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Applying supplier selection methodologies in a multi-stakeholder environment: A case study and a critical assessment

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ABSTRACT

In the contemporary global market, supplier selection represents a crucial process for enhancing firms' competitiveness. In firms operating in low-complexity sectors, supplier selection generally leverages on few significant variables (price, delivery time, quality) and it is often left to the buyers' experience. On the other hand, in industries characterised by remarkable product complexity, supplier selection systems gain the characteristics of a multi-stakeholder and multi-criteria problem, which needs to be theoretically formalised and realistically adapted to specific contexts.

An increasing number of researches have been devoted to the development of different methodologies to cope with this problem. Nevertheless, while the number of applications is growing, there is little empirical evidence of the practical usefulness of such tools, that are mainly tested on numerical examples or computational experiments and focused on a dyadic version of the problem, overlooking the wider set of actors involved in the decision-making problem. The result is a clear dichotomy between academic theory and business practice.

Therefore, the paper contributes to understand the above dichotomy by evaluating the applicability to real-world multi-stakeholder problems of the two main approaches proposed in the literature to deal with supplier selection, the analytic hierarchic process (AHP) and the fuzzy set theory (FST). Based on an industrial case study, a thorough discussion is developed, dealing with the issues arising during the implementation and practical functioning of such decision support systems, also providing provide practical guidelines and managerial implications.

1. Introduction

In the contemporary global market, supplier selection (SS) represents a crucial process for enhancing firms' competitiveness and to rapidly react to market requirements and innovation process (Esposito & Raffa, 1994, 2007; Ghodsypour & O'Brien, 2001; Gules & Burgess, 1996; Prahinski & Benton, 2004; Saen, 2007; Sarkar & Mohapatra, 2006).

In firms operating in sectors characterised by a low level of complexity, SS generally leverages on one or two significant variables (such as price, delivery time, quality); the selection process is often entirely ruled by buyers' experience. On the other hand, in industries characterised by remarkable product complexity, SS systems gain the characteristics of a multi-criteria problem, which needs to be theoretically formalised and realistically adapted to specific contexts (Bruno, Esposito, Genovese, & Passaro, 2012; Esposito & Raffa, 2007).

An increasing number of researches have been devoted to the development of different methodologies to cope with this problem. Nevertheless, while the number of applications is growing, there is little empirical evidence of the practical usefulness of such tools (Bruno et al., 2012; de Boer & Van der Wegen, 2003; Weber, Current, & Benton, 1991). Moreover, the analysis of the literature shows that authors tend to stress the strengths of their models neglecting or giving little attention to the weaknesses. It is not by chance that, in many cases, proposed models are tested on generic applications, numerical examples and computational experiments (Bhutta, 2003; Rodriguez, Ortega, & Concepcion, 2013; Saen, 2007), with less emphasis on issues and problems emerging in the actual implementation and on the inherent complexities deriving from the multi-stakeholder nature of the problem, just focusing on basic and dyadic versions of the problem.

The result is a clear dichotomy between theory and business practice (Bruno et al., 2012). In other words, the literature is rich of models which present a variety of approaches that are rarely used to solve

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real problems in the corporate practice (Genovese, Lenny Koh, Bruno, & Esposito, 2013; Genovese, Lenny Koh, Kumar, & Tripathi, 2014).

Considering this evidence, the goal of this paper is to contribute to understand the above dichotomy by evaluating the two main approaches proposed in the literature to deal with the SS, analytic hierarchic process (AHP) and fuzzy set theory (FST). Starting from the characteristics of these two approaches, we propose an integrated model which combines their respective strengths. The usability of the model and its adaptability to real-world problems are investigated through an empirical study carried out in a large firm operating in the industry of railway and transportation systems design. Issues emerging during the implementation phase and subsequent results trigger some interesting implications regarding the model itself and its usability in a complex supply chain.

The paper is organised as follows. Firstly, a thorough literature review is proposed. It describes the main methods available in the literature for dealing with the SS problem, with a special focus on AHP and FST approaches. Then, based on emerging literature gaps, the integrated model is introduced, indicating how it combines the strengths and overtakes some of the weaknesses of traditional AHP and FST approaches. Thereafter, the empirical study (based on a real-world case study) is outlined; a discussion about managerial implications is then developed. Finally, conclusions are reported.

2. The supplier selection problem: a literature review

In the contemporary market, firms have implemented various actions and strategies to ensure their competitiveness: in particular, a special attention has been paid to vendor assessment processes, which represent a compulsory and critical starting point for the achievement of a collaborative customer–supplier relationship. Vendors are required to have an adequate set of competencies, in order to create a supply system capable of facing market challenges (de Boer, Labro, & Morlacchi, 2001; García, Puente, Fernández, & Priore, 2013; Karande and Chakraborty, 2013; Zhao & Zhang, 2012).

