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Supplier selection using ANP and ELECTRE II in interval 2-tuple linguistic environment

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ABSTRACT

In supply chain management, supplier selection can be treated as a type of hierarchical multi-criteria decision-making (MCDM) problems since it involves various criteria and hierarchical structure among criteria often exists. This paper investigates a kind of MCDM problems with two-level criteria and develops a novel hybrid method integrating TL-ANP (2-tuple linguistic analytic network process) and IT-ELECTRE II (interval 2-tuple Elimination and Choice Translating Reality II). Considering interactions among criteria, a TL-ANP approach, in which comparison matrices are consistent 2-tuple linguistic preference relations, is put forward to determine weights of criteria and sub-criteria. To deal with the case of criteria being not compensated, an IT-ELECTRE II approach is proposed. In this approach, ratings of alternatives on sub-criteria are represented as interval 2-tuple linguistic variables. A possible degree and a likelihood-based preference degree are respectively defined, followed by concordance, discordance and indifferent sets. Afterwards, concordance and discordance indices are identified and applied to establish net concordance and net discordance indices. Further, comprehensive dominant values of alternatives are obtained to rank alternatives. Thereby, a novel hybrid method is presented for MCDM with two-level criteria under interval 2-tuple linguistic environment. At length, a real case of supplier selection is examined and comparison analyses are conducted to illustrate the application and superiority of the proposed method.

1. Introduction

With the acceleration of economic globalization process, today's enterprises are exposed to fierce competition. To attract more customers, many enterprises improve the quality and reduce cost (price) of their products. In this process, the raw material supplier plays an important role. Therefore, Enterprises must select appropriate suppliers and retain good relations of cooperation with them. While selecting suppliers, various criteria are involved and some of them are conflict, such as quality and cost. Hence, the supplier selection can be considered as a kind of multi-criteria decision-making (MCDM) problems [8,26,34–36]. Current research on supplier selection mainly focuses on two key issues: evaluation criteria identification and decision-making methods.

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Table 1
Criteria and corresponding sub-criteria for supplier selections.

Criteria	Sub-criteria	Literature
Quality	Quality performance; Quality containment & VDCS feed back	Yang and Tzeng [41]
Price & Terms	Price; Terms; Responsiveness; Lead time, VMI/VOI hub set up cost	
Supply chain support	Purchase order reactiveness; Capacity support & flexibility; Delivery/VMI operation	
Technology	Technical support, Design involvement; ECN/PCN process	
Cost	Product price, Freight cost; Tariff and custom duties	Chen and Yang [2]
Quality	Rejection rate of product; Increased lead time; Quality assessment; Remedy for quality problems	
Service performance	Delivery schedule, Technological and R & D support; Response to changes; Ease of communication	
Supplier Profile	Financial status, Customer base; Performance history; Production facility and capacity	
Risk	Geographical location, Political stability; Economy, Terrorism	
General management capability perspective	Management and strategy; Financial status; Customer relations; Training program; Reputation, History; Language; License; Geographical location	Lee et al. [16]
Manufacturing capability perspective	Production capacity; Product diversity; R & D capability, Safety regulations; Environmental regulations, Quality control; Product price	
Collaboration capability perspective	After-sales service, Delivery reliability	
Agility perspective	Delivery speed; Delivery flexibility; Make flexibility; Source flexibility; Agile customer responsiveness; Collaboration with partners, IT infrastructure	

For evaluation criteria identification, Dickson [6] firstly performed an investigation and proposed 23 different criteria including quality, on-time delivery, price, performance history, warranties policy, technical capability, etc. Among these criteria, the first three criteria are most popular and applied in many supplier selection problems [2,16,27,41]. Subsequently, a lot of new evaluation criteria were introduced, such as finance, management and reputation, service, etc. According to these criteria, different sub-criteria [2,16,41] were presented and listed in Table 1.

In the regard of decision-making methods, earlier studies adopted some classical methods to solve supplier selection problems with crisp numerical assessment information, such as AHP (Analytic Hierarchical Process) [20], ANP (Analytic Network Process) [32] and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) [17]. However, as the complexity of decision-making problems increases, decision information is more and more vague. In this context, Pedrycz [24,25] suggested that linguistic variable [7,18] is suitable to describe quantitative assessment information. For example, when we evaluate the reputation of a supplier, terms like “poor”, “good” and “very good” are usually employed. By converting linguistic variables into triangle fuzzy numbers (TFNs), many fuzzy decision methods [1,11,14,16,21,27,28,33] have been proposed. Roughly speaking, these methods can be divided into two classes: single methods and hybrid methods.

Common single methods are fuzzy AHP (FAHP) [27], fuzzy ANP (FANP) [33] and fuzzy TOPSIS (FTOPSIS) [28]. Hybrid methods are those which fuse at least two single methods. Generally, some single methods are used to determine criteria weights and others are applied to rank suppliers. For example, considering that criteria are independent on each other, Hashemian et al. [11] and Lee et al. [16] derived criteria weights by FAHP, and then ranked suppliers by fuzzy PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation) and FTOPSIS, respectively. Considering interactions among criteria, Nguyen et al. [21] used FANP to determine criteria weights and adopted COPRAS-G (Complex Proportional Assessment of alternatives with Grey relations) to rank suppliers; Büyüközkan and Çifçi [1] obtained criteria weights by fuzzy DEMATEL and FANP, and sorted suppliers by FTOPSIS; Karsak and Dursun [14] used QFD (Quality Function Deployment) to derive criteria weights, and then applied DEA (Data Envelopment Analysis) to rank suppliers.

The aforementioned methods demonstrate that most researchers solved supplier selection problems by transforming linguistic variables into TFNs. As a result, computation results usually do not exactly match any of initial linguistic terms and an approximation process must be used to express results in the initial expression domain, which easily leads to loss of information and lack of precision in the final results. To overcome these limitations, Herrera and Martínez [12] introduced 2-tuple linguistic representation model which consists of a linguistic term and a numeric value. The main advantage of this representation is to be continuous in its domain. Therefore, it can express any counting of information in the universe of the discourse. Subsequently, Zhang [44] further extended the 2-tuple linguistic variable into the interval 2-tuple linguistic variable. In 2-tuple linguistic context, Wang [37] proposed Hierarchy Arithmetic Weighted Average approach to rank suppliers; Karsak and Dursun [15] used QFD to give a decision framework for medical supplier selection problems. You et al. [42] addressed an interval 2-tuple linguistic VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje technique) method to tackle anesthetic equipment supplier problems. However, methods [37, 42] assumed that criteria are independent and assigned criteria weights in advance.

Though previous linguistic decision making methods can solve some supplier selection problems, there are some shortcomings: (1) Fuzzy decision methods [1,16,21,28,33] may result in information loss or distortion. (2) Although 2-tuple decision methods [37,42] can overcome the information loss, they did not consider interactions among criteria. The phenomena of interaction among criteria often exist in real-world decision making problems. For instance, while evaluating a