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An Analysis on Sustainable Supplier Countries for Steel Industry Using the DEMATEL Method

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ABSTRACT

The development of Iran's economy depends heavily on the steel industry, which serves as the foundation for many infrastructures, manufacturing, and building projects. Ensuring a sustainable and consistent supply of raw materials becomes crucial as the demand for steel rises. Iran's steel industry must carefully consider a number of criteria, including as resource availability, geopolitical stability, environmental restrictions, and long-term collaborations, when choosing sustainable supply nations.

Research significance: Supply chain (SC) managers have a significant problem with supplier selection, a multi-criteria decision-making dilemma that heavily depends on the decision makers' vision. Recent emphasis has been placed on SC sustainability, which considers the environmental, economic, and social elements of SC, in the evaluation process that SC managers through. Suppliers are crucial in building a sustainable SC because they are the foundational elements of the SC. Therefore, the primary goal of this study is to establish the analytical hierarchy process's weights for the sustainability criteria. The study's second objective is to assess suppliers using four primary factors: CO_2 emissions, the number of workers in the industry in the supplier's country, water usage, and distance from the supplier's country to the final destination. Finally, sensitivity analysis has been conducted using the various sustainability criterion weights. Managers in the steel sector can use the findings of this study to address the macro-level supplier selection issue. The research's suggested approach can also help managers of other sectors choose and assess their suppliers.

Methodology: In this paper the DEMATEL is used for the assessment of sustainable supplier countries for steel industries.

Parameters Evaluated: Quality, cost of production, lead time, reputation supplier, transport cost is used to optimize sustainable supplier countries for steel industries.

Result: Quality has an Ri + Ci value of 9.739269 and a Ri - Ci value of 0.678325. It is ranked 1, indicating that it has the greatest combined influence and impact among the factors. Quality is classified as a cause within the system. Similarly, Cost of production has an Ri + Ci value of 9.443031 and a Ri - Ci value of -0.19979. It is ranked 2 and categorized as an effect within the system. Lead time has an Ri + Ci value of 8.06006 and a Ri - Ci value of -0.96732. It is ranked 5 and considered an effect. Reputation supplier has an Ri + Ci value of 8.422893 and a Ri - Ci value of -0.41017. It is ranked 4 and classified as an effect. Transport cost has an Ri + Ci value of 9.004593 and a Ri - Ci value of 0.898958. It is ranked 3 and identified as a cause.

Quality stands out as a significant cause with a high Ri + Ci value and a positive Ri - Ci value, ranking first. Cost of production is more influenced as an effect, with a lower Ri + Ci value and a negative Ri - Ci value, ranking second. Lead time is ranked fifth as an effect, with a relatively lower Ri + Ci value and a negative Ri - Ci value. Reputation supplier is ranked fourth as an effect, with an Ri + Ci value and a negative Ri - Ci value. Transport cost is a significant cause, positioned at rank three with an Ri + Ci value and a positive Ri - Ci value. Analyzing these values aids decision-makers in understanding the relative influence, impact, and roles of each factor, facilitating processes such as prioritization and resource allocation.

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INTRODUCTION

The development of Iran's economy depends heavily on the steel industry, which serves as the foundation for many infrastructures, manufacturing, and building projects. Ensuring a sustainable and consistent supply of raw materials becomes crucial as the demand for steel rises. Iran's steel industry must carefully consider a number of criteria, including as resource availability, geopolitical stability, environmental restrictions, and long-term collaborations, when choosing sustainable supply nations. Iron ore, coal, and scrap metal are major raw materials imported by Iran's steel industry. The best supplier nations must have large reserves of these resources, assuring a steady supply to meet the demands of the sector. A key element in the selection process is evaluating the resource availability and reserves of possible supplier countries. Another one is geopolitical stability. Another important aspect to take into account when picking supplier nations is geopolitical stability. Iran's steel industry needs consistent, uninterrupted access to raw materials, which might be adversely impacted by political unrest, armed conflict, or commercial disagreements. The danger of supply chain disruptions is decreased by choosing supplier nations with stable political situations and solid diplomatic ties. Certainly! When choosing sustainable supplier nations for Iran's steel sector, keep the following additional factors in mind: Economic variables include the competitiveness and stability of the supplying nations' economies. Assessing elements including production prices, shipping costs, currency stability, and trade agreements can assist in figuring out whether sourcing from a given nation is economically viable. Supply chains can be affordable and effective by selecting nations with strong economies.2. Supply Quality and Consistency: For Iran's steel industry to run well, raw material supplies must be dependable and consistent. Supplier nations that have a track record of reliable supply and adherence to delivery schedules help reduce production disruptions and satisfy market demand.3. Technology and Innovation: Cooperating with supplier nations with cutting-edge technology.