In this context, some fundamental decision-making problems arise (Ho, Xu, & Dey, 2010). The first concerns the selection process (*selection problem*) of new suppliers for inclusion in the vendor list. It is generally performed through ranking or rating (*evaluation problem*) a set of qualified suppliers. Once suppliers have been evaluated, in tactical operations an *order allocation problem* has to be tackled, consisting in the determination of the order size to be assigned to each supplier, with the objective of optimising a given utility function.

Since 1960s, the identification of attributes and criteria to be considered in the SS problem has constituted an attractive research area. Traditionally, supplier evaluation was fundamentally based on financial measures; recently, more and more emphasis has been devoted to other aspects, bringing multiple criteria into the evaluation process (de Boer et al., 2001). Dickson (1966) listed the most utilised criteria for SS. The analysis showed that price, quality, delivery and performance history could be considered the most important criteria. Ha and Krishnan (2008) enlarged the list to a set 30 attributes, very often conflicting with each other, requiring either quantitative or qualitative measurements. The intrinsic multi-criteria nature of the problem requires focussing not only on *what* has to be computed but also on *how* multiple criteria have to be combined. Therefore, a broad body of literature dealing with decision support methods and systems for the SS problem has been developed.

Several literature reviews (Bruno et al., 2012; de Boer et al., 2001; Ha & Krishnan, 2008; Ho et al., 2010) show that, especially in the last years, Analytic Hierarchy Process (AHP) (Saaty, 1980, 1994) and fuzzy set theory (Zadeh, 1965) are the most widely adopted methodologies (Amin & Razmi, 2008; Bhutta, 2003; Bottani & Rizzi, 2008; Chan & Kumar, 2007; Labib, 2011; Sarkar & Mohapatra, 2006) for dealing with the SS problem. The following sub-sections provide a review of approaches based on these methodologies, also highlighting the gaps in the extant literature.

2.1. AHP-based approaches

The main steps of the application of the AHP methodology can be summarised as follows:

(1) *Structuring the problem into a hierarchy*. Hierarchies distribute a property (the goal) among the elements being compared (attributes and characteristics), to judge which one influences or is influenced more.
(2) *Comparative judgments*. The aim is to measure the relative importance of the elements (attributes, characteristics) to the overall goal. The question to ask when comparing two elements is: *how important is one of the two elements to the goal of the problem?* Pair-wise comparison matrices are associated with the set of attributes and each set of characteristics within each attribute. To compare two generic elements i and j, a value a_{ij} is attributed on a ratio scale ranging from 1 (meaning equally important) to 9 (meaning extremely more important) is generally used (Saaty, 1980). At each hierarchical level the decision-maker establishes scores between elements by defining a_{ij} values. In general a reciprocity condition should be satisfied, i.e. $a_{ji} = (a_{ij})^{-1}$. However, AHP allows for inconsistencies in pair-wise judgments, i.e. $a_{ij} \times a_{jk}$ do not need to be equal to a_{ik}.
(3) *Calculation of the attribute weights*. Starting from the data obtained through the comparative judgments, the objective is to calculate the vector whose components are the priorities of each element of the hierarchy, namely weights to be assigned to each element of the hierarchy for the calculation of the global score.
(4) *Calculation of global score*. Using the attribute and characteristic weights and considering the related measures, global scores are calculated.

In solving the SS problem, as regards the fourth step, alternatives can be evaluated in different ways: *(i)* through a pair-wise comparison of the alternatives for each criterion; *(ii)* by assigning an absolute normalised performance measure to each alternative for each criterion; *(iii)* by scaling performances through a set of qualitative ranges and then assigning to each range a relative weight on the basis of a pair-wise comparison among the ranges. In any case, performances are combined through an additive synthetic methodology using the weights of each criterion to get the final ranking.

In case of multiple decision-makers, pair-wise comparisons performed at each step can be combined through the calculation of geometric averages among the a_{ij} values assigned by each decision-maker (Forman & Peniwati, 1998).

Along with a huge literature about the application of the above-mentioned classical version of the AHP approach, specific proposals for the SS have been provided. Narasimhan (1983), Soukup (1987), Nydick and Hill (1992), and Barbarosoglu and Yazgac (1997) proposed the use of the AHP to deal with imprecision in SS. Ghodsypour and O'Brien (1998) integrated AHP with linear programming to consider both tangible and intangible factors in order to maximise the total purchasing value. Sarkis and Talluri (2002) also utilised a more sophisticated version of AHP, the Analytical Network Process (ANP) in dealing with purchasing decisions.

AHP (and ANP) appears to be among the most utilised methodologies to cope with the supplier selection problem (Chai, Liu, & Ngai, 2013); this is due to several reasons. Having been widely applied in multi-attribute decision-making problems, AHP provides a hierarchical representation of the problem that helps analytic decision-making. It can handle both tangible and intangible attributes and