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Research Article

A Soft Approach to Supplier Selection Problem for Steel Company under Future Uncertainty

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Abstract

The steel industry is a whole industry worldwide and a fundamental industry sector in the national economy. It is undeniable that raw materials are an essential part of a steel company's operations. Therefore, steel companies require reliable and valid raw material suppliers. One of the strategic activities of supply chain management is selecting suitable suppliers. Supplier selection (SS) is a multi-criteria decision-making process and requires a comprehensive evaluation process, often under uncertain conditions. While the application of MCDM tools is continuously growing in the SS literature, these tools can not cope with future or environmental uncertainty. The matrix approach to robustness analysis as a method capable of covering this type of uncertainty has a fundamental weakness; This approach uses only one criterion to check the performance of alternatives. This point has been considered in this study. For this purpose, a study has been conducted in a steel manufacturing company to choose the most suitable supplier among the four. Based on the proposed approach, problem owners defined future scenarios by considering different states of economic, social, and environmental variables. Then, the performance of the suppliers was judged by experts according to the cost, quality, time, supply security, and capacity criteria in the form of future scenarios. Finally, we placed the average performance of the suppliers in the five criteria in the decision matrix and prioritized them. The results showed that supplier A_3 is the best option.

Keywords: Supplier Selection; Steel Industry; Decision-Making; Soft Approach; Uncertainty

1. Introduction

The steel industry is a significant industry worldwide and an essential fundamental industry sector in the national economy. At the same time, It symbolizes the nation's power as a whole. The high tensile strength of steel and its relatively low price make it an ideal material for various industries, including infrastructure, ships, trains, automobiles, and machinery. With Iran's economy improving and people's living standards rising, steel demand has increased in industries such as construction, transportation, and household appliances (Nguyen et al., 2022). As a leading manufacturer of rails, plates, wires, rods, wheels, axles, etc., Iran's steel industry caters to domestic and international customers (Jain & Singh, 2020). Various stages of the steel chain follow iron ore extraction from the mine, including limestone conversion to concentrate, pellets, sponge iron, and ingots. Steel companies need raw materials such as incombustible matter, iron ore, limestone, scrap iron, coal, and slabs. This industry relies heavily on the supply of raw materials and the continuity of production. Additionally, steel derivatives are the raw materials for many factories, including pipe and profiles, automobiles, steel reinforcement bars, etc. The lack of sufficient raw materials for steel-related industries due to shortages or pricing policies can cause many production lines to stop and cause severe factory crises. A short-term interruption in raw material supply will have a negative impact on production. Hence, a critical problem impacting the steel industry is the supply of raw materials for steel companies (Ghamari et al., 2022).

A supply chain management (SCM) system is regarded as one of the most vital aspects of any organization's survival in today's highly competitive manufacturing environment (Chakraborty et al., 2020). the "supply chain" encompasses all the processes involved in manufacturing, transferring, servicing, maintaining, or selling physical goods or services from raw material producers to customers (Sayyadi tooranloo et al., 2022). As upstream supply chain partners, suppliers play a critical role in industry prosperity (Hosseini-Motlagh et al., 2018). The supplier base's quality affects companies' competitiveness (Shafi Salimi & Edalatpanah, 2020). Organizations should find more efficient suppliers to increase the competitiveness of their supply chain (Shahriari & pilevari, 2016). Suppliers who meet these requirements at the right time and with acceptable quality and standards are suitable (Sobhanallahi et al., 2019). According to the literature, evaluating and selecting suppliers is a strategic

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and vital part of selecting a long-range method regarding the supply chain (Ghasempoor Anaraki et al., 2021). Selecting a supplier is a complex activity that affects profitability and customer satisfaction. Hence, choosing suppliers is an important strategic decision for a company's long-term success (Pantha et al., 2020).