MATERIALS AND METHODS

Materials and Methods for Selecting Sustainable Supplier Countries for Iran's Steel Industry:

1. Data Collection:

a. Resource Assessment: Compile information on the availability and reserves of important raw materials, such as iron ore, coal, and scrap metal, that are needed by the steel industry. Reputable sources for this include government reports, business databases, and geological surveys.

a. Geopolitical Analysis: Gather data on the countries of possible suppliers' diplomatic ties, trade agreements, and political stability. Governmental agencies, international organisations, and companies that analyse political risks are possible sources for this information.

c. Environmental Regulations: Investigate and evaluate the environmental policies and laws of potential supplier nations, paying special attention to compliance with global environmental standards, ethical resource exploitation, and sustainable mining practises. Examine government documents, environmental evaluations, and pertinent laws.

d. Economic Indicators: To determine the economic sustainability of sourcing from other nations, gather economic data such as manufacturing costs, transportation costs, currency stability, and trade statistics. access articles from international financial organisations, trade databases, and official economic reports.

2. Development of the selection criteria:

a. Consultation with Stakeholders: Work with government organisations, environmental groups, and members of civil society to determine the most important factors to consider when choosing sustainable supplier nations. Think about how they view resource security, environmental sustainability, and social responsibility. Take note of their priorities.

a. Definition of Criteria: Establish the selection criteria that will be used to assess possible supplier countries in light of the information gathered and input from stakeholders. Resources availability, geopolitical stability, environmental restrictions, social and labourpractises, economic factors, and quality are some examples of these characteristics.3. Scoring and Weighting:

Weighting: Based on the significance and applicability of each selection criterion to the objectives of Iran's steel industry, assign relative weights to each one. Expert judgement, stakeholder consultations, or the use of analytical methods like the Analytic Hierarchy Process (AHP) can all be used to calculate the weights.

b. Scoring System: Create a system of points or a rating scale to assess prospective supplier nations in relation to each criterion. This may take the form of a quantitative scale or a qualitative evaluation based on established benchmarks or thresholds. The evaluation process should follow the predetermined standards and take into account Iran's steel industry's top priorities.

DEMATEL method: The DEMATEL method, developed by Prof. V. Ramanathan in the 1970s, is a structured approach used to analyze complex decision-making scenarios and assess the interconnections among various factors involved. Its primary goal is to provide decision-makers with insights into the cause-and-effect relationships within a system, enabling them to comprehend the underlying dynamics and prioritize their actions accordingly. This method is particularly beneficial when dealing with intricate systems where multiple factors interact and mutually influence one another.

The DEMATEL method involves several steps. First, the decision-making problem is clearly identified, and the factors or elements involved are identified. Next, experts or stakeholders assign ratings to the causal relationships between each pair of factors, indicating the strength and direction of influence. These ratings are used to construct a Causal Relationship Matrix.

Based on the Causal Relationship Matrix, the method proceeds to develop a Direct and Indirect Relations Matrix. This matrix calculates the direct relationships, representing immediate influences, and the indirect relationships, considering the mediating effects of other factors.

The Total Effect of each factor is then determined by summing up its direct and indirect relationships with other factors. Factors are subsequently classified into two categories: influential factors and dependent factors. Influential factors are those that exhibit a high Total Effect, indicating their significant influence on the system.

