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Evaluation and Selection of Steel Raw Material Suppliers in the Context of ESG

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Abstract

With the rapid development of the world economy, Environmental pollution is becoming increasingly serious. For the steel industry, high-quality steel raw material suppliers can help steel enterprises better improve steel quality and achieve ESG (Environmental, Social and Governance-related) friendliness. And gain a competitive advantage. Therefore, this paper proposes a new model based on IVPFS(Interval-Valued Pythagorean Fuzzy Set) and CoCoSo (Combined Compromise Solution) to solve the problems in vendor evaluation process. In this paper, the ambiguity and uncertainty in expert evaluation can be solved by introducing interval-valued fuzzy sets. On this basis, Analytic Network Process (ANP) method is used to calculate the weights of evaluation indicators, and CoCoSo method is used to sort alternative suppliers.The method proposed in this article is conducive to urging relevant enterprises to make improvements and provides a new direction for enterprise transformation.

Keywords

Supplier Selection; Interval-Valued Fuzzy Set; ANP Method; CoCoSo Method.

1. Introduction

With the development of the global economy and the acceleration of industrialization, while humans enjoy the tremendous achievements brought by modern life and technological progress, multiple pressures such as energy and resource shortages, ecological and environmental distress, and prominent social issues are increasing day by day [1]. With the establishment of the "dual carbon" goals and the enhancement of social awareness of a low-carbon environment, green and low-carbon development has become a broad consensus across society [2]. The 14th Five-Year Plan also points out [3] that we must accelerate green transformation, adhere to ecological priority, pursue green development, synergize high-quality development with high-level ecological and environmental protection, uphold the concept that clear waters and lush mountains are invaluable assets, and implement a sustainable development strategy. Moreover, under the "dual carbon" goals, ESG (Environmental, Social, and Governance-related) reports have become an important foothold for policies. Within the broad framework of global sustainable development, enterprises are not only the main driving force of economic growth but also important participants in achieving sustainable development goals. Therefore, the ESG performance of enterprises is crucial for their long-term development, competitiveness, and global sustainable development.

The steel industry is an important basic industry in the national economy, greatly promoting China's economic development. Steel products penetrate into people's production activities, all aspects of life, transportation, and more. It can be said that people are exposed to steel products all the time. At the same time, the development of the steel industry often means "high emissions", "high pollution", and "high energy consumption". Therefore, in order to achieve the "dual carbon" goals, it is necessary to promote green and low-carbon development of steel enterprises. Most steel raw materials are non-renewable resources, so mining raw materials

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and smelting steel will cause environmental pollution. At the same time, the depletion of natural resources is an inevitable problem, making green development an inevitable choice. According to relevant statistical data, China's steel production accounted for 53.9% of the global total in 2022, with over 5 trillion tons of production capacity completed or undergoing ultra-low emission transformation. The atmospheric pollution emission intensity of some key steel enterprises has reached the world's advanced level [4]. Choosing the right suppliers for steel enterprises not only helps their long-term development and reflects their own value, but also helps alleviate environmental pressure and achieve sustainable development in the industry and society.

Compared to traditional supply chains, green supply chains fully integrate the concept of "green production". As raw material suppliers in the upstream position of the steel industry supply chain, the quality of the raw materials or services they provide not only directly affects the quality of the final steel products of downstream enterprises, but also determines the potential for environmental protection and production efficiency. High-quality suppliers can not only help enterprises improve product quality but also reduce costs and increase efficiency, giving enterprises a core competitiveness.

The supplier selection problem in the steel industry often involves multiple indicators, representing a multi-criteria decision-making issue. However, in real-world scenarios, the evaluation information provided by each expert is subject to uncertainty and ambiguity. Furthermore, the supplier evaluation process is complex, involving numerous indicators, each with varying contributions to the outcome. Consequently, it becomes challenging to make the right choice among alternative suppliers.

2. Research on corporate ESG

Since the Global Compact (UN Global Compact) first introduced the ESG concept in "Who Cares Wins" in 2004[5], the concept of ESG has rapidly gained popularity worldwide. As the pursuit of sustainable development increasingly aligns with the global agenda, the importance of ESG in academic and practical research across various industries has been elevated. ESG performance evaluates the environmental, social, and governance factors of steel raw material suppliers to determine their sustainable development effectiveness and social responsibility.

Internationally, the ideas and theories of ESG performance can serve as a quantitative system for evaluating corporate sustainability, which is explained by Drempetic S [6] based on organizational legitimacy. Meanwhile, Francisco D et al. [7] propose that the perception of organizational legitimacy is influenced by different factors at both micro and macro levels, analyzing the impact of legitimacy standards on different types of organizational legitimacy. Under the domestic implementation of the "1+N" dual-carbon policy, Han Yiming et al. [8] found that strengthening ESG practices can enhance the stability of the supply chain, thereby facilitating high-quality development of enterprises. This, in turn, helps enterprises to increase social value, grasp technological and core competitiveness, enhance product and service quality, and build a good social image. Wang Sanxing and Wang Ziming [9] analyze the path through which ESG enhances total factor productivity from a new perspective, providing a practical and reliable basis for enterprises to better serve China's high-quality economic development and sustainable development through ESG construction.

