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Supplier evaluation and selection: a fuzzy novel multi-criteria group decision-making approach

Abstract

Suppliers' evaluation and selection is a subject widely explored through many different kinds of approaches and multi-criteria decision methods, and more recently also through group decision making ones. This paper addresses these problems by proposing an easy-going two-phase supplier selection decision model that uses a scientific approach and incorporates performance criteria in screening and selecting the potential suppliers for further optimal supplier selection. The first phase of the model determines the performance of the suppliers on both quantitative and qualitative criteria and the relative importance weights of the criteria. Fuzzy set theory is utilized to deal with the imprecision and vagueness involved with the subjective judgment of both the qualitative data of the decision-matrix and the relative importance weights of the criteria. In the second phase, the suppliers are screened using their efficiencies and an agreed threshold. Then, the optimal supplier for corporation is selected from the limited potential suppliers set. To illustrate the applicability and validate the proposed model, a case study of a beverage producing company located in Ghana, the Sub-Saharan Africa is proposed. The results of the study can provide valuable clues and guidelines to decision-makers and analyst in pre-contract negotiations. The proposed model will assist practicing managers to effectively reduce their supply-base and efficiently select the optimal supplier for corporation. Implications of the study to the theory and practice and future research directions are also outlined.

Keywords

Supply Management; Supplier Screening; Supplier Evaluation and Selection; Fuzzy Logic; Group Multi-Criteria Decision-Making.

1. Introduction

The cost of raw materials and component parts contribute about 70% of the total cost of a product (Ghodsypour & O'brien, 2001; Şen et al., 2008). Therefore, companies are required to strategically partnership/align and maintain long-term relationship with their strategic and efficient suppliers (Sarkar & Mohapatra, 2006; Chan et al., 2008; Ho et al., 2010) to reduce the total cost of ownership drastically. Prior to forging a long-term strategic supplier partnership requires a small supply-base to manage (Sarkar & Mohapatra, 2006). Since selecting the optimal supplier for corporation has a greater repercussion on the total purchasing cost and corporate competitiveness, the purchasing department which is responsible for suppliers selection and acquisition of materials, services and equipment can play a tremendous role in this regard (Chen et al., 2006; De Boer et al., 2001, Golmohammadi & Mellat-Parast, 2012).

However, choosing amongst these suppliers for strategic partnership by the purchasing managers or decision-makers in the purchasing department is always a difficult and risk prone task (Chan et al., 2008; Şen et al., 2008). These decisions are typically very complicated, critical and multi-criteria decision-making (MCDM) problem that involves both

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qualitative and quantitative criteria (Chai & Ngai, 2015). Decision-makers and analyst are expected to trade-off amongst these multiple criteria in their decisions (Ngan, 2015). Partaking in these decisions is multi-dimensional requiring the support of decision support tools.

This has subsequently raised tremendous attention in the academic literature in the development of a more systematic and efficient supplier selection decision-making processes and tools over the last couple of years (Badri Ahmadi et al., 2016; Bruno et al. 2016; Dweiri et al., 2016; Gold & Awasthi, 2015). Many methods and techniques (e.g. multi-criteria decision-making aids (Mardani, 2015)) have been proposed in literature to support purchasing decision-makers to deal with the importance and complexity in the decision-making process.

The purchasing decision (supplier selection and evaluation problem) processes typically involves four main phases according to De Boer et al., (2001) and are listed below;

1. Problem description
2. Formulation of Criteria
3. Qualification of potential suppliers
4. Final selection of the optimal supplier

Prior to selecting the optimal supplier for corporation, there is the need to screen pool of suppliers against some basic requirements of the specific need to select the potential suppliers to narrow down the number of suppliers for evaluation. However, this qualification screening phase of the supplier selection process has seen limited attention in literature (Choi & Kim, 2008). Again, a few if not any of these limited attempts have considered scientific approach in selecting potential suppliers from the pool of suppliers and consider evaluation criteria in the selection process (see Sarkar & Mohapatra, 2006). Most purchasing managers heavily rely on non-scientific approaches such as introduction of potential suppliers from friends, previous customers, engineering managers, production managers, etc. Some of the reference checks include supplier's delivery performance, adherence to contract terms, without critically investigating these suppliers pool against certain basic criteria using a more scientific approach.

The preliminary selection of the potential supplier is considered equally imperative and nearly the same as the optimal supplier selection since the optimal supplier is selected from amongst the limited potential supplier list and therefore requires to be completed with greater precision. The overall objective of the preliminary supplier selection phase is to identify potential suppliers who can stand the decision criteria. Furthermore, the quantification of the qualitative criteria has considerably relied on subjectivity making the optimal supplier selection process ineffective. Yet, in dealing with criteria such as suppliers' product technological level, suppliers' production systems flexibility and suppliers' products quality standards, the subjectivity and qualitative aspect of the optimal supplier selection process becomes increasingly paramount. This therefore requires a supplier selection model that is capable of dealing with these inherent complexities (Chan et al., 2008).

