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Compound mechanism design of supplier selection based on multi-attribute auction and risk management of supply chain

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ABSTRACT

The quality of the supplier base affects the competitiveness of firms and the attendant supply chain. The supplier selection decision is key to effective supply chain management. This paper investigates the problem of supplier selection under multi-source procurement for a type of divisible goods (such as coal, oil, and natural gas). By considering both the risk attributes and the attributes under a commercial criterion, we design a new two-stage compound mechanism for supplier selection based on multi-attribute auction and supply chain risk management. In the first stage, a multi-auction mechanism is established to determine the shortlist among all qualified suppliers based on four attributes (quality, price, quantity flexibility, and delivery time reliability) under a commercial criterion. In the second stage, seven risk attributes against the shortlisted suppliers are further considered, and a new ranking method based on grey correlation degree of mixed sequence is proposed to rank the finalists and to select the final winners. Moreover, the implementation, availability, and feasibility of the two-stage compound mechanism are highlighted by using an example of the multi-source procurement of electricity coal. This presented compound mechanism may well improve the procurement efficiency of divisible goods and greatly reduce the procurement risk.

1. Introduction

Suppliers have several roles under supply chain management: to manufacture parts and components for their customers, to ensure product quality and assurance, to indirectly help manage the cost over-runs of their downstream partners in the supply chain. As such, a supplier's production capacity can limit the output level of the entire supply chain. Further, a supplier's quality level determines the quality assurance of the final product, and the supplier's cost control affects the cost control capacity of the entire supply chain, and the supplier's new product development capacity influences the quality and cycle of the new product development. In short, the supplier is the foundation of supply chain operation, and is key to the competitiveness of the supply chain for a focal firm (Adida & DeMiguel, 2011; Azadi, Jafarian, Saen, & Mirhedayatian, 2015; Li, 2013; Rao, Zhao, Zheng, Wang, & Chen, 2016b).

As a supply chain grows in scale and operations, its structure will become more complicated. This then engenders greater supply chain risk (Cárdenas-Barrón, González-Velarde, & Treviño-Garza, 2015; Federgruen & Yang, 2008; Ma, Lin, & Chen, 2000). Thus, in managing this risk, by sharing supply chain information for all members, improving the overall flexibility of the supply chain, and enhancing the competitiveness of supply chain, managers can better assess, control, and act on the risks resident in the chain (Aqlan & Lam, 2015; Ho, Zheng, Yildiz, & Talluri, 2015). In this regard, the evaluation and selection of suppliers are imperative in the risk control of a supply chain. Through better supplier evaluation and selection, we can effectively reduce a chain's operational risk.

The extant literature has studied supplier evaluation and selection, in particular, the design of a system for supplier evaluation and the methods and models of supplier selection (Yu, Kaihara, Fujii, Sun, & Yang, 2015). On the supplier evaluation system, Dickson first proposed 23 attributes such as quality, delivery time,

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historical performance as the evaluation measures (Dickson, 1966). Then, Weber reviewed, annotated, and classified 74 related articles which have appeared from 1966 to 1990, and ranked all the attributes in these articles. He concluded that price, delivery time, quality, and capacity are the most important evaluation attributes (Weber, Current, & Benton, 1991). Later, Choy and Lee (2003) studied the problem of evaluating and selecting the outsourcing of suppliers in the manufacturing industry, and chose manufacturing capacity, product price, delivery time, shipping quality, product development, process improvement, sales performance, marketing objectives, quality planning as the evaluation attributes to select the manufacturing outsourcing suppliers. Wilson (2006) studied the relative importance of supplier selection criteria, and constructed an index system formed by quality, price, service, technology, finance, location, reputation, and mutual benefits to comprehensively evaluate the suppliers. For firms that rely on a just-in-time production system, Willis, Huston, and Pohlkamp (2005) proposed a supplier evaluation system of 8 attributes (quality, price, order response speed, customer service, inventory planning, delivery time, financial health, and ease of ordering). Similarly, Patton (2008) proposed a system of supplier evaluation with Willis using price, quality, delivery time, sales support, equipment and technology, order situation, and financial health. Yahya and Kingsman (2009) interviewed 16 senior executives and proposed a similar evaluation system to Willis et al. and Patton. Moreover, Patton weighted all the attributes using AHP. Petroni and Braglia (2010) used Principal Components Analysis to construct a system of supplier evaluation from a supply chain perspective. The composition of Bragha's system is similar to the system with Patton, less the attributes of sales support and financial health, but included the attribute of management capacity. Menon, McGinnis, and Ackerman (2008) studied supplier selection for third-party logistics services, and established a supplier evaluation system that included price, delivery punctuality, management efficiency, corporate reputation, financial health, ability to implement the contract and disruption responsiveness, and empirically validated the effectiveness of the selection system. Shemshadi, Shirazi, Toreihi, and Tarokh (2011) chose product quality, effort to establish cooperation, supplier's technical level, supplier's delay on delivery and price/cost to evaluate and rank suppliers. Similarly, Chen and Wu (2013) proposed cost, quality, deliverability, technology, productivity, service to select new suppliers from a supply chain risk's perspective and AHP to determine the weight of each attribute.

