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Simulation based fuzzy TOPSIS approach for group multi-criteria supplier selection problem

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ABSTRACT

Supplier selection is nowadays one of the critical topics in supply chain management. This paper presents a new decision making approach for group multi-criteria supplier selection problem, which clubs supplier selection process with order allocation for dynamic supply chains to cope market variations. More specifically, the developed approach imitates the knowledge acquisition and manipulation in a manner similar to the decision makers who have gathered considerable knowledge and expertise in procurement domain. Nevertheless, under many conditions, exact data are inadequate to model real-life situation and fuzzy logic can be incorporated to handle the vagueness of the decision makers. As per this concept, fuzzy-AHP method is used first for supplier selection through four classes (CLASS I: Performance strategy, CLASS II: Quality of service, CLASS III: Innovation and CLASS IV: Risk), which are qualitatively meaningful. Thereafter, using simulation based fuzzy TOPSIS technique, the criteria application is quantitatively evaluated for order allocation among the selected suppliers. As a result, the approach generates decision-making knowledge, and thereafter, the developed combination of rules order allocation can easily be interpreted, adopted and at the same time if necessary, modified by decision makers. To demonstrate the applicability of the proposed approach, an illustrative example is presented and the results analyzed.

1. Introduction

Nowadays, supplier selection with order allocation represents one of the most important functions to be performed by the purchasing decision makers, which determines the long-term viability of the company. For most of the procurement/purchasing departments, supplier selection is considered as a five-phase process starting from the realization of the need for a new supplier; determination and formulation of decision criteria; pre-qualification (initial screening and drawing up a shortlist of potential suppliers from a large list); final supplier selection; to the monitoring of the suppliers selected (i.e., continuous evaluation and assessment).

In order to ensure an uninterrupted supply of products, it has been observed that more than one supplier is normally available for each product. Periodic evaluation of supplier quality is carried out to ensure relevant quality standards for all incoming products are met. *The key objective is to purchase the right quality of product in the right quantity from the right source at the right time and at reasonable price*. With the increase in use of quality management and just in time (JIT) concepts by a wide range of companies, the supplier selection decision has become even more critical (Muralidharan et al., 2002). As customer's demands are always uncertain, companies tend to manage their suppliers in different ways leading to a supplier–supplier development, supplier evaluation, supplier selection, supplier association, supplier coordination, etc. (Chan, 2003; Jain et al., 2009).

Based on a synthesis of the literature and interviews of several industrial partners in the EU-I*Proms project (www.iproms.org), we present some of the extracted motivations for this study:

Motivation 1: The strategic nature of the supplier selection decision determines the long-term viability of the company. However, the majority of the existing models/approaches/methods are based on functional criteria like quality, price, delivery time, etc., and does not take into account the repercussions of the company strategy on the decisions by taking into account several novel criteria such as innovation, flexibility, risk, agility, responsiveness, etc. (Chan and Kumar, 2007).

Motivation 2: The multi-criteria aspect of the supplier selection problem is an essential aspect when we deal with a global approach. However, there are more studies emphasizing the use of mathematical programming based decision-making methods and total cost based approaches in particular. These approaches fail to address the subjective (qualitative) criteria for supplier selection with order

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allocation and treat this significant aspect of the problem by imposing some assumptions and mainly converting qualitative criteria to quantitative criteria. *A decision model that accommodates explicitly both subjective and objective criteria is desirable* (Chan, 2003; Chan and Kumar, 2007).

Motivation 3: The supplier selection problem requires decision or a set of decisions, which needs the intervention of different services (departments) of the company (Dyer and Forman, 1992). The AHP method takes into account this aspect of the problem. Indeed, Saaty (1989, 1990) has described group decision making with AHP, including suggestions for assembling the group, running the decision-making session, trying to get the group to agree, inequalities of power, concealed or distorted preferences and implementing the results. Moreover, in practice, smaller decision groups are more efficient but larger groups are often required for effective decision making so that stakeholders are represented and the final decision accepted, and implementation is facilitated (Mitchell and Wasil, 1989).

Motivation 4: In practice, if a supplier cannot satisfy a minimal threshold compared to certain criterion, it cannot be selected in spite of its possible effectiveness with respect to other criteria. The elimination method is the only method in the literature, which takes into account this aspect of the problem. But this method does not plan to choose the most powerful among qualified suppliers (Mobolurin, 1995; Thompson, 1990). Indeed, with this method we are not interested by the total performance of the suppliers with respect to all the criteria. A method, which can take into account the conjunctive rules (minimal threshold) and choose the most powerful suppliers (by considering all the criteria) is a lack in the literature (Jain et al., 2007).

