MCDM Approach in Steel Industry

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Supply chain sustainability, which takes environmental, economic, and social factors into account, was recently recognized as a critical component of the supply chain (SC) management evaluation process and known as a multi-criteria decision-making problem (MCDM) that is heavily influenced by the decision-makers. While some criteria can be analyzed numerically, a large number of qualitative criteria require expert review in linguistic terms.

1. Introduction

The steel industry is an important fundamental industry sector in the national economy, and it is regarded as a significant symbol of the nation's overall power. As Vietnam's economy improves and people's living standards rise, the demand for steel in industries such as buildings, transportation, and household appliances increases. The rapid growth of steel demand has attracted various steel companies to invest in new steel production facilities in Vietnam. Therefore, finding the appropriate supplier is critical for organizations at this time [1]. There is a growing recognition of the need for businesses to collaborate closely with their supply chain partners to optimize their business processes. Supplier selection is one of the purchasing function's most crucial components, as it is critical for improving the organization's competitiveness and increasing customer satisfaction [2]. With increased government regulation and public awareness of environmental preservation, businesses cannot afford to disregard environmental concerns if they want to compete in the global market. Businesses must voluntarily develop plans to reduce their products' environmental impact [3]. Supplier selection is a foundation for forecasting and evaluating the suppliers' ability to form a collaborative partnership. As a result, businesses should employ a suitable supplier selection strategy to identify potential partners, thereby maintaining their competitive advantages during globalization [4]. Due to rising awareness and understanding of sustainability and government initiatives in this area, businesses cannot afford to ignore the issue of sustainability in their operations [5].

Sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". This concept incorporated the critical intertemporal dimension of human impact on the natural ecosystem [6]. The triple bottom line (TBL) has been developed to evaluate industrial performance across social, economic, and environmental sustainability. TBL states that a firm's long-term success can be attained by balancing economic objectives and social and environmental concerns [7]. Due to society's goal for a sustainable future, sustainability has been emphasized in the manufacturing supply chain (SC). To create a sustainable supply chain, all stakeholders must be invested in sustainability, from suppliers to top management [8]. Moreover, large-scale industries such as the iron and steel enterprises have a greater impact on the TBL than medium- and small-scale industries. As a large-scale industry, this industry has a considerable influence on sustainability dimensions, having a three-fold impact on economic, environmental, and social dimensions: (i) colossal sums of money are invested, which affects the nation's economic growth; (ii) industry operations include mineral extraction, greenhouse gas emissions, and waste disposal, all of which affect the environment; and (iii) the industry should ensure that its employees have workplace safety and receive proper health care. From a sustainability perspective, decision-makers must establish important criteria for identifying sustainable suppliers in the social, environmental, and economic domains. As a result, decision-makers must manage numerous sustainability criteria to evaluate supplier performance, and rigorous clustering is needed to classify criteria into each sustainability category. Hence, in light of the steel sector's importance as an infrastructure industry for nations' economies, the main objective of this research is to identify the most sustainable suppliers for the steel industry based on three levels (economic, environmental, and social) utilizing multi-criteria decision-making problem (MCDM) approaches.

Over time, the MCDM has attracted the research community's attention. It has discovered unique approaches to assist decision-makers in weighing various options and selecting the optimal option while considering conflicting qualitative and quantitative criteria. Numerous MCDM strategies are applied in supplier selection with the following objectives: (a) finding the preference weights (relative importance) of the considered criteria through comparison, and (b) ranking possible

suppliers based on the collected score for each criterion. In this manner, an infinite number of MCDM techniques are relevant, including the analytic hierarchy process (AHP), the technique of order preference similarity to the ideal solution (TOPSIS), VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR), preference ranking organization method for enrichment evaluation (PROMETHEE), combinative distance-based assessment (CODAS), grey relational analysis (GRA), and weighted aggregated sum product assessment (WAPAS). For example, Shemshadi et al. [9] adapted the VIKOR approach to derive and apply objective weights based on the Shannon entropy idea to solve supplier selection issues. According to Mousavi-Nasab and Sotoudeh-Anvari [10], TOPSIS and COPRAS have been effective procedures in general practice when it comes to material selection problems. Garg and Kumar [11] created the TOPSIS technique, which combines innovative exponential distance measurements with the theory of set pairs to solve real-world problems involving interval-valued intuitionistic fuzzy sets. Among these techniques, weighted aggregated sum product assessment (WASPAS) is a comparatively new and simple MCDM technique widely employed in various useful applications [12].