The objective of this paper is to propose an easy going two-phase supplier selection and evaluation decision support model that uses a scientific approach and incorporates performance evaluation criteria into the preliminary supplier screening and selection of optimal supplier involving both qualitative and quantitative criteria under uncertainty (Kusi-Sarpong, et al, 2018). The first phase of the model determines both the performance of the supplier on quantitative and qualitative criteria and the relative importance weights of the criteria. Fuzzy logic is then adopted and utilized to deal with the imprecision and vagueness with the subjective evaluation of both the qualitative data of the decision- matrix and the weights of the criteria. In addition, the preliminary supplier selection is conducted to screen the suppliers' pool using suppliers' efficiencies and an agreed threshold to determine the potential suppliers. In the second phase, the potential suppliers identified in the first phase are subjected to a second round of evaluation to obtain the optimal supplier to be awarded the contract. To illustrate the applicability and validate the proposed model, a case study of a beverage producing company located in Ghana, the Sub-Saharan Africa is proposed.

The rest of the paper is organized as follows. Section 2 reviews previous related works on supplier selection models and the fuzzy group decision-making and proposed two-phase model is presented in section 3. A case study is utilized to illustrate the applicability and validate the proposed model and discussion of the results in

section 4. Managerial implications are presented in section 5 and section 6 concludes by presenting limitations of the study and future research direction.

2. Review of Related Works

In contemporary supply chain management system, selection of optimal supplier for corporation is based on potential suppliers' performance evaluation against multiple criteria contrary to the single cost criterion consideration. This has shifted the attention from a single cost criterion approach used to evaluate potential suppliers' performance to a multiple criteria evaluation. The shift has subsequently made supplier selection and evaluation receive much more attention in the academic literature. Many tools to support these decisions have been proposed and utilized in literature. The rest of the section looks into the trend of related works on the multiple criteria decision support tools proposed and utilized in supplier selection and evaluation in literature.

2.1. MCDM Methods for Supplier Selection and Evaluation

To support multiple criteria supplier selection and evaluation decision-making problem, various researchers have proposed the use of many decision-making approaches. The multiple criteria conflicting choices evaluation approaches such as data envelopment analysis (DEA) has been used to evaluate and select the optimal supplier based on potential suppliers efficiency performances (Ahmady et al., 2013). Analytic hierarchy process (AHP) has also been used to generate overall score of potential suppliers based on relative importance ratings for supplier selection and evaluation (Deng et al., 2014). Fuzzy logic has also been used either alone or in combination with other models to address the linguistic ratings in the qualitative criteria for supplier selection (for example fuzzy-AHP (Chan et al., 2008)). Analytic network process (ANP) has been utilized to evaluate potential supplier considering both the interrelationship between and within the clusters of the criteria to derive the importance weightings to select the best supplier (Dargi et al., 2014; Vinodh et al., 2011).

Other integrated approaches have also been proposed and utilized by many researchers in an attempt to improve the multiple criteria supplier selection process such as AHP-based DEA model which deploys AHP to determine the relative importance (local) weights of all potential suppliers and utilize these weights as input to the DEA to compute the efficiency score for optimal supplier selection (Zhou et al., 2016). AHP-based Goal Programming (GP) model also uses the AHP to determine the weights of the criteria as input to the GP to evaluate and select the best supplier/set of suppliers (Liao & Kao, 2010). AHP/ANP-based GRA (grey relational analysis) equally utilized the AHP/ANP to acquire the local weightings of the qualitative criteria and used these weightings as coefficients for the qualitative criteria in combination with the quantitative data in the GRA to determine the best supplier (Badri Ahmadi et al., 2016).

The reviewed literature depicts there are many models that have been utilized in the multiple criteria supplier selection and evaluation decision-making process. However, few of the models and studies have placed much attention on scientific preliminary screening (pre-qualification phase) to identify the potential suppliers and also uses both cost and benefits criteria in supporting the decision. Even with those attempts, their proposed approaches are difficult for decision-makers to handle or implement. It must be emphasized that, the screening and selection of potential supplier from pool of suppliers is equally important as the optimal supplier selection. This is because the optimal supplier is selected from amongst the potential suppliers list, therefore the process in selecting the potential suppliers ought to be precision as that of the optimal supplier selection process.

This study therefore as part of its contribution to decision-making theory, proposes an easy going two-phase supplier selection decision support tool that uses a more scientific approach and incorporates cost and benefits evaluation criteria into the supplier pre-qualification/preliminary selection process/stage. The model also uses fuzzy logic to address the subjectivity and vagueness involved with both the supplier qualitative criteria and the criteria weights evaluation. The identified limited sets of potential suppliers are further evaluated to identify the optimal supplier.

