Paper ID: 505

Optimizing Sustainable Supplier Selection: A BWM-VIKOR Approach in the Green Steel Industry

Ajoy Nath[1], Fahad Bin Yousuf[2], Shahed Mahmud[3]
Department of Industrial and Production Engineering[1-3], Rajshahi University of Engineering and Technology, Rajshahi-6204, Bangladesh
E-mail: nathajoy19@gmail.com[1], fahad1905007@gmail.com[2], shahed.mahmud@ipe.ruet.ac.bd[3]

Abstract

For the purpose of implementing the circular economy, this paper suggests a decision-making framework based on green industry initiatives for assessing and choosing sustainable suppliers. In this regard, green industry, the circular economy, and sustainable supplier selection have become hot buttons in the discussion of modern operations management. Twelve sub-criteria and four primary categories that are pertinent to the supplier selection process were identified using the mix method approach, which combines the opinions of industrial experts. A multi-criteria decision making aid made consisting of the Best-Worst technique (BWM) and VIKOR were used to help Bangladeshi steel industry evaluate and choose a sustainable supplier. Following the application of the BWM technique to ascertain the relative importance weights, the providers were ranked using VIKOR. The study's conclusions indicate that, when making such decisions the steel industries in Bangladesh give significant weight to "Cost Effectiveness (ES1)" with a global weight of 0.18; "Recyclability of Product (CE3)" with a global weight of 0.168; and "Cost Transparency (ES4)" with a global weight of 0.108. Supplier 1 was ranked as the top sustainable supplier.

Keywords: *Green Steel, BMW, VIKOR, MCDM, Sustainability.*

1. Introduction

The steel sector is a vital part of Bangladesh's economic progression, significantly contributing to the development of infrastructure and industry. Nevertheless, conventional methods of steel production have led to serious environmental issues due to their substantial energy requirements and considerable carbon emissions. In light of this, a new wave of "green steel" suppliers has appeared, dedicated to adopting eco-friendly practices across the entire supply chain. These suppliers seek to lower the environmental impact of steel manufacturing by utilizing sustainable technologies, reducing waste, and endorsing principles of a circular economy.

This case study examines the swift emergence of green steel suppliers in Bangladesh, looking into the primary factors that propel their growth and the obstacles they encounter in the market. It also assesses the potential environmental and economic implications of green steel suppliers on the national steel sector. By concentrating on innovative production strategies, this study aims to offer valuable knowledge for industry participants, policymakers, and researchers focused on sustainable development.

This study uses a multi-criteria decision-making framework that combines the Best-Worst Method (BWM) and VIKOR to assess and select the most sustainable green steel suppliers. BWM prevents inconsistencies in weighting, while VIKOR is excellent at managing trade-offs and prioritizing options based on optimal solutions. When combined, they beat techniques like AHP or TOPSIS in striking a balance between decision robustness and precision for supplier selection that is focused on sustainability.

2. Literature review

Sustainability is becoming increasingly crucial in the steel industry due to environmental concerns. Steel production is a major contributor to greenhouse gas emissions [1]. In this paper, we are focusing on reducing emissions, which requires a multi-faceted approach, and that includes finding suppliers who prioritize eco-friendly practices throughout the supply chain [2]. The importance of supplier management in achieving environmental sustainability within a supply chain is increasing day by day. It includes certifications, supplier codes of conduct, and collaborative efforts [3]. There is a showcase of trends related to environmental sustainability and energy efficiency in supply chain management. Topics like measuring performance, reverse logistics (recycling and reuse), and finding a balance between cost and environmental impact play an important role in environmental sustainability and energy-efficient supply chain management [4]. There is an essential link between sustainable

supply management practices and a company's environmental performance, which expedites practices like supplier selection based on environmental criteria, collaboration with suppliers on environmental initiatives, and supplier development programs focused on sustainability [5]. MCDM (Multi-Criteria Decision Making) approaches are used in sustainable supplier selection. It explores popular methods like AHP (Analytic Hierarchy Process), TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), and VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje) and also delves into integrating these methods for more nuanced decision-making [6]. The Best Worst Method (BWM) is broadly integrated with fuzzy logic for green-resilient supplier selection [6].

.

3. Methodology

Proposed Algorithm

An algorithm was developed for selecting sustainable suppliers, focusing on environmental sustainability. It outlines the data collection process, criteria selection, weighting, and final supplier choice. The process consists of:

Step 1: Categorizing according to criteria and sub-criteria

Suppliers are evaluated based on environmental criteria and sub-criteria, ensuring a thorough assessment of sustainability factors.

Step 2: weighting criteria using BWM

The Best-Worst Method (BWM) is applied to determine the importance of each criterion, ensuring precise and consistent weightings.

Step 3: Ranking suppliers using VIKOR

The VIKOR method ranks suppliers by their proximity to an ideal solution, enabling the selection of the most environmentally sustainable options.

However, the framework of the proposed approach is presented in Fig. 01.

