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# Group multi-criteria supplier selection using an extended VIKOR method with interval 2-tuple linguistic information

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ABSTRACT

How to select the suitable suppliers in the supply chain is critical for an organization's success and has attracted much attention of both researchers and practitioners. Supplier selection can be regarded as a complex group multiple criteria decision making problem requiring consideration of a number of alternative suppliers and quantitative and qualitative criteria. Additionally, decision makers cannot easily express their judgments on the alternatives with exact numerical values in many practical situations, and there usually exists uncertain and incomplete assessments. In response, this paper proposes an extended VIKOR method for group multi-criteria supplier selection with interval 2-tuple linguistic information. The feasibility and practicability of the proposed interval 2-tuple linguistic VIKOR (ITL-VIKOR) method are demonstrated through three realistic supplier selection examples and comparisons with the existing approaches. Results show that the ITL-VIKOR method being proposed is more suitable and effective to handle the supplier selection problem under vague, uncertain and incomplete information environment.



## 1. Introduction

Supply chain management is the strategic coordination of the supply chain for the purpose of integrating supply and demand management (Chu & Varma, 2012; Lee, Cho, & Kim, 2014). It aims to reduce supply chain risk and uncertainty, diminish production costs, and optimize inventory levels, business processes, and cycle times, thus resulting in increased competitiveness, customer satisfaction and profitability (Boran, Genç, Kurt, & Akay, 2009). A supply chain is a network of suppliers, manufacturing plants, warehouses, and distribution channels organized to extract raw materials, convert these raw materials into intermediate and finished products, and distribute the finished products to customers (Bidhandi, Yusuff, Ahmad, & Abu Bakar, 2009). With the competition between companies evolved to competition between supply chains, supplier selection becomes one of the most critical activities of any business organization in purchasing and supply chain management nowadays.

Supplier selection is the process of identifying the most suitable suppliers who are able to provide the buyer with the right products/services at the right price, in the right quantities and at the right time (Yu & Wong, 2015). A good supplier selection makes a significant difference to an organization's future to reduce operational costs and improve the quality of its end products (Zeydan, Çolpan, & Çobanoğlu, 2011). Through supplier selection it is also possible to establish a strategic relationship with suppliers to gain competitive advantages and to improve organizational performance (Lima, Osiro, & Carpinetti, 2014). Therefore, companies have to select the best-fit suppliers and build long-term and profitable relationships with them to achieve growth and progress in today's global competitive market.

Due to the factors such as globalization and accelerated technological change, the selection of appropriate suppliers has received a great deal of attention of both researchers and practitioners. In the literature, a variety of approaches have been suggested to construct effective selection systems, which include analytic hierarchy process (AHP) (Deng, Hu, Deng, & Mahadevan, 2014; Shaw, Shankar, Yadav, & Thakur, 2012), grey relational analysis (GRA) (Rajesh & Ravi, in press), technique for order preference by similarity to ideal solution (TOPSIS) (Lima et al., 2014), data envelopment analysis (DEA) (Kumar, Jain, & Kumar, 2014; Toloo & Nalchigar, 2011), decision-making trial and evaluation laboratory (DEMATEL) (Ho, Feng, Lee, & Yen, 2012), linear program (LP) (Jadidi, Zolfaghari, & Cavalieri, 2014; Sawik, 2014; Ware, Singh, & Banwet, 2014), and some hybrid methods (Abdollahi, Razmi, & Arvan, 2015; Singh,

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2014; Vahdani, Tavakkoli-Moghaddam, Mousavi, & Ghodratnama, 2013). In addition, a detailed review and classification of the supplier selection methods can be found in Chai, Liu, and Ngai (2013) and Ho, Xu, and Dey (2010). Under many conditions, however, exact data are inadequate to model real-life situations because of the complexity of supplier selection problems. Therefore, fuzzy set theory (Zadeh, 1965) was incorporated to deal with the vagueness and ambiguity in the real decision making process. For example, Rezaei, Fahim, and Tavasszy (2014) investigated supplier selection in the airline retail industry by using a funnel methodology, in which conjunctive screening method is used to reduce the initial set of potential suppliers and then fuzzy AHP is used to rank and select the most suitable supplier(s). Kannan, Jabbour, and Jabbour (2014) proposed a framework using fuzzy TOPSIS to evaluate green suppliers for a Brazilian electronics company based on the criteria of green supply chain management practices. Kannan, Govindan, and Rajendran (in press) proposed a multiple criteria decision making (MCDM) model called fuzzy axiomatic design to select the most suitable supplier for the plastic manufacturing company in Singapore. Roshandel, Miri-Nargesi, and Hatami-Shirkouhi (2013) presented the fuzzy hierarchical TOPSIS for supplier selection and evaluation in detergent production industry. On the other hand, Liou, Chuang, and Tzeng (2014) proposed a fuzzy integral-based model for supplier evaluation and improvement based on DEMATEL-based analytic network process (ANP) combined with the basic concepts of VIKOR method. Lee et al. (2014) integrated AHP and TOPSIS based on the fuzzy theory to determine the prior weights of multiple criteria and select the best-fit suppliers taking the subjective and vague preferences of decision makers into consideration. Karsak and Dursun (2014) proposed a novel fuzzy MCDM framework for supplier selection by integrating quality function deployment (QFD) and DEA which considers the impacts of inner dependence among supplier assessment criteria through constructing a house of quality. Kar (2014) provided an integrated approach for group decision support for the supplier selection problem by employing fuzzy AHP for group decision making and fuzzy goal programming for discriminant analysis. Büyüközkan and Çifçi (2012) proposed a hybrid MCDM model to evaluate green suppliers by combining fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS. Wu (2009) suggested a hybrid method to deal with supplier selection problems with fuzzy numbers based on GRA and Dempster–Shafer theory. In Deng and Chan (2011) a MCDM methodology, using fuzzy set theory and Dempster–Shafer theory, based on the main idea of the TOPSIS, was developed to deal with supplier selection under uncertain environments.