3. Fuzzy Group Decision-Making

Decision-making involves the process of identifying the best option from all possible alternatives (Chen, 2000). Group decision making (also known as collaborative decision-making) is a situation where multiple individuals

acting collectively make a choice from feasible alternatives beforehand with the final decision not attributed to a single individual member within the group but to the group generically (consensus) (Lin & Wu, 2008). Within this context, decision-makers tend to provide assessment of the alternatives based on their past experiences and knowledge, expressing their estimations in equivocal linguistic terms (Wang et al., 2014). To address the subjectivity and vagueness in the human thought and expression during group decision-making, fuzzy set theory is known to be extremely suitable and powerful. More importantly, to deal with the uncertainties involved in the process of linguistic estimations, it is better to introduce fuzzy number to convert the linguistic data into fuzzy data (Chen, 2014). Thus, the problems involved in group decision-making in real-life situation where decision data of human judgments with preference are often vague have resulted in the need to employ fuzzy logic.

4. Managerial Input

A small survey with some mathematical background associated with the technique was sent to the decision-makers (managers) asking them about the usefulness of our proposed model in a form of post hoc analysis. This was presented to them to show transparency and robustness of the model for them to have the feeling that the model is scientific and mathematical principled and logic based. All managers replied. Although they understood the usefulness of the model and they agreed that the issue addressed by the model is encountered, the mathematical descriptions and process was very complicated to them.

In response to this, we developed a more simplified step-by-step description with absolutely minimal mathematical description to explain the overall process. We believe that our proposed step-by-step based model will turn our proposed approach easy to understand and accessible to management and practitioners. Clearly, the technique and methodology would best be framed as a model in a decision support system using spreadsheet package with a practitioner friendly user interface.

Another important issue we tried to seek manager's feedback was the validity and confidence in the final results that should be obtained through out proposed model. Even though the processes followed in achieving these results may have been very complicated to them, the managers believe the final results would be what they expected and what they wished to communicate. Thus, the final results could be viewed as managerially valid and reliable.

5. Conclusion Remarks and Future Research Directions

Supplier selection and evaluation is a decision-making problem that requires decision-makers to determine a solution based on multiple criteria with some level of input and decisions uncertainty. These decisions are characterized by the conflicting trade-offs amongst the multiple criteria to select an optimal solution requiring the support of multi-criteria decision-making (MCDM) systems. Notwithstanding the heavy development of MCDM tools, methods and approaches to support suppliers selection and evaluation, most of these decision support systems are limited to just the final optimal supplier selection. However, the few that have attempted prescreening suppliers have also proposed approaches that are difficult to handle or implement by decision-makers.

This paper has explicitly modeled and proposed an easy going two-phase supplier selection and evaluation model that combines both pre-qualification (screening of supplier pool for potential suppliers) stage and evaluate the potential suppliers for optimal supplier selection. The model combines both qualitative (decision-maker's linguistic evaluations for supplier influence on criteria and criteria important) and quantitative (from RFQ of suppliers) criteria and utilized fuzzy set theory to covert the linguistic evaluations to fuzzy evaluations. The proposed model was applied to a real case in a beverage producing company located in Ghana, Sub-Saharan Africa with it customer-base across the Africa continent and beyond. The company intended to select an optimal supplier for a long-term supplier contract. Fifteen suppliers were prescreened to obtain seven potential suppliers. These seven potential suppliers were further evaluated to recommend an optimal supplier to management based on the final score. Based on our proposed model, supplier 2 was ranked the topmost hence considered the optimal supplier for the newly installed electrical critical spare consignment stock contract. The proposed model for multiple criteria supplier selection and evaluation decision problem can be

implemented using a spreadsheet package making it cheaper and easier to implement with simple user interface and promotes information sharing with other excel users.

This study thus do provides some contributes to decision-making theory and practice. The results from the underlying study can provide valuable clues and guidelines to decision-makers and analyst in establishing systematic approach to prescreening, evaluation and selecting optimal supplier for corporation (Kusi-Sarpong, et al, 2018). Since contract negotiation strategy is an important post supplier selection stage, the results attained from this study can assist management of the beverage producing company to effectively negotiate with the selected optimal supplier to achieve win-win situation in terms of reduced resources and improved benefit criteria. Also, the proposed model will assist practicing managers to effectively reduce their supply-base or potential suppliers for detailed evaluation and efficiently select the optimal supplier for corporation or order allocation.

Notwithstanding these promising aspects, this paper still has some limitations. One of the primary limitations is the small/limited number of respondents (managers) involved with the decision-making process (Kusi-Sarpong, et al, 2018). Future studies could extend the coverage of respondents to ensure the validity of the research. Another limitation is the lack of proposed supplier selection and evaluation decision framework (criteria and indicators) in this study to guide the evaluation and selection of the suppliers (Kusi-Sarpong, et al, 2018). A more rigorous and scientific approach for developing a supplier selection and evaluation decision framework could add some insights to framework developments in literature.

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