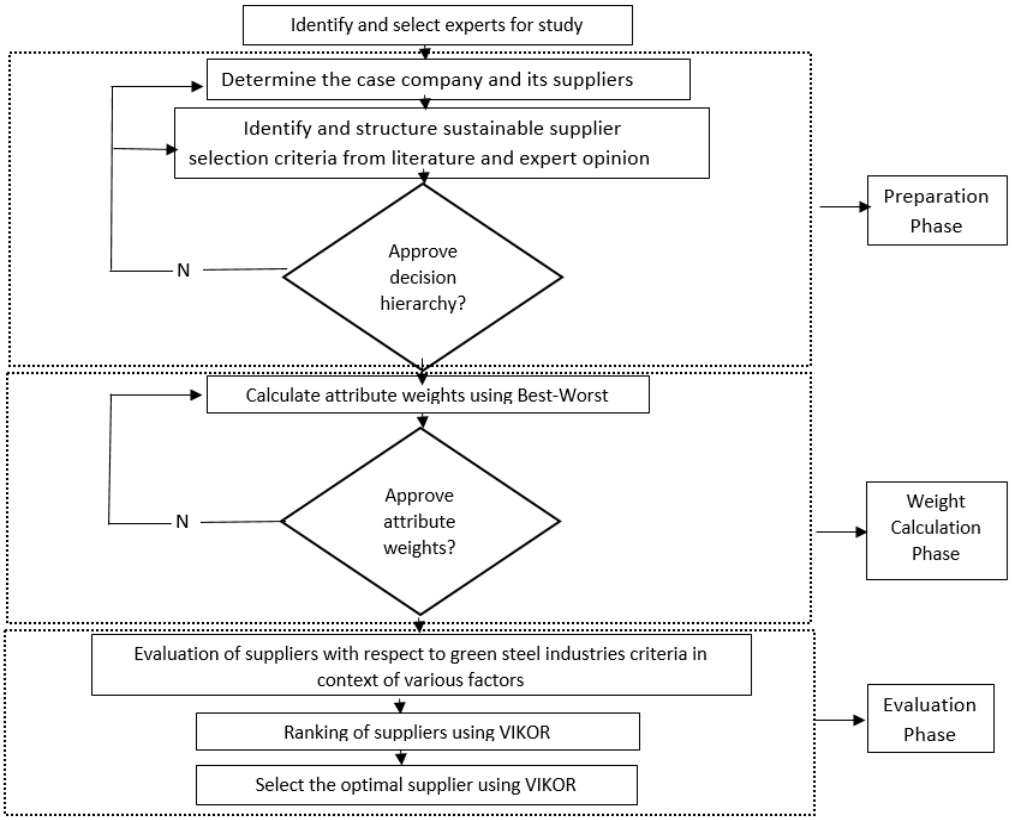


Fig. 01. Methodology Framework

4. Results analysis

The evaluation framework incorporates five primary criteria, each supported by a comprehensive set of sub-criteria to ensure a rigorous assessment as reported in Table 01. Economic Sustainability is represented by four sub-criteria, reflecting the multifaceted financial aspects of supplier performance. Environmental Sustainability, Waste Management, Pollution Control, and the Circular Economy Principle are each examined through three sub-criteria, enabling a detailed analysis of suppliers' commitment to reducing environmental impact, managing waste efficiently, controlling pollution, and adhering to circular economy practices. This structured approach ensures that all key dimensions of sustainability are thoroughly evaluated, providing a robust basis for informed decision-making.

Table 01: Main and Sub category criteria for Green Steel Suppliers

Main Criteria	Sub- Criteria
Economic Sustainability (ES)	Cost Effectiveness (ES1)
	Supply Chain Resilience (ES2)
	Long Term Investment (ES3)
	Cost Transparency (ES4)
Environment Sustainability (RE)	Carbon Footprint (RE1)
	Energy Efficiency (RE2)
	Use of Renewable Energy (RE3)
Waste Management (WM)	Waste Minimization (WM1)
	Waste Recycling (WM2)
	Waste Disposal (WM3)
Pollution Control (PC)	Air Emission Control (PC1)
	Water Discharge Control (PC2)
	Hazard Waste Management (PC3)
Circular Economy Principle (CE)	Use of Recycled Steel Coolant (CE1)
	Closed Loop Recycling (CE2)
	Recyclability of Product (CE3)

The process commences by determining the supplier selection criteria through an integration of comprehensive literature review and expert insights. Once finalized, experts and managers are tasked with identifying the best and worst criteria across both the main categories and subcategories. Preference ratings, ranging from 1 to 9, are then provided by each expert, comparing the best criterion against the others. Likewise, comparative ratings are gathered for the worst criterion. These preference ratings are used to calculate optimized weights for each criterion (in table 02), ensuring a more informed and balanced approach to decision-making in the supplier selection process.

The selection process initiates by constructing a pairwise matrix of criteria and alternatives, followed by the formulation of an average decision matrix. This step is crucial in identifying both the best (positive ideal) and worst (negative ideal) values for each criterion, serving as benchmarks for evaluation. Next, the S and R values, which represent the relative distances of each alternative from the ideal solutions, are computed (in table 03) based on the weighted criteria (in table 02). These distances enable the calculation of Q scores for each alternative, which are subsequently ranked. The alternative with the lowest Q score is deemed the optimal choice, ensuring compliance with ranking conditions for both the S (overall distance) and R (maximum deviation) values. This method provides a robust and systematic approach to selecting the most suitable option.