The results obtained from the DEMATEL method are then interpreted and analyzed. They aid in the identification of key influential factors and the understanding of causal relationships within the system. Decision-makers can use these findings to make informed decisions and develop appropriate strategies.

One of the notable features of the DEMATEL method is its ability to provide a visual representation of the causal relationships through network diagrams or influence maps. This visualization helps decision-makers grasp the intricate interactions among factors. By comprehending the cause-and-effect dynamics, decision-makers can focus their efforts on addressing influential factors, thereby achieving desired outcomes and avoiding unintended consequences.

In summary, the DEMATEL method is a valuable tool for decision-making in complex systems. It enables a systematic analysis of interdependencies and facilitates the identification of key factors. By employing this method, decision-makers can gain a deeper understanding of the problem at hand and make effective decisions and solve problems more efficiently.

RESULT AND DISCUSSION

TABLE 1. Direct relation matrix

	Quality	Cost of production	Lead time	Reputation supplier	Transport cost	SUM
Quality	0	2	4	2	3	11
Cost of production	4	0	2	1	2	9
Lead time	2	1	0	3	1	7
Reputation supplier	1	3	2	0	2	8
Transport cost	2	4	1	3	0	10

Table 1 illustrates the Direct Relation Matrix within the framework of the DEMATEL method. This matrix depicts the direct connections and the degree of influence among various factors in a system. Each row and column correspond to a specific factor, and the values in the cells indicate the magnitude of influence between the respective factors. The entries in the Quality row specifically reflect the direct relationships and strengths of influence that Quality exerts on other factors. The value of 0 at the intersection of Quality with itself indicates that Quality does not directly influence itself. The value of 2 at the intersection of Quality and Cost of production suggests that Quality moderately affects the Cost of production. The value of 4 at the intersection of Quality and Lead time signifies a strong direct influence of Quality on Lead time. The value of 2 at the intersection of Quality and Reputation supplier indicates that Quality has a moderate direct influence on Reputation supplier. The value of 3 at the intersection of Quality and Transport cost implies a strong direct influence of Quality on Transport cost. Similar interpretations can be derived for the other rows and columns of the matrix. The cell values represent the relative strength of influence, with higher values denoting stronger direct relationships between factors. Analyzing this Direct Relation Matrix allows decision-makers to gain insights into the direct influence exerted by each factor on others within the system. Such insights aid in prioritizing actions, identifying influential factors, and comprehending the overall dynamics of the decision-making problem.

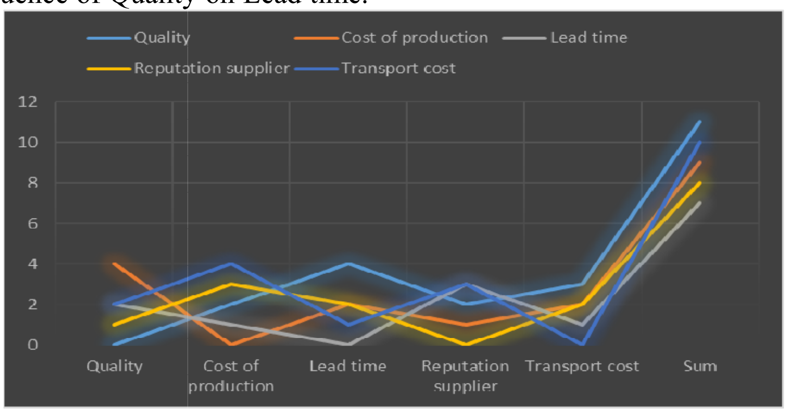

FIGURE 1. Direct relation matrix

Figure 1 presents the Direct Relation Matrix, which shows the direct relationships and strength of influence among factors in the DEMATEL method. Each factor corresponds to a row and column, and the values in the cells indicate the level of influence between the factors. The Quality row specifically represents the direct relationships and strengths of influence that Quality has on other factors. A value of 0 signifies that Quality does not directly influence itself. Values such as 2, 4, and 3 indicate moderate to strong direct influences of Quality on factors like Cost of production, Lead time, Reputation supplier, and Transport cost. Similar interpretations can be made for other rows and columns. The cell values reflect the relative strength of influence, with higher values indicating stronger direct relationships. Analyzing this matrix helps decision-makers understand the direct influence of each factor on others, enabling them to prioritize actions, identify influential factors, and grasp the overall dynamics of the decision-making problem.

