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Supplier Selection and Quota Allocation Decisions Under Uncertainty: Review and Future Research Directions

Atefeh Amindoust[1], Shamsuddin Ahmed[2], Ali Saghafinia[3]
[1,2]Engineering Design & Manufacture Department, [3] Electrical Engineering Department
[123] University of Malaya, Kuala Lumpur, Malaysia
[1]Atefeh_Amindoust@yahoo.com, [2]Ahmed@um.edu.my, [3]Saghafi_Ali@yahoo.com

Abstract: **The rigorous pressure for outsourcing and competitive marketing has exerted firms to rethink about supplier selection strategies. To date, an extensive range of criteria and methods have been proposed to solve supplier selection and order allocation problems. The supplier selection problem is often faced by ambiguity and vagueness in practice. Very often decision makers express their preferences in linguistic terms instead of numerical values. In such circumstance integrated fuzzy methods are used to handle these uncertainties. This study aims to review the literatures on supplier selection and order allocation decisions in uncertain environments. Twelve journal articles published between 2008 and 2012 have been surveyed for this purpose. The articles are analyzed to summarize the criteria and methods to be relevant to different types of industries for supplier selection and order allocation problems in literature. In addition, some discussions on criteria and methods are done and presented in this paper. Finally, suggestions for future researches are proposed for academics and decision makers.**

Keywords: Criteria method, decision making, Supplier selection, quota allocation, uncertainty.

Introduction

Purchasing decision as one of the central components of supply chain management has significant effects on lowering costs and increasing profits in business activities. Purchasing processes are analyzed in two stages: first stage is the selection of suppliers formally by filtering them through an evaluation process that includes both qualitative and quantitative measures. Second stage is the order allocation where the order amounts for each supplier are determined[1]. Usually the supplier selection process involves with vagueness in practice. The candidate suppliers need to be verified with the relevant decision makers. Decision makers normally prefer to justify suppliers in linguistic terms instead of numerical form. Linguistic term is simple and tangible for them to express their perceptions. To handle this issue and deal with the vagueness that is being existed, application of fuzzy logic has been explored in supplier selection and quota allocation literature.

There are some journal articles reviewing the literature regarding supplier selection and quota allocation problems-separately or together [2-8]. Since these articles review the literature up to 2008, this paper extends them through a literature review on the sample of international journal articles between 2008 and 2012 which focused on the both supplier selection and order allocation problems in fuzzy environments. This paper intends to identify three issues including the existing criteria and methods, application of the methods in which industry, and the most popular criteria and methods.

Supplier selection and Quota Allocation

Supplier selection is the process by which group or large number of suppliers' performances and abilities are reviewed, evaluated, and chosen to become a part of company's supply chain. Basically, there are two kinds of supplier selection problem as multiple sourcing and single sourcing. In single sourcing, one supplier can satisfy all the buyer's needs and the management needs to make only one decision, which supplier is the best. However, the best is always cunning, whereas in multiple sourcing as no supplier can satisfy all the buyer's requirements, more than one supplier has to be selected [9]. Therefore, in multiple sourcing environments the order allocation decision must be considered besides supplier selection decision. In addition, to handle the ambiguity in supplier selection problem, fuzzy logic has been applied in literature. A wide range of criteria and integrated fuzzy methods have been applied in supplier selection and order allocation problems. In this section, a sample of supplier selection and quota allocation papers which have taken place in uncertain environments are chosen to analyze and summarize the existing criteria and methods to be relevant to different types of industries for supplier selection and quota allocation problems in recent years. This information is shown in Table I.