3. Fuzzy sets and their applications

The Interval-Valued Pythagorean Fuzzy Set (IVPFS) is a further improvement based on Pythagorean Fuzzy Sets (PFS). Previous research has focused on the classic Type 1 fuzzy sets [10] in fuzzy set theory, characterized by a clear membership function in the interval [0,1], but it cannot fully support the types of uncertainty that arise in linguistic descriptions of numerical

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quantities or in subjective expressions of expert knowledge. Based on Type 1 fuzzy sets, Interval Type 2 fuzzy sets [11] were introduced to address decision-making issues in high-tech projects, but they still cannot express non-membership and degrees in the expert decision-making process.

Intuitionist Fuzzy Set (IFS) [12] can incorporate member characteristics, yet it cannot convey the more comprehensive opinions of experts. PFS, an extension of IFS, was developed by Yager R and Abbasov A M [13] specifically to address the shortcomings of the IFS method. IVPFS allows for interval values for both membership and non-membership of a given set [14], making it suitable for capturing uncertain information in the process of selecting steel raw material suppliers [15].

4. Research on evaluation indicators for steel raw material suppliers

Due to the increasingly severe global climate issues, green and low-carbon practices are not only a requirement for manufacturers from customers, but also among manufacturers themselves, and have become a widespread consensus across society. The main challenge in the supplier selection process is establishing appropriate and correct evaluation criteria. For the selection of steel raw material suppliers, there are primarily four criteria: environmental, social, governance, and supplier qualification. Shen L et al. [16] conducted a comprehensive evaluation of nine evaluation indicators for supplier production, including pollution generation, resource consumption, use of environmental protection technology, environmental management systems, etc. In Azimifard A et al.'s [17] study on supplier selection in Iran's steel industry, the main selection criteria included water consumption, carbon monoxide emissions, distance from the supplier's country/region to the destination, and the number of employees in the supplier's country/region's industry, in order to select the best sustainable suppliers. Javad M O M et al. [18] evaluated green suppliers by dividing indicators into seven categories: cooperation, environmental investment and economic benefits, resource availability and green capabilities, environmental management measures, research and design plans, green procurement capabilities, regulatory obligations, pressure, and market demand. This approach facilitates long-term cooperation between buyers and suppliers. Kumar S et al. [19] considered seven different criteria based on four decision-making alternatives for core materials in the steel industry, namely environmental protection technology, environmentally friendly materials, management commitment, lean process planning, employee training, cooperation with green organizations, and pollution control measures. Mostafa H et al. [20] proposed that in addition to service standards, cost, quality, production standards, etc., ecological design, transportation, waste management, environmental protection technology, employee training, green image, environmentally friendly materials, and environmental management systems should also be considered. Wang Xu et al.[21] obtained a preliminary indicator system through questionnaire collection and analysis, and then used factor analysis to divide the indicator system into supplier qualification, supplier capability, supplier culture, and supplier environmental awareness. Subsequently, Wang Daoping and Wang Xu [22] distributed questionnaires to various steel enterprise procurement departments through a website platform. After data processing, membership degree analysis, and correlation analysis, they constructed a green supplier selection indicator system based on criteria such as environmental protection, supplier development potential, supplier qualification, philosophy, price, and quality.

5. Research on the selection method of steel raw material suppliers

The research on the selection method of steel raw material suppliers can assist enterprises in choosing suppliers that align with environmental sustainability requirements. Essentially, it

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involves evaluating suppliers from various dimensions. This article primarily explores distance-based methods, trade-off-based methods, composite models, and other steel raw material supplier selection methods, aiming to select suppliers that meet environmental development requirements.

(1) Distance-based method

Common distance-based methods for supplier selection include the DEMATEL method (Decision-Making Trial and Evaluation Laboratory-based Analytic Network Process), the GRA method (Grey Relational Analysis), and the TOPSIS method (Technique for Order Preference by Similarity to an Ideal Solution).

Azadeh J et al. [23] employed the DEMATEL model to assess the internal relationships among criteria and utilized the Analytic Network Process (ANP) to assign weights. Subsequently, the layers were superimposed using the overlay technique. Finally, the natural break classification method was adopted to categorize the resilience layers into low, medium, and high levels. Xu Jinbo and Cao Jingjing [24] delved into the intrinsic mechanism of how different dimensions and factors influence the development of cross-border e-commerce, as well as identifying key dimensions and factors, through DEMATEL. Zhao Lu et al. [25] focused on the cost of military complex equipment, screened similar samples and key cost elements through Grey Relational Analysis (GRA), calculated the comparative importance of each element, and thereby determined the weights. Peng Dinghong and Song Bo[26] took an internet company as an example, conducted a graded evaluation of Customer Service Unit (CSU) behavior based on the TOPSIS-Sort-C classification framework, and summarized a series of metrics to measure the trust level of CSU behavior. Ultimately, a set of evaluation indicators for CSU behavior information was formed, and the weights of each indicator were determined.