On the methods and models to evaluate suppliers, research has proposed various evaluation schemes. These can be divided into three categories. First, the qualitative selection methods (Ma et al., 2000), for example, the judgment method based on direct experience, and the consultation choice method. Qualitative selection methods are simple and practicable, albeit too subjective and lack science and rationality to make choices based on experience or some certainty attributes. Quantitative selection methods, such as linear weighting (Ma et al., 2000), benefit-cost analysis (Federgruen & Yang, 2011; Hammami, Temponi, & Frein, 2014), new normalized goal programming (Jadidi, Zolfaghari, & Cavalieri, 2014), locally linear neuro-fuzzy model (Vahdani, Iranmanesh, Mousavi, & Abdollahzade, 2012), fuzzy integral-based model (Liou, Chuang, & Tzeng, 2014), believable rough set approach (Chai & Liu, 2014), integrated data envelopment analysis (DEA) (Toloo & Nalchigar, 2011), Green DEA (Kumar, Jain, & Kumar, 2014), multi-objective integer linear programming (Choudhary & Shankar, 2014), multi-objective linear programming (Arikan, 2013), mixed integer programming (Rezaei & Davoodi, 2011; Ventura, Valdebenito, & Golany, 2013; Zhang & Chen, 2013), multi-choice goal programming (MCGP) approach (Jadidi, Cavalieri, & Zolfaghari, 2015), Possibilistic programming (Li, 2014), algorithm for linearly constrained C-convex vector optimization (Qu, Goh, Ji, & Robert, 2015), Bayesian network model (Hosseini & Barker, 2016), multi-criteria DC programming (Ji & Goh, 2016), two-stage stochastic mixed-integer programming model (Amorim, Curcio, Almada-Lobo, Barbosa-Póvoa, & Grossmann, 2016), and two-level genetic algorithm (Aliabadi, Kaazemi, & Pourghannad, 2013), are better than the qualitative selection methods, and can solve specific problems under a deterministic environment, but the quantitative selection methods are generally based on deterministic evaluation attributes, and are difficult to quantify some qualitative attributes, and are thus unable to meet all requirements of processing uncertain information in a supply chain environment. The hybrid of quantitative and qualitative methods, such as integrated fuzzy MCDM approach (Karsak & Dursun, 2015), integrated approach based on Weighted Aggregated Sum Product Assessment (WASPAS) method (Ghorabaee, Zavadskas, Amiri, & Esmaeili, 2016), integrated approach including F-AHP and MILP model (Ayhan & Kilic, 2015), clustering method based on interval type-2 fuzzy sets (Heidarzadea, Mahdavi, & Mahdavi-Amiri, 2016), fuzzy AHP (Shawa, Shankar, Yadav, & Thakur, 2012), D-AHP (Deng, Hu, Deng, & Mahadevan, 2014), integrated fuzzy TOPSIS and MCGP (Liao & Kao, 2011), integrated approach including fuzzy techniques for order preferences by similarity to ideal solution (TOPSIS) and a mixed integer linear programming model (Kilic, 2013), parameterized non-linear programming approach (Li & Liu, 2015), Hesitant fuzzy linguistic VIKOR method (Liao, Xu, & Zeng, 2015; Liao, Xu, Zeng, & Xu, 2016), ranking method of fuzzy inference system (Amindousta, Ahmeda, Saghafiniab, & Bahreininejada, 2012) approach based on adaptive neuro-fuzzy inferences (Güneri, Ertay, & Yücel, 2011), method combined grey systems theory and uncertainty theory (Memon, Lee, & Mari, 2015), meta-approach by integrating multi-criteria decision analysis and linear programming (LP) (Sodenkamp, Tavana, & Caprio, 2016), and weighted max–min models (Amid, Ghodsypour, & O'Brien, 2011), however, is better at solving such problems more scientifically and rationally.

From above literature review, we can conclude that the study of supplier evaluation and selection has been a hot research direction of supply chain management, and the recent research has the following characteristics. Firstly, the evaluation criteria and index system gradually become systematic, diverse and comprehensive. The original single evaluation which only considers the production factors such as quality, price and cost is gradually replaced by the comprehensive evaluation by considering many aspects such as production, service, cooperation, and environmental (Hashemi, Karimi, & Tavana, 2015; Orji & Wei, 2015; Rezaei, Nispeling, Sarkis, & Tavasszy, 2016; Yu, Xue, Sun, & Zhang, 2016). So the evaluation index system is more comprehensive, and the evaluation results are more scientific. Secondly, the evaluation methods and models tended to more and more reasonable from the original mainly qualitative judgment, gradually to develop in the direction of the combination of qualitative and quantitative. On model applications, it is from using a single model to evaluate, gradually to develop in the direction of the combination evaluation with multiple models. Thirdly, the evaluation object gradually refined from the original general studies to steer specific industries and specific supplier evaluation. And some studies have proposed different evaluation index system for different industries and suppliers.

However, there are also some disadvantages for existing studies. First, no clear evaluation measurement standards are given for some evaluation indexes. And these index data is rarely combined with enterprise's actual demand, so it is difficult to apply in practice. Secondly, the evaluation index weight determination and the evaluation results are over-reliance on mathematical models, so the limitations of the model itself may affect on the accuracy of the evaluation results. Third, in the supplier evaluation, most of