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Supplier selection in nuclear power industry with extended VIKOR method under linguistic information

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ABSTRACT

With Chinese nuclear power restarting, supplier selection in quality-sensitive nuclear power industry has become increasingly urgent and necessary. However, the current research on supplier selection in nuclear power industry is rather few. Moreover, there is still one great problem in the present methods: the description of the information uncertainty is inadequate. This paper proposes an extended VIsekriterijumska Optimizacija I Kompromisno Resenje (VIKOR) under linguistic information to evaluate the uncertainty of potential supplier quantitatively and scientifically. The cloud model is used to handle imprecise numerical quantities, which can give consideration to both fuzziness and randomness of uncertain information. An empirical example of a nuclear power plant in China illustrates an application to supplier selection in nuclear power industry, which proves the effectiveness of the proposed method. Finally, a comparative analysis with fuzzy VIKOR and sensitivity analysis of results are presented to verify the correctness and robustness of the extended method respectively.

1. Introduction

The nuclear power industry belongs to a quality-sensitive one, as nuclear power plants have an extremely high request for the security and reliability compared with the conventional ones. Once nuclear incidents appear, the consequences will be significantly catastrophic. And China put its nuclear power projects on hold to assess safety concerns due to Japan's Fukushima disaster. Chinese government approved the resumption of nuclear energy until the first quarter of 2015, facing triple pressure of environmental, energy and economic. Given the booming construction of nuclear plants and stricter security requirements in recent five years, supplier selection in nuclear power industry in China has become increasingly urgent and necessary. However, very few scholars, such as Yang, Huang and Lei [1], kept supplier selection in nuclear power industry in their study. Currently, the research on supplier selection mainly focus on manufacturing industry [2], automotive industry [3], household appliance industry [4], electronic industry [5], airline retail industry [6] and so forth.

Selecting the best supplier from a large number of alternatives involves many complex and time-consuming tasks [7]. Actually, many tasks may be meaningless and unnecessary due to invalid alternatives. To optimize decision process and improve the efficiency of management, we propose a two-stage methodology for the supplier selection in nuclear power industry. These two subsequent stages are defined as phase I (Qualification) and phase II (Ranking), respectively. Phase I aims to select the qualified suppliers, which firstly ensures the final selected supplier can meet requirements, and secondly reduces the complexity of decision-making by avoiding useless tasks. For phase II, we propose an extended VIsekriterijumska optimizacija i KOmpromisno Resenje (VIKOR) method under linguistic information.

When selecting the optimal supplier, quite a few criteria, including qualitative and quantitative ones, should be taken into consideration, such as quality, cost and technological capacity and the like. Thus, supplier selection is a multi-criteria decision-making (MCDM) problem. And the VIKOR method, based on an aggregating function representing "closeness to the ideal" using linear normalization, has been widely used for supplier selection [8–11]. It considers group utility maximization and individual regret minimization and fully reflects the decision makers' subjective preferences, which makes it superior to some traditional MCDM methods [12,13]. In decision situations, some problems present qualitative aspects that are complex to assess by means of

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precise [14,15], and thus, the use of a linguistic approach is necessary [16,17]. For supplier selection in nuclear power industry, some performance values cannot be assessed precisely in a quantitative form but may be in a qualitative one, such as service, credit, environmental consciousness. By the use of a linguistic approach, the experts can easier express their perception preferences about the alternatives [18]. As the natural language is the standard representation of those concepts that humans use for communication [19], the application of the qualitative concept makes communication among experts comprehensive and cognitive, and also can largely facilitate experts' work [20]. However, natural languages usually involve ambiguity and uncertainty, so it is difficult to form an exact definition of linguistic information. Among the uncertainties involved in natural language, randomness and fuzziness are the two most important aspects [21]. Fortunately, the proposed extended VIKOR can express human fuzziness and randomness with cloud variables, which can effectively improve decision quality.

This paper aims to design an applicable method for supplier selection in nuclear power industry. The main contributions of this article are: Firstly, there is no investigation of supplier selection in nuclear power industry using extended VIKOR with cloud variables. Therefore, this is the first work attempting to use this technique to select the best supplier, which can enrich research idea and provide reference for practice. Secondly, the proposed method can promote the accuracy and quality of decision-making. The VIKOR method is applied to aggregate the whole criteria, which can fully consider the relative importance of the criteria, and a balance between total and individual satisfaction. And the cloud model is introduced to describe the information uncertainty, which can give consideration to both fuzziness and randomness to reduce information loss. Both efforts contribute to a better decision-making. Thirdly, the decision process and management efficiency can be improved. By designing the two-phase method, the unqualified suppliers will be excluded in an early stage, which avoids the unqualified ones to participate in the selection from beginning to end. The tasks related to the unqualified suppliers can be substantially decreased. And the final selected supplier must conform to the fundamental requirements.