Besides, Data Envelopment Analysis (DEA) is concerned with evaluating the performance of decision-making units (DMUs) that conduct transformations on many inputs and outputs [13], and the results of DEA provide a measure of efficiency for each DMU, allowing for separating efficient and inefficient DMUs and identifying each inefficient DMU's efficient peers [14]. The effectiveness of DEA in performance evaluation, combined with the formal analogies between DEA and MCDM (which become obvious when DMU is replaced with alternatives, outputs are replaced with criteria to be maximized, inputs are replaced with criteria to be minimized, and so on) has prompted some authors to propose using DEA as a tool for MCDM [15]. A number of recent papers have begun to analyze the relationship between DEA and MCDM, and they show the potential usefulness of DEA for MCDM. For example, Mousavi-Nasab and Sotoudeh-Anvari [10] examined the use of DEA as a material selection problem MCDM tool. DEA can be used to solve this problem when a classical remark is considered; however, DEA cannot replace MCDM in this area in general. In order to calculate the final efficiency of transport businesses based on 10 input-output variables, Stević et al. [16] built a model that integrates DEA and other MCDM techniques. Additionally, spherical fuzzy sets (SFSs) may be used to implement criteria for dealing with ambiguity and vagueness in linguistic expressions, which provides a novel perspective for decision-making in a fuzzy environment. The decision maker's level of uncertainty is provided independently of the items' membership or non-membership in these sets. The membership function in SFSs is defined on a spherical fuzzy to infer additional fuzzy sets from which the membership function's parameters can be extended over a larger domain [17].

2. Development and Application

In today's highly competitive market, businesses prioritize strengthening their core competencies while outsourcing certain tasks to suppliers with various professional capabilities to gain a competitive edge using these external resources. On the other hand, the supply of raw materials across many industrialized countries is becoming scarce, forcing them to seek suppliers from other countries to maintain the firm's operation stability. Thus, Nguyen et al. [18] addressed the impacts of domestic raw materials and international raw materials on firm performance, which would aid firms in diversifying products and generating products while meeting the stringent requirements of today's market. In these contexts, the function of suppliers and challenges relating to them have played a significant part in supplier chain management. Evaluation or selection of suppliers is a typical issue in acquiring the required essential aspects to support the outputs of organizations. The challenge for enterprises is identifying and evaluating the optimal period or the most appropriate supplier for their various capabilities [19]. In the previous decade, there have been a tiny number of relevant research on steel selection, in which MCDM techniques have demonstrated impressive outcomes in various case evaluations globally. Some wide methodologies are used in the steel industry's evaluation, including AHP, TOPSIS, decision making trial and evaluation laboratory (DEMATEL), Delphi, slacks-based measure (SBM), best-worst method (BWM), fuzzy Kano, measurement alternatives and ranking according to compromise solution (MARCOS), and interpretive structural modeling (ISM).

Amiran et al. [20] used a hybrid fuzzy AHP and TOPSIS approach to evaluate Iran's steel industry's performance based on a balanced scorecard. Jafarnejad et al. [21] proposed a combination of DEMATEL and fuzzy AHP models to tackle the problem of selecting an enterprise resource planning system for the steel sector. Mohaghar and Zarchi [22] deployed a hybrid of AHP and DEMATEL models to identify and rank steel industry-funded projects in Iran. Quader and Ahmed [23] suggested integrating Delphi, two-tuple decision-making trials and DEMATEL, and fuzzy AHP models to identify dimensions and key indicators for evaluating alternative iron-making innovations in the Malaysian and Indian steel industries. Azimifard et al. [24] applied the AHP and TOPSIS techniques to pick sustainable supplier countries for Iran's steel sector. Choi et al. [25] employed a DEA- SBM approach to evaluate the steel industry's environmental and traditional energy efficiency in Korea. Javad et al. [26] employed BWM and fuzzy TOPSIS models to determine the critical parameters affecting Khouzestan Steel Company's selection of green suppliers. Jain and Singh [27] provided a fuzzy modified Kano model to classify sustainable suppliers in the Indian iron and steel industry. Chakraborty et al. [28] used D numbers and

MARCOS models to resolve the ambiguity inherent in the decision-making process for supplier selection in India's iron and steel sector. Ghamari et al. [29] proposed a framework for selecting sustainable suppliers in the Iranian steel industry based on three models: ISM, BWM, and TOPSIS.

Notably, many works have investigated economic-environmentally focused supplier decision-making in developed nations, but there is still a lack of research on supplier selection for sustainability in developing nations [30]. In a developing nation like Vietnam, understanding and awareness of the three pillars of economic-ecological-social dimensions are severely lacking. Furthermore, sustainability criteria may differ from the perspective of developing nations since consumers may not be ready to pay more for sustainable items. Additionally, other SSS-related gaps might be investigated. Existing literature, for instance, fails to indicate that the sustainability dimensions should correspond with supplier selection criteria within a hierarchical framework. In addition, the literature reveals a vast body of work on green-oriented supplier selection [31]. Nevertheless, academics have ignored the social aspects of supplier selection decisions [32]. Following this, Seuring and Müller [33] observed a clear deficiency in supply chain management and purchasing literature about incorporating all three elements of sustainable development in supply networks.

According to above content, there is a dearth of example research on sustainable supplier selection, particularly in the Vietnamese steel industry. Keeping this in mind, for the first time, attempts have been made in this study to find the best suitable sustainable supplier by employing the merits of DEA, AHP, and WASPAS based on spherical fuzzy sets. The suggested MCDM approach can process uncertain assessments through spherical fuzzy environments that do not ignore any information from human judgments and create a more robust and accurate ranking for the alternatives through the novel SF-WASPAS method. Furthermore, to the best of the authors' knowledge, this is the first study to use DEA, SF-AHP, and SF-WASPAS analysis for sustainable supplier selection in the Vietnamese steel sector.

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