One of the supply chain management's strategic activities is selecting suitable suppliers and allocating orders to them to reduce costs and increase profits (Sayyadi tooranloo et al., 2022). Product quality can be improved by selecting appropriate suppliers, and purchasing costs can be reduced (Forghani et al., 2021). Forecasting and evaluating suppliers' ability to form a collaborative partnership begins with supplier selection. In order to maintain their competitive advantages during globalization, businesses should employ a supplier selection strategy suitable for identifying potential partners (Maulidina & Putra, 2018). Due to the differences between the needs and wishes of customers and organizations, organizations must consider various factors when choosing suppliers (Shadkam et al., 2021). The SS process primarily focuses on the following steps: a; identifying the products to be procured, b; assimilating a list of possible suppliers, c; choosing the critical indicators (criteria), d; forming a decision-maker team, e; selecting the most apposite supplier, and f; Evaluation of the final supplier's performance continuously (Chakraborty et al., 2020). Due to its long-term effects on the environment, supplier selection is a multi-criteria decision-making process (Oroojeni Mohammad Javad et al., 2020). Selecting suitable suppliers in supply chain management requires a comprehensive evaluation process, often under uncertain conditions (Mao et al., 2020). According to the literature, supplier selection plays a crucial role in manufacturing. Nevertheless, relatively less light has been reflected on the environmental (or future) uncertainty involved in the decision-making process (Chakraborty et al., 2020). As a result, businesses should use a supplier selection model to determine which partners are suitable (Azimifard et al., 2018).

A critical issue in supply chain management is the issue of supplier selection (Mohammad & Kazemipoor, 2020). The supplier selection process has received considerable attention in the literature for over two decades. Organizations operate in a very complex and dynamic environment, which presents challenges in decision-making, particularly when selecting suppliers (Sorourkhah, 2022). In supply chain management, methods for selecting suppliers are in the spotlight. Numerous unstable information and variables affecting the consequences of the decision challenge the manager to make the right and fast decision (Shafi Salimi & Edalatpanah, 2020). In order to help these organizations prequalify their suppliers based on their overall performance, a tool that allows them to develop and execute strategic partnerships with their suppliers is needed (Ghasempoor Anaraki et al., 2021). In the SS literature, as a result of its ability to capture multidimensional data, MCDM is continuously growing (Kavta & Goswami, 2021).

Forghani et al. (2021) examined SS publications from 1973 to 2019 using Scopus, Elsevier's abstract, and a citation database. They concluded that the analytic hierarchy process (AHP), data envelopment analysis (DEA), and the technique for order of preference by similarity to ideal solution (TOPSIS) had been applied as preferred methods since the inception of SS. Sustainable supplier selection for SMEs based on an extended PROMETHEE Ⅱ approach (Tong et al., 2022), Supplier selection in the oil & gas industry applying COPRAS and SWARA methods (Yazdi et al., 2022), and using a hybrid decision model base on BWM and VIKOR approaches for supplier selection in Online Fashion Retail (Kaushik et al., 2020) are some examples of these efforts. Additionally, some researchers combined these tools with fuzzy set theory to cope with verbal uncertainty arising from decision-makers judgments (Garg & Kumar, 2020; Sorourkhah, 2022), such as supplier selection through the Fuzzy Ordinal Priority Approach (Mahmoudi et al., 2022), strategic supplier selection for renewable energy supply chain using fuzzy BWM-WASPAS-COPRAS approach (Masoomi et al., 2022), supplier selection through Picture fuzzy MABAC method based on prospect theory for multiple attribute group decision making (Jiang et al., 2022), and application of Choquet integral in interval type-2 Pythagorean fuzzy sustainable supply chain management under risk (Mondal & Roy, 2022). Despite combining quantitative and qualitative criteria regarding the opinions of multiple decision-makers and expressing human thinking mathematically, MCDM tools could not formulate the probable futures (Sorourkhah & Edalatpanah, 2021a).

Selecting an appropriate alternative is said to be one of the biggest challenges for decision-makers (Azar & Sorourkhah, 2015). There are two critical factors to consider when reviewing decision-making literature: complexity and uncertainty (Ocampo et al., 2019). Complexity includes multiple criteria, and their interrelationships and uncertainty include judgmental and environmental (future) uncertainty (Mallick et al., 2020). Researchers' most widely known and used approaches to select the best option or supplier have some weaknesses related to either complexity or uncertainty (Sorourkhah & Edalatpanah, 2021b). Managers may encounter increasing uncertainty (Engau & Hoffmann, 2011), numerous options available, and quantitative data lacking on the future and outcomes (Wong, 2007) when making decisions. It has therefore been of particular importance to design a model to answer such complexities (Sorourkhah et al., 2019).