Motivation 5: In the supplier selection problem, we *have various constraints* to take into account. These constraints are of different natures. It can be the constraints evoked by the suppliers such as minimal order quantity, maximum production capacity, etc. or the constraints of the customer like budget devoted to the purchasing activity, maximum rate of unqualified products, etc. *In addition, if the company would wish several suppliers, it must choose at the same time the suppliers and the quantity to be ordered from each one*. Consequently, only mathematical optimization methods can take these aspects of the problem under several restrictive assumptions. *Moreover, these mathematical optimization methods cannot consider the qualitative criteria, which are very essential for supplier selection problem* (Ding et al., 2008).

Motivation 6: In reality, the future behaviors of the suppliers and the environment are uncertain. Consequently, it is difficult to assign a fixed mark to the suppliers with respect to a criterion. However, it is more practical to affect a fork of mark or a random variable, which describes the probabilistic behavior of the supplier and market using simulation. The scenario method treats this type of problems. Unfortunately, in order to cover all the situations for both the markets and the supply chains, huge number of scenarios is necessary, where efficient analysis can be a challenging issue to come with a solution (Jain et al., 2009).

Motivation 7: Moreover, the previous synthesis shows us that the current methods have some limits to cover the various aspects of the supplier selection problem with order splitting. Our objective is to build an approach, which can take into account all the characteristics of the problem: the strategy of the company, the multi-actors aspect, the subjective and objective criteria, the constraints of both suppliers and customer (company), the multi-suppliers aspect, the probabilistic aspect (supplier behaviors and the economic environment…) and finally the order splitting aspects (Wu et al., 2009; Guneri et al., 2009).

Motivation 8: Although, there are a large number of reported studies/papers addressing the decision criteria to be used for the supplier selection process. *Nevertheless, this rich literature do fail to address the need to include the criteria related to risk, which have become extremely important given the present threats to security, geographical location, political and economical stabilities, etc. around the world. Surprisingly, there are very less evidence of such research on how companies evaluate and select suppliers* (Chan and Kumar, 2007).

In this paper, we propose a two-phase decision making approach for group multi-criteria supplier selection problem, which integrates supplier selection process with order allocation. The first phase, suppliers are selected using fuzzy-AHP through four classes of criteria (CLASS I: Performance strategy, CLASS II: Quality of service, CLASS III: Innovation and CLASS IV: Risk). In the second phase, using simulation based fuzzy TOPSIS technique; the criteria (price, quality and delivery) are quantitatively evaluated for order allocation among the selected suppliers.

The purpose of this approach is to:

- Determine preferred suppliers which can be geographically dispersed.
- Focus business with preferred suppliers and build long term-strategic relationships based on all the four classes (performance, quality of service, innovation and risk).
- Work with current and potential preferred suppliers to continuously improve performance standards and enhance the suppliers' position to receive future business opportunities.
- Determine the order allocation strategy to adopt by the company.

The rest of the paper is organized as follows. Section 2 illustrates some complexities observed in the supplier selection processes by reviewing the most existing studies. Section 3 gives the structure of the considered supply chain with the subjected decision criteria for the selecting suppliers and order splitting. Section 4 presents the theoretical background of our work. Section 5 illustrates the proposed simulation-based knowledge approach. Section 6 gives an illustrative example. Section 7 concludes the paper with discussions and future directions.

2. Supplier selection and order allocation: state of the art

A number of research works published in the last decades emphasized the strategic importance of the supplier selection process. In this section, we limit our literature review to the works where supplier selection and order allocation are considered. Moreover, we present the most recent published studies using techniques/methods such as analytic hierarchy process (AHP), analytic network process (ANP), technique for order performance by similarity to ideal solution (TOPSIS), potential support vector machine (P-SVM), preference programming (PP), fuzzy logic, case-based reasoning (CBR), mathematical programming (MP), etc.

Recently, Mafakheri et al. (2011) proposed a two-stage multi-criteria dynamic programming approach for supplier selection and order allocation problem. In the first stage, the AHP method is employed to address the multi-criteria decision in supplier ranking. In the second stage, order allocation model that aims at maximizing a utility function for the company as well as minimizing the total supply chain costs is proposed. Several logistics constraints are considered including demand constraints, capacity constraints and inventory levels constraints. To solve the bi-objective model, a dynamic programming approach is developed.

Rezaei and Davoodi (2011) developed two multi-objective mixed integer non-linear models for multi-period lot-sizing problems involving multiple products and multiple suppliers' selection. The two models are constructed on the basis of three objective functions respectively cost, quality and service level and a set of constraints. The first model considers the case where shortage is not allowed while in the second model, all the demand during the stock-out