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TABLE I. SUPPLIER SELECTION UNDER UNCERTAINTIES IN LITRUTURE

Researchers	Methods	Implementation	Evaluation and Selection Criteria
Ozgen et al. (2008)	Analytic Hierarchy Process (AHP), Fuzzy Multi-Objective Linear Programming	Pipe clamps and hanging systems	Delivery performance; fill rate; perfect order fulfillment; order fulfillment lead-time; supply chain responsiveness; production flexibility; total logistics management costs; value added employee productivity; warrant costs; cash to cash cycle time; inventory days of supply; asset turns; environmental costs; green image; design for environmental; environmental management systems; environmental competencies
Amid et al. (2009)	Fuzzy Mix Integer Linear Programming	Supposed illustration	Quality; price; delivery
Chen (2009)	Fuzzy Mathematical Programming	Supposed illustration	Price; quality; delivery
Wang and Yang (2009)	AHP, Multi-Objective Linear Programming, Fuzzy Compromise Programming	Pharmaceutical company	Cost; delivery; quality
Amid et al. (2010)	Fuzzy Multi-Objective Programming, AHP	Supposed illustration	Manufacturing capabilities; defects; total quality management; net cost; on time delivery; response to change; product development; financial and organization capability
Amin et al. (2010)	Fuzzy SWOT (Strengths, Weaknesses, Opportunities, and Threats), Fuzzy Linear Programming	Automobile company	Internal criteria: unit cost; quality; percent of on time delivery; management stability, External criteria: mutual trust; strength of geographical location; international communication
Yucel and Guneri (2010)	Fuzzy Multi-Objective Linear Programming	Supposed illustration	Price, quality, delivery
Amin and Zhang (2012)	Fuzzy set theory, Multi-objective programming, FAHP, Compromise programming	Supposed illustration	Cost, delivery, experience, quality, part safety, lightweight, recyclable, process capability, design process, reduction of wastes, using clean technology
Ku et al. (2010)	Fuzzy AHP, Fuzzy Goal Programming	Digital consumer products manufacturer	Cost; quality; service; risk; economy
Jolai et al. (2010)	Fuzzy AHP, Fuzzy TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution), Goal Programming	Automotive manufacturing	On time delivery; closeness of relationship with the supplier; supplier's product quality; supplier's technological capability; price/cost
Lin (2009)	Fuzzy Preference Programming, ANP (Analytic Network Process), Multi-Objective Linear Programming	Car manufacturer	Quality; price; delivery; technique
Shaw et al.(2012)	Fuzzy AHP, Fuzzy Multi-objective Linear Programming	Garment manufacturing company	Cost; Quality rejection; Percentage of late delivered item; Greenhouse gas emission

Ozgen et al. (2008) used AHP to calculate the weights of the alternative suppliers for selecting the best ones. Then fuzzy theory was implemented to handle the imprecision data and consequently a multi-objective probabilistic linear programming approach was suggested to allocate order quantities to selected suppliers [10].

Amid et al. (2009) developed a fuzzy multi objective model to handle simultaneously the imprecision of data and determine the order quantities based on price breaks for each supplier. In this model, the weighted additive rule was applied to cope with the unequal importance of fuzzy goals and fuzzy constraints [11].

Chen (2009) suggested a decision support model for supplier selection and order allocation problems. An interactive procedure based on past problem solving experiences was applied through a fuzzy-based mathematical programming approach to incorporate multiple uncertain criteria under the demand constraint of multiple items with varied importance to the purchasing firm [12].

Wang and Yang (2009) applied a multi objective linear programming model for allocating order quantities to each supplier in quantity discount environments. In this model, AHP was applied to calculate the weights of the objective functions for each criterion. Then the multi-objective model was reformulated into a fuzzy compromise programming approach to have a more reasonable compromise solution [13].

Amid et al. (2010) developed a weighted max–min fuzzy multi-objective model to complete the Amid et al.'s work in 2009 for supplier selection and order allocation problems. The current model considered imprecision of data and varying importance of quantitative/qualitative criteria. AHP was used to determine the weights of criteria in the model [14].

Amin et al. (2010) suggested a strategic model for supplier selection which included two stages. In the first stage, fuzzy logic was integrated with quantified SWOT algorithm. In the second stage, the output of SWOT algorithm was implemented as an input in a fuzzy linear programming model to determine the order quantity [15].

Yucel and Guneri (2010) proposed a weighted additive fuzzy programming approach for supplier selection and order allocation problems. Linguistic variables were used to assess weights of the factors as trapezoidal fuzzy numbers. The weights were obtained by applying a procedure to calculate fuzzy positive ideal rating and fuzzy negative ideal rating for applying in a fuzzy multi-objective linear model [16].