Several approaches use future scenarios as the basis for analysis. Scenario Planning (SP) is a well-thought-of method to support decision-making (Ghahremani Nahr & Zahedi, 2021). In terms of the future, it defines a specific set of uncertainties and how the environment will change over time (Edalatpanah, 2022). It is common for scenario planning models to include only three, four, or five scenarios, which does not allow them to consider various factors that may affect the problem (Goecks et al., 2020). Using an unsuitable tool in the decision-making process guides mistaken outcomes (Dinçer et al., 2019), so selecting a tool that can manage the uncertain environment and reduce its impact on results can be helpful (Chutia & Gogoi, 2018). Robustness Analysis (RA), introduced by Rosenhead (2011), is a scenario-based tool dealing with future uncertainty. A decision leads to more reasonable and less adverse outcomes among possible futures in RA models (Montibeller & Franco, 2011). This approach is generally collaborative and flexible, allowing participants' opinions to be considered. Users find it more straightforward and understandable than the other techniques (Månsson, 2016). nevertheless, due to its inability to handle a wide range of options (scenarios or indicators), this approach has always suffered some weaknesses in selecting the strategy. (Ram et al., 2011). Matrix Approach to RA (MARA) addressed these weaknesses including number of scenarios, options, and criteria (Sorourkhah, Babaie-Kafaki, et al., 2018).

Though the MARA approach can remarkably face the dimensions of a decision-making problem, it has a significant weakness. In this approach, generally, after determining the key indicators (preferably called variables in this study) and specifying the possible states for each of them, future scenarios are designed, and the performance of each option in different scenarios is evaluated and judged by experts. In this way, it can be seen that in this approach, only one indicator that expresses the overall performance of each option is evaluated. While in a multi-indicator decision-making problem, assessing the options based on different indicators is necessary. Based on this, the main goal of the current research is to solve this weakness of the MARA approach. To show how to address this weakness, the following sections of the article are structured as follows: In section 2, the research methodology is introduced. The proposed approach is implemented in a case study in section 3, and the results are presented in section 4.

2. Methodology

Based on MARA (Sorourkhah, Azar, et al., 2018), the proposed methodology consists of 9 steps as follows:

Step 1- listing potential suppliers (A_i, i=1, 2, …, n)

Step 2- Choosing variables shaping the future (V_k, k=1, 2, …, q)

These variables can be identified from the research background or with the help of experts or problem owners. In addition, a combination of the above can also be helpful.

Step 3- Defining the various states of the variables (V_{1L}, V_{2L}, …, V_{KL}, L=1, 2, …, r)

Step 4- Forming the scenario matrix (S) by removing impossible states

$$S = \begin{pmatrix} V_{11} & \dots & V_{1r} \\ V_{21} & \dots & V_{2r} \\ V_{31} & \dots & V_{3r} \end{pmatrix}.$$

The number of scenarios (columns) is equal to the multiplication of the different states of the variables. If we know that some states (in the decision horizon) will not occur, we can leave them aside.

Step 5- Specifying assessing criteria (indicators) (C_j, j=1, 2, …, m)

While the MARA approach evaluates only the overall performance of the options in future scenarios, this review is based on the criteria adopted from the research background or experts' views in this study.

Step 6- Determining each supplier's performance considering the variables' different states (Jc_j, j=1,2,…,m)

Separately for each of the criteria, the performance of each of the suppliers should be judged in different states of the variables. This research uses the Likert scale (1: very weak to 5: very strong) for judgments.

Step 7- Calculating suppliers' performance in terms of matrix Pc_j, j=1,2,…,m

Matrix P is achieved by matching step 6 outputs with matrix S. To know more, see (Sorourkhah et al., 2019; Sorourkhah & Edalatpanah, 2021b, 2022). Next, to calculate the final performance of each supplier (i) in terms of the given criterion (j), the average performance of that supplier in future scenarios is calculated and named n_{ij}.

Step 8- Forming decision matrix D

After calculating the suppliers' performance for all the indicators, a decision matrix is formed.

Step 9- Selecting the best supplier

In this step, applying any MADM tools, we can prioritize and select the best option.

3. Case Study

This research was done to choose a suitable supplier for one of the big steel companies in Iran. Because information is not allowed to be published, we present it as a numerical example and focus more on the methodological development aspect of the approach.

According to the proposed methodology, we listed four suppliers, including 2 Iranian, 1 Chines, and 1 Indian (S_1, S_2, S_3, and S_4). In step 2, based on the literature, we chose economic, social, and environmental variables (Ghamari et al., 2022), which are considered more than any other variable in the supplier selection problem (Azimifard et al., 2018). Next, the problem owners defined the various states as better (1), stable (2), and worse (3) for all three variables. Accordingly, we had 3×3×3=27 future scenarios. Following step 4, the experts declared that economic conditions would not get worse (3), social conditions would not get worse (3), and environmental conditions will not get better (1). Based on this, by removing the impossible states, eight final scenarios were defined according to the matrix S:

$$S = \begin{pmatrix} 1 & 1 & 1 & 1 & 2 & 2 & 2 & 2 \\ 1 & 1 & 2 & 2 & 1 & 1 & 2 & 2 \\ 2 & 3 & 2 & 3 & 2 & 3 & 2 & 3 \end{pmatrix}.$$