Table 02: Aggregated weights of Main and sub-criteria

Main criteria	Weight	Sub criteria	Sub weight	Global weight	Ranking
RE	0.08	RE1	0.76	0.0608	7
	0.08	RE2	0.156	0.01248	14
	0.08	RE3	0.083	0.00664	16
WM	0.16	WM1	0.667	0.10672	4
	0.16	WM2	0.222	0.03552	10
	0.16	WM3	0.111	0.01776	13
PC	0.12	PC1	0.712	0.08544	5
	0.12	PC2	0.091	0.01092	15
	0.12	PC3	0.197	0.02364	12
CE	0.24	CE1	0.1	0.024	11
	0.24	CE2	0.2	0.048	8
	0.24	CE3	0.7	0.168	2
ES	0.4	ES1	0.45	0.18	1
	0.4	ES2	0.18	0.072	6
	0.4	ES3	0.09	0.036	9
	0.4	ES4	0.27	0.108	3

Table 03: Ranking of alternatives for R, S and Q values

	S	R	Q	Rank
SP1	0.4009	0.1200	0.0907	1
SP2	0.4396	0.1800	0.5861	3
SP3	0.4975	0.1067	0.21516	2
SP4	0.5955	0.1680	0.8512	5
SP5	0.6255	0.1200	0.5907	4

From table 02 & table 03 it is finalized that the 1st ranked sub-criteria is Economic Sustainability (ES1) with a global weight of 0.18. The following sub-criteria is Circular Economy Principle (CE3) with a global weight of 0.168. The last ranked sub-criteria is Environment Sustainability (RE3) with a global weight of 0.00664. Supplier 1 (SP1) is selected based on Q values, which is 0.0907.

5. Discussion

A key challenge for businesses aiming to build sustainable supply chains is selecting suppliers committed to sustainability, particularly in industries where outsourcing is necessary. This decision involves multiple factors, including economic and environmental considerations, making multi-criteria decision-making (MCDM) methods crucial. While various MCDM techniques exist, each has limitations. In this study, the integration of the Best Worst Method (BWM) and VIKOR approach is used to enhance decision-making in the Green Steel Industry, addressing gaps in existing methods.

The research framework developed focuses on four main categories and twelve subcategories, addressing a gap in current supplier evaluations where sustainability metrics are often lacking. By applying this approach, the study aligns with recent research and underscores the need for comprehensive sustainability criteria in supplier selection.

6. Conclusion

This study presents an effective framework for selecting sustainable suppliers in the Green Steel Industry, integrating the Best Worst Method and VIKOR approaches to enhance decision-making. Applied in a Bangladeshi steel company, the framework revealed "Cost Effectiveness," "Recyclability of Product," and "Cost Transparency" as key factors. Supplier 1 was ranked the most sustainable, demonstrating the utility of this approach.

The framework addresses a critical gap by offering a structured method for assessing supplier sustainability, especially in green manufacturing. Future research can expand its application to other sectors, supporting sustainable supply chains aligned with companies' strategic and global sustainability goals.

7. References

[1] S. Kusi-Sarpong, H. Gupta, S. A. Khan, S. T. Rehman, and H. Kusi-Sarpong, "Sustainable supplier selection based on industry 4.0 initiatives within the context of circular economy implementation in supply chain operations," *ePrints Soton*, Oct. 2021. [Online]. Available: https://eprints.soton.ac.uk/434401/1/FullLengthManuscript.docx.

[2] A. Kaur and P. C. Sharma, "Sustainability as a strategy incorporated in decision-making at Supply Chain Management: Case study of General Motors," *International Journal of Sustainable Strategic Management*, vol. 6, no. 1, p. 56, 2018.

[3] G. Yadav, S. Luthra, S. K. Jakhar, S. K. Mangla, and D. P. Rai, "A framework to overcome sustainable supply chain challenges through solution measures of Industry 4.0 and circular economy: An automotive case," *Journal of Cleaner Production*, vol. 254, p. 120112, 2020.

[4] M. J. Paz and M. E. Ruiz Gálvez, "Effects of modular platforms on suppliers companies: Evidence from Volkswagen Polo Manufacturing in Navarra (Spain)," *Journal of Manufacturing Technology Management*, vol. 32, no. 2, pp. 337–355, 2020.

[5] V. E. Castillo, D. A. Mollenkopf, J. E. Bell, and H. Bozdogan, "Supply Chain Integrity: A key to sustainable supply chain management," *Journal of Business Logistics*, vol. 39, no. 1, pp. 38–56, 2018.

[6] P. Centobelli, R. Cerchione, and E. Esposito, "Environmental sustainability and energy-efficient supply chain management: A review of research trends and proposed guidelines," *Energies*, vol. 11, no. 2, pp. 275–275, Jan. 2018, doi: https://doi.org/10.3390/en11020275.