limited number of studies to solve an extensive supplier selection problem including multi-item, multi-supplier, multi-criteria with all-unit quantity discount.

Hence, in order to find the best suppliers in this multi-item/multi-supplier environment with quantity discounts allowed, a novel integrated approach including Fuzzy AHP (to determine the relative weights of different criteria) and Mixed Integer Linear Programming (MILP) model is proposed in this study. The contributions of the study differing from the other related studies in the literature are in threefold. Firstly, the relative weights of criteria are considered with respect to different item types. To be more precise, for example, price criterion can have different relative weights due to the item types. It is proper for real life situations because while purchasing an item, price can have the greatest relative weight, however for another item, price can have a different relative importance. This case has not been considered in the literature and is one of the main contributions of this study. Secondly, while calculating the relative weights for each criterion with respect to each item, F-AHP is utilized. This approach can easily overcome the problems associated with the vague structure of defining the important weights of both quantitative and qualitative criteria. As the third, an integration is provided between the outputs of F-AHP and the developed MILP model. The model uses the importance weights of criteria which are derived from F-AHP as an input. Unlike the existing MILP models in the literature, the model not only differs from them by the integration with F-AHP but also it considers many conditions simultaneously. These conditions can be listed as: multi-item/multi-supplier environment, all-unit quantity discount, varying weights for each criterion, and consideration of limited number of suppliers for a sustainable long term partnership. Moreover, to validate the proposed model, an application is performed in a manufacturing company.

The remainder of this paper is mapped as follows. Section 2 cites the relevant literature according to this problem type. Section 3 explains the proposed integrated approach in two parts. In the first part, F-AHP is clarified by breaking down to particular steps. In the second part, MILP model is revealed to solve this problem by using the outputs of F-AHP part. Section 4 presents the application of the proposed approach. In parallel to Section 3, the application of this model is explained in two sub-sections. In the first one, relative weights of each criterion for each item type are found by F-AHP technique. In the latter one, by using these weights, MILP model is run to find the best suppliers by maximizing the total supplier score given the required constraints. Finally, concluding remarks and further studies are provided in Section 5.

2. Literature review

Starting from the study of Dickson (1966), various studies about supplier selection have been performed. Although all of them have the simple common aim as to find the best supplier, they differ