In matrix S, the columns represent future scenarios, and the rows represent economic, social, and environmental variables, respectively. For example, the first scenario (first column) describes a scenario in which the economic and social conditions are better than now, and the environmental conditions are also stable. In step 5, we reviewed SS literature to specify the problem criteria. Cost, quality, and delivery time (Sobhanallahi et al., 2019), security of supply (Sayyadi tooranloo et al., 2022), and production or technology capacity (Chakraborty et al., 2020) were chosen by problem owners. Accordingly, in step 6, the performance of each supplier was judged in different states of the variables for each criterion. The results are shown in tables 1-5:

Table 1

The problem owners' judgments based on the cost criterion Jc_1

Variables	Economical			Social			Environmental		
States	1	2	3	1	2	3	1	2	3
S_1	4	3	3	4	3	3	4	3	1
S_2	5	4	3	4	3	3	4	2	1
S_3	4	4	4	5	4	2	4	3	3
S_4	3	3	3	4	4	1	5	3	3

Table 2

The problem owners' judgments based on quality criterion Jc_2

Variables	Economical			Social			Environmental		
States	1	2	3	1	2	3	1	2	3
S_1	4	3	2	4	3	2	3	2	1
S_2	4	3	1	4	4	3	3	2	1
S_3	3	3	3	3	3	3	5	4	4
S_4	3	3	3	3	3	3	5	4	3

Table 3

The problem owners' judgments based on lead time criterion Jc_3

Variables	Economical			Social			Environmental		
States	1	2	3	1	2	3	1	2	3
S_1	5	4	3	3	3	2	4	3	2
S_2	5	5	3	4	4	3	4	3	2
S_3	3	2	1	2	3	3	3	3	3
S_4	3	2	1	2	3	3	3	3	3

Table 4

The problem owners' judgments based on security criterion Jc_4

Variables	Economical			Social			Environmental		
States	1	2	3	1	2	3	1	2	3
S_1	5	4	3	4	4	2	4	4	1
S_2	5	4	3	5	4	3	4	4	2
S_3	4	4	2	3	4	3	4	4	3
S_4	3	3	2	2	3	3	4	4	3

Table 5

The problem owners' judgments based on capacity criterion Jc_5

Variables	Economical			Social			Environmental		
States	1	2	3	1	2	3	1	2	3
S_1	5	3	2	3	4	4	4	3	2
S_2	5	4	3	5	5	4	4	3	2
S_3	5	5	5	5	5	5	5	5	5
S_4	4	4	4	4	4	4	4	4	4

Following step 7, we calculated matrix P for every criterion shown in Tables 6-10:

Table 6

Suppliers' performance based on the cost criterion Pc_1

P_{cost}	1	2	3	4	5	6	7	8	average
S_1	11	9	10	8	10	8	9	7	9
S_2	11	10	10	9	10	9	9	8	9.5
S_3	12	12	11	11	12	12	11	11	11.5
S_4	10	10	10	10	10	10	10	10	10

Considering matrix S and Table 1, the performance score of supplier S1 in terms of the cost index in the first scenario has been calculated as follows: In the first scenario (1, 1, 2), the economic conditions will improve, and according to table 1, supplier S1 earns a score of 4; The social situation has improved, and it also gets 4 points, and finally, the environmental condition has been stable and therefore, 3 points have been considered for this supplier. In total, the score of the first supplier in terms of the cost index in scenario 1 is equal to 11. In the same scenario, supplier 4 gets 3, 4, and 3 points, respectively (10 points in total) in the first scenario according to the economic, social, and environmental indicators.