Previous studies have made significant contributions to supplier selection; however, the majority of researchers concentrated on supplier selection methods applying linguistic value by using fuzzy logic to handle the uncertainty in real decision making situations. As a result, an approximation process must be developed to express the results in the initial expression domain, which produces a loss of information and hence a lack of precision in the final results (Herrera & Martínez, 2000; Liu, Liu, & Wu, 2013). Furthermore, decision makers are often unsure of their preferences during the supplier selection process because of the reasons such as time pressure, lack of experience and data. They often demonstrate different evaluations or opinions from one to another and produce different types of assessment information for a certain alternative concerning a given criterion, some of which may be imprecise, uncertain and incomplete. These different types of information are very hard to incorporate into the supplier selection by using the crisp and fuzzy logic approaches. Whereas, the interval 2-tuple linguistic representation model (Liu, You, & You, in press; Zhang, 2012) overcomes the above-mentioned weaknesses. The advantages of this model are that decision makers can express their preferences by the use of linguistic term sets with different granularity of uncertainty and/or semantics (multigranular linguistic contexts), and their judgments can be expressed with an interval 2-tuple from the predefined linguistic term set. Therefore, the approach based on the interval 2-tuple linguistic representation model will be more flexible and precise to deal with linguistic terms in solving the supplier selection problems.

In other way, many quantitative and qualitative criteria (or factors) should be taken into consideration when selecting suppliers for an organization, including price, quality, delivery, service, reputation, and so on (Boran et al., 2009; Guo, Zhu, & Shi, 2014; Yücel & Güneri, 2011). In order to select the optimum suppliers it is necessary to make balance among these tangible and intangible factors some of which may conflict and compete like low price versus high quality. Moreover, there may be multiple decision makers taking part in the evaluation of alternatives together during the supplier selection process. Therefore, supplier selection is a kind of group MCDM problem (Deng et al., 2014) and MCDM techniques can be utilized to solve supplier selection problem of an organization. The VIKOR method, a very useful technique for MCDM, was first developed by Opricovic (1998) to solve a discrete decision problem with noncommensurable and conflicting criteria. This method focuses on ranking and selecting from a set of alternatives, and determines compromise solutions for a problem with conflicting criteria, which can help the decision makers to reach a final decision (Opricovic & Tzeng, 2007). The main advantages of the VIKOR method are that it introduces the multi-criteria ranking index based on the particular measure of "closeness" to the ideal solution (Opricovic & Tzeng, 2004), and the obtained compromise solution provides a maximum group utility for the "majority" and a minimum individual regret for the "opponent" (Opricovic & Tzeng, 2007). Due to its characteristics and capabilities, the VIKOR method has been widely studied and applied in group decision making problems in recent years (Liu, Mao, Zhang, & Li, 2013; Liu, Ren, Wu, & Lin, 2014; Liu, You, Fan, & Chen, 2014; Sanayei, Farid Mousavi, & Yazdankhah, 2010; Vahdani, Mousavi, Hashemi, Mousakhani, & Tavakkoli-Moghaddam, 2013).

The background introduced above shows that it may be inappropriate to use fuzzy logic based methods for evaluation and selection of suppliers because of the loss of information in the linguistic information processing. Moreover, decision makers tend to use different linguistic term sets to express their judgments on the subjective criteria, and there usually exists uncertain and incomplete assessments. In response, this paper develops a new group MCDM model using interval 2-tuple linguistic variables and extended VIKOR method to solve the supplier selection problems under uncertain and incomplete information environment. The proposed method can not only avoid information distortion and loss which occur formerly in the linguistic information processing, but also model the diversity and uncertainty of the assessment information provided by decision makers in supplier selection. Furthermore, both conflicting quantitative and qualitative criteria in real-life applications can be considered simultaneously in the developed method. The rest of the paper is organized as follows. In Section 2, some basic concepts of interval 2-tuple linguistic variables are briefly reviewed. In Section 3, an extended VIKOR approach is proposed to solve the group multi-criteria supplier selection problem with interval 2-tuple linguistic information. Three numerical examples are provided in Section 4 to illustrate the proposed approach and finally, some conclusions and future research directions are summarized in Section 5.

## 2. Preliminaries

### 2.1. 2-Tuple linguistic variables

The 2-tuple linguistic representation model was initiated by Herrera and Martínez (2000) based on the concept of symbolic