Ku et al. (2010) utilized fuzzy goal programming considering the manufacturer's supply chain strategies for the supplier selection problem. Fuzzy AHP was applied to calculate the relative weights of criteria and then the weight numbers were used as goals' coefficients in objective function of fuzzy goal programming to determine the optimal order allocation [17].

Jolai et al. (2010) employed fuzzy AHP to calculate the importance weights of criteria and a modified fuzzy TOPSIS approach to gain the scores of alternative suppliers in multi-product environment. Also, the goal programming method was applied to construct a multi-objective mixed integer linear programming model to determine the quantity of order allocation to each selected supplier in each period [18].

Lin (2009) integrated the Fuzzy preference programming method with ANP to measure the weights of the suppliers. Then, the weights were used as coefficients in the objective function of the multi-objective linear programming model to obtain optimal allocation of orders [19].

Amin and Zhang (2012) employed fuzzy set theory to rank suppliers in closed-loop supply chain based on qualitative indicators through a weighting procedure. A multi-objective mixed integer linear programming model was applied to rank the suppliers based on quantitative indicators and also to assign order allocation. It is noted that, the fuzzy AHP method was combined with compromise programming to determine the weights of each objective function in the proposed model. In this work, a framework for supplier selection criteria in reverse logistic was proposed [20].

Shaw et al. (2012) implemented fuzzy AHP to weight the indicators. These weights were passed to fuzzy multi-objective linear programming to select the suppliers and assign orders allocation [21].

Observations on Criteria and Methods

Many criteria have been suggested in the supplier selection decision as seen in Table 1. The most popular criterion is quality, followed by cost/price, delivery on time, service, organization and management, financial situation, flexibility, technological level, production facilities and capacities, relationship, environmental competencies and so on.

Since supplier selection is a multi-criteria decision making, this issue can be modeled as a multi-objective programming technique. Usually one or more than one criterion is considered in objective functions and other criteria are considered as constraints. Besides evaluation and selection criteria, companies are exposed to various constraints in the supplier selection problem which can be formulated as mathematical programming models. Moreover, in multiple sourcing environments mathematical programming methods are famous because these assist not only to select the appropriate suppliers but also determine the amount of order allocation to selected supplier simultaneously. That is why; the integrated mathematical programming is one of the most popular methods for supplier selection and order allocation problems as seen in Table 1.

However, mathematical programming method has some drawbacks as follows. Mathematical Programming models often neglect to consider scaling and subjective weighting issues and have no possibility for the decision makers to apply his or her preference. The weight determination is a challenging task for implementing these models. Moreover, mathematical programming models have no ability to cope with the qualitative criteria.

To overcome the weightless drawback of mathematical programming models, there are some solution methods. As seen in Table I, AHP technique provides the most functional solution method in this sample. AHP is a common approach for calculating the relative importance weightings of criteria and sub-criteria owing to its simplicity and flexibility. Based on the above analysis, it is obvious that mathematical programming models are the most prevalent methods for quota allocation problem and integrated mathematical programming-AHP method is the most popular hybrid methods for supplier selection and order allocation scenarios.

Conclusion and Suggestions

This study reviews a sample of supplier selection and quota allocation papers from 2008 to 2012 in fuzzy environments and provides valuable insights on existing criteria and methods. The most popular criterion to evaluate suppliers is quality, followed by cost/price, delivery, and so on. Also, the most popular method for supplier selection and order allocation problems is integrated AHP-Mathematical Programming method. To pave to future researches on criteria, the green issues can be considered in the supplier selection problem and environmental aspects can be added to existing criteria. In addition, after analyzing the implementations of existing methods in this review article, it is found that the researchers have focused on manufacturing industries. It is worthwhile and essential to apply the methods for supplier selection in service industries and sectors as well. To improve the existing methods, it can be focused on shortcomings of AHP technique. The AHP technique is a time-consuming model in consideration of large number of criteria and alternatives (Amin and Zhang, 2012). It can compare a very limited number of decision alternatives, usually not more than 15 (Wang et al., 2008) due to employing a pair-wise comparison procedure. So, developing on methods which cope with the large number of criteria and alternatives is a fertile area for research.

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