Table 7

Suppliers' performance based on the quality criterion Pc_2

$P_{quality}$	1	2	3	4	5	6	7	8	average
S_1	10	9	9	8	9	8	8	7	8.5
S_2	10	9	10	9	9	8	9	8	9
S_3	10	10	10	10	10	10	10	10	10
S_4	10	9	10	9	10	9	10	9	9.5

Table 8

Suppliers' performance based on the lead time criterion Pc_3

P_{time}	1	2	3	4	5	6	7	8	average
S_1	11	10	11	10	10	9	10	9	10
S_2	12	11	12	11	12	11	12	11	11.5
S_3	8	8	9	9	7	7	8	8	8
S_4	8	8	9	9	7	7	8	8	8

Table 9

Suppliers' performance based on supply security criterion Pc_4

$P_{security}$	1	2	3	4	5	6	7	8	average
S_1	13	10	13	10	12	9	12	9	11
S_2	14	12	13	11	13	11	12	10	12
S_3	11	10	12	11	11	10	12	11	11
S_4	9	8	10	9	9	8	10	9	9

Table 10
Suppliers' performance based on the capacity criterion Pc_5

$P_{capacity}$	1	2	3	4	5	6	7	8	average
S_1	11	10	12	11	9	8	10	9	10
S_2	13	12	13	12	12	11	12	11	12
S_3	15	15	15	15	15	15	15	15	15
S_4	12	12	12	12	12	12	12	12	12

In step 8, , using the average columns, we reached the decision matrix D, shown in Table 11:

Table 11
Suppliers' performance based on the capacity criterion

Matrix D	Cost	Quality	Time	Security	Capacity	average
S_1	9	8.5	10	11	10	9.7
S_2	9.5	9	11.5	12	12	10.8
S_3	11.5	10	8	11	15	11.1
S_4	10	9.5	8	9	12	9.7

Finally, in step 9, applying an MADM tool, we can prioritize the suppliers. Here, we just used the average score for every supplier for brevity. Table 11 shows supplier S_3 is the best, and S_2 is the second best alternative.

4. Conclusion

Every community depends on the steel industry for its development. Without the steel industry, several industries would not have been possible. The supply of raw materials and the continuity of production play a significant role in the manufacturing industry. Therefore, To supply their raw materials, steel companies need resilient and sustainable suppliers (Ghamari et al., 2022). Organizations should find more efficient suppliers to increase the competitiveness of their supply chain (Shahriari & pilevari, 2016). According to the literature, selecting suppliers is a strategic and vital part of selecting a long-range method regarding the supply chain (Ghasempoor Anaraki et al., 2021). Supply chain selection is a complex enterprise that can significantly impact profitability and customer satisfaction. Therefore, a company must select suppliers wisely to ensure its long-term survival (Pantha et al., 2020), and it requires a comprehensive evaluation process, often under uncertain conditions (Mao et al., 2020).

Manufacturing industries should pay close attention to supplier selection, as demonstrated in this fully described research. Nevertheless, relatively less light has been reflected on the environmental (or future) uncertainty involved in the decision-making process (Chakraborty et al., 2020). Though continuously growing in the SS literature Due to its ability to capture multidimensionality (Kavta & Goswami, 2021), MCDM tools failed to formulate the probable futures (Sorourkhah & Edalatpanah, 2021a). Robustness analysis is an alternative for addressing this kind of uncertainty. As a result of this approach's inability to handle many options (scenarios or indicators), it has always been vulnerable to some weaknesses when selecting a strategy (Ram et al., 2011). The matrix Approach to RA (MARA) addressed these weaknesses (Sorourkhah, Babaie-Kafaki, et al., 2018). Still, it has a significant disadvantage: it evaluates only one indicator that expresses the overall performance of each option. While in a multi-indicator decision-making problem, assessing the options based on different indicators is necessary. We addressed this disadvantage in this study.

In the proposed approach, five different criteria were considered, including cost (C_1), quality (C_2), lead time (C_3), supply security (C_4), and technology capacity (C_5). We chose three variables shaping future uncertainty: economic, social, and environmental, and specified their probable states (better, stable, and worse). Then, eliminating impossible states, we formed scenario matrix S. Applying MARA, we calculated suppliers' performance in terms of the future scenario for each criterion separately. Using the average performance of the suppliers in the five criteria, we formed the decision matrix in the next step. The results indicated that supplier S_3 was the best and S_2 was the second-best alternative.

In the end, we should mention that further research has diverse directions. While we considered the importance of all criteria equally, the main challenge and mathematical complexity in supplier selection lie in identifying disparate evaluation criteria with varying degrees of importance (Chakraborty et al., 2020). It is generally necessary to deal with problems in uncertain environments that are highly subjective, vague, and/or imprecise, both in terms of descriptions of the environment and decision elements (Edalatpanah, 2018). This point has not been considered in the present study. Furthermore, Increasingly, the manufacturing supply chain emphasizes sustainability to achieve society's goal of a sustainable future (Nguyen et al., 2022). This study considered all four aspects of economics, social, environment, and resilience in determining the criteria (Ghamari et al., 2022).

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