(2) Based on a compromise approach

Common methods based on compromise include the VIKOR method (VIekriterijumsko KOmpromisno Rangir-anje), the CoCoSo method (Combined Compromise Solution), the AHP method (Analytic Hierarchy Process), and so on.

Schramm B V et al. [27] proposed that VIKOR is one of the three most commonly used methods in Multi-criteria Decision Making (MCDM). Rodrigues F L et al. [28] suggested combining VIKOR with fuzzy set theory to handle uncertainty and quantify experts' linguistic judgments. Gholamreza H et al.[29] used a method based on Design Modeler (DM) and experts' fuzzy ZE-CoCoSo to calculate, compute each initial matrix, and have each expert vote. They used an equation to evaluate the proportional weight of alternative solutions, ultimately determining the best urban transportation alternative for Mexico City. Wang Haolun [30] proposed a multi-attribute SPBRT (SpanBERT) selection method based on the ILRHM aggregation operator and improved CoCoSo. This method allows for the adjustment of four parameters and analyzes changes in these parameters to examine their impact on decision-making results. Zou You et al. [31] employed the Analytic Hierarchy Process (AHP) to construct target, criterion, and scheme layers, then conducted hierarchical and graded assignment, and referenced previous scholars' opinions for scoring. They sorted the indicators at each level to obtain the evaluation results of ecotourism carrying capacity.

(3) Composite model

The composite model combines multiple evaluation indicators and methods, allowing for a comprehensive consideration of environmental performance and sustainable development factors of steel suppliers. Lima-Junior R F et al. [32] proposed a method combining SCOR® and fuzzy TOPSIS, which is not limited to the number of evaluation schemes and can avoid the ranking reversal problem, thereby assisting in supplier evaluation and management. Barrios O M et al. [33] introduced a new model for selecting sustainable suppliers, combining the FAHP method with the FDEMATEL method to determine the weights of sub-criteria, and using the

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TOPSIS method to rank supplier alternatives, thus helping companies develop better sustainable suppliers. Methods such as SWARA (Stepwise Weight Assessment Ratio Analysis), MOORA (Multi Objective Optimization on the basis of Ratio Analysis), and WASPAS (Weighted Aggregated Sum Product Assessment) all belong to multi-objective optimization. Ashutosh C et al. [34] used a hybrid combination of SWARA-MOORA and SWARA-WASPAS, combining the subjective and objective weights of decision-makers to obtain more realistic weights, ultimately selecting the best fruit drying scheme from six different drying methods. Salma K et al.[35] used the q-Rung Orthopair Fuzzy Hypersoft Set (q-ROFHSS), a hybrid of super soft and q-rung orthogonal pair fuzzy sets, to address the uncertainty in selecting green suppliers. Mostafa H et al. [36] proposed combining sets with Pythagorean Fuzzy (PF-TOPSIS) to evaluate five cardboard box suppliers, and compared the results with those obtained using the classic TOPSIS method, concluding that the proposed method is consistent and effective. Zhang Ni et al.[37] proposed an improved method integrating NHFLS and priority QUALIFLEX, which can avoid distortions in decision-makers' original information and subjective factors affecting the ranking results during supplier selection, greatly reflecting the decision-makers' true evaluations.

(4) Selection methods for other steel raw material suppliers

In addition to the above methods, there are other methods for selecting steel raw material suppliers that can be considered, such as the Best-Worst Method (BWM), Linear Programming Techniques for Multidimensional Analysis of Preference (LINMAP), Entropy Weight Method (EMM), Analytic Network Process (ANP), and so on.

Roya G et al. [38] determined the relationships between factors through ISM, obtained more precise weights through BWM, and finally utilized TOPSIS to rank the suppliers of Jilan Steel Company. The main advantage of BWM is that it can reduce the difficulty for experts in the pairwise comparison process. Nian Z et al. [39] addressed the preferences of decision-makers (DM) for different alternatives, using the LINMAP method to process the preference information of DM, which can make the decision-making process more objective. Zhang Yinlin [40] determined the weights of evaluation indicators for suppliers based on a combined weighting method of AHP-entropy weight method, avoiding the subjectivity of human judgment and the one-sidedness of objective evaluation, thus obtaining the comprehensive score of ingot mold suppliers. Guo Bin et al. [41] based on the supplier indicator system in the green supply chain, utilized a combination of ANP and TOPSIS methods to evaluate and select alternative suppliers.

6. Conclusion

Based on a review of domestic and international literature, it is found that traditional methods are limited due to their inability to properly handle uncertainty and ambiguity, which affects the accuracy of decision-making and the comprehensiveness of information. Interval-valued Pythagorean fuzzy sets have significant implications for enhancing evaluation quality. Under the ESG framework, the green transformation of enterprises has promoted the diversification of evaluation indicators, covering resource efficiency, innovation capability, and waste emissions. This paper adopts the ANP method and CoCoSo method to assist enterprises in making more comprehensive decisions, promoting the construction of green supply chains, and achieving the vision of sustainable development.

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