The remainder of the paper is structured as follows. Section 2 reviews supplier selection methods and analyzes the detailed sub-criteria of criteria considered for the selection of suppliers in the nuclear industry. A two-phase extended VIKOR method under linguistic information is proposed in Section 3. In Section 4, a case study from China is evaluated. And results and discussion are shown in Section 5. Subsequently, final conclusion is provided in Section 6.

2. Literature review

2.1. Supplier selection methods

Currently, the research on supplier selection methods in nuclear industry is very few. Yang, Huang and Lei [1] proposed an integrated framework based on analytic hierarchy process (AHP) and technique for order preference by similarity to an ideal solution (TOPSIS) for selecting the suitable supplier. Besides, some MCDM methods used for supplier selection can be listed as follows: analytic network process (ANP) [22–24], preference ranking organization method for enrichment evaluations (PROMETHEE) [25] and elimination et choice translating reality (ELECTRE) [26,27] and other hybrid methods integrating fuzzy set theory [28,29], etc. A disadvantage of AHP and ANP is that exact numerical values are needed for the pair-wise comparison judgments, which is difficult for DMs to express due to the perceptual preference and uncertainty [4,6]. The TOPSIS method uses vector normalization to introduce two reference points, failing to consider the relative importance of the distances from these points [12,13]. PROMETHEE can't satisfy the independence from irrelevant alternatives. In other words, increasing or decreasing an alternative will influence the final results, which may limit its application. And ELECTRE can't make the best of decision information, which may lead to decision mistakes.

Based on the above analysis, The VIKOR method is used for supplier selection in nuclear industry. As VIKOR is applicable to rank and select a set of conflicting alternatives in MCDM problems. Compared with other MCDM methods, VIKOR has the following advantages: ① By using linear standardization, it is not affected by individual indicators unit [12]; ② Sorting theory is reasonable. It can give consideration to both group utility maximization and individual regret minimization [10,30–32]. Therefore, the final optimal solution is a compromise with priority, which is more likely to be accepted by DMs. Also because of the advantages, VIKOR has been widely used in many areas, such as selection of supplier [9,11,33,34], site [35], material [36,37], project [38,39], assessment of risk [40,41], entrepreneurial intensity [42], quality [43,44] and so on. All above research have proved the effectiveness and correctness of VIKOR.

Decision quality is greatly influenced by the MCDM methods. However, traditional VIKOR has displayed limitation in describe criteria or sub-criteria information under linguistic environment, which will lead to loss of information and accuracy. Many research proposed extended VIKOR method to solve that problem. Jahan and Edwards [45] extended VIKOR to interval numbers for material selection; literature [46] proposed an integrating VIKOR with interval numbers. Kuo and Liang [43], Bazzazi, Osanloo and Karimi [47] and Rezaie, Ramiyani, Nazari-Shirkouhi and Badizadeh [48] proposed extended VIKOR with triangular fuzzy number for MCDM problems. Girubha and Vinodh [36] integrated trapezoidal fuzzy number with VIKOR to select the best material of an automotive component; and Ju and Wang [49] extended VIKOR to trapezoidal fuzzy number to solve MCDM problems. By integrating with fuzzy set theory, the extended VIKOR can reduce the uncertainty to some extent. In order to exactly and fully describe the information uncertainty, some scholars introduced fuzzy sets and 2-tuple linguistic fuzzy sets into their research. Wei and Zhang [50] proposed an extended VIKOR method based on hesitant fuzzy set; Devi [51] proposed extended VIKOR with triangular intuitionistic fuzzy number for robot selection; Qin, Liu and Pedrycz [52] and Ghorabaee, Amiri, Sadaghiani and Zavadskas [53] extended VIKOR to interval 2-tuple linguistic fuzzy sets to solve MCDM problems. Although the latter ones can reduce more information uncertainty compared with the former ones, they still only work from the perspective of fuzziness. Actually, randomness and fuzziness are the most important and fundamental in all kinds of uncertainty [54]. In other words, the randomness of the information has not been paid attention in above research.

As to the analysis above, cloud theory put forward by Deyi, Haijun and Xuemei [55] is introduced in this paper. Cloud theory can give consideration to the randomness and fuzziness of information, which can reduce greatly loss of information. It has been extensively studied and applied by scholars. Wang, Xu and Li [56] proposed a 2nd-order generic normal cloud model and carried on the thorough analysis and discussion; Wang, Peng, Zhang, Liu and Chen [57] proposed an uncertain linguistic MCDM method based on a cloud model; Li, Liu, Yang and Li [58] applied cloud model for the comprehensive evaluation of smart distribution grid. Besides, some researchers applied it for risk management [59,60] and route assessment [61]. The above mentioned researches proved the effectiveness and correctness of cloud theory from two aspects of theory and practice. In conclusion, the combination of cloud and VIKOR is meaningful and beneficial work, which will contribute to a