TABLE 2. Normalisationof direct relation matrix (Y)

0	0.181818	0.363636	0.181818	0.272727
0.363636	0	0.181818	0.090909	0.181818
0.181818	0.090909	0	0.272727	0.090909
0.090909	0.272727	0.181818	0	0.181818
0.181818	0.363636	0.090909	0.272727	0

Table 2 displays the normalized Direct Relation Matrix derived from the DEMATEL method. The values in this matrix have been adjusted to represent the relative strength of influence between factors on a scale ranging from 0 to 1. The diagonal cells, where a factor is compared to itself, are assigned a value of 0 since a factor does not have a direct impact on itself. Normalizing the values in the Direct Relation Matrix enables decision-makers to gain a clearer understanding of the relative strength of influence among the factors. This normalization process ensures a fair comparison and facilitates the identification of factors that exert the most significant influence within the system. By analyzing the normalized matrix, decision-makers can make more informed decisions regarding the prioritization of actions and the recognition of influential factors.

TABLE 3. Identity matrix (I)

1	0	0	0	0
0	1	0	0	0
0	0	1	0	0
0	0		1	0
0	0	0	0	1

Table 3 depicts the Identity Matrix, which follows a specific pattern. In an Identity Matrix, the diagonal elements, running from the top left to the bottom right, are set to 1, while all other elements are assigned a value of 0. This matrix is square, meaning it has the same number of rows and columns. In this particular Identity Matrix, the diagonal elements are all 1, indicating that each factor is directly related to itself. Conversely, the off-diagonal elements are all 0, signifying the absence of direct relationships between different factors. The Identity Matrix holds significance in mathematics and various matrix operations as it serves as a starting point or reference. In the context of the DEMATEL method, it can be employed as a basis for comparison when examining the direct relationships and influence among factors in other matrices.

TABLE 4. Total Relation matrix ($T = Y(1-Y)^{-1}$)

0.890832	**1.100689**	**1.168345**	**1.038156**	**1.010775**
1.081081	0.837838	**0.963964**	0.864865	0.873874
0.749868	0.735559	0.612259	0.81558	0.633104
0.788553	**0.952305**	0.832538	0.666137	0.766826
1.020138	**1.195019**	**0.936584**	**1.031797**	0.768239

Table 4 displays the Total Relation Matrix, which is computed using the formula T = Y (1-Y)-1. Each cell in the matrix corresponds to a value obtained from a previous matrix, likely the normalized Direct Relation Matrix (Y). The Total Relation Matrix is derived by subtracting each value in the Y matrix from 1 and then dividing 1 by the resulting value. This formula allows for the assessment of the overall relationships and interactions between factors, encompassing both direct and indirect influences. The values in Table 4 represent the total relationships between factors within the system. Higher values indicate stronger relationships or dependencies, while lower values signify weaker relationships.

In order to filter out some insignificant impacts, a decision maker must set up a threshold value since matrix T shows how one component influences another. Only the effects that were bigger than the threshold value would then be selected and displayed in a digraph. The threshold value in this study is established by averaging the elements of matrix T. Here Alpha value= 0.893397 is the average of the total relation matrix. Values higher than alpha are highlighted in total relation matrix (table 4)

TABLE 5. Ri and Ci values

	Ri	Ci
Quality	5.208797	4.530472

Cost of production	4.621622	4.82141
Lead time	3.54637	4.51369
Reputation supplier	4.006359	4.416534
Transport cost	4.951775	4.052818

Table 5 displays the Ri and Ci values, representing the Row Sum and Column Sum, respectively, for different factors. The Ri values indicate the total influence of a factor on all other factors, while the Ci values represent the total influence received by a factor from all other factors. These values provide insights into the relative importance and influence of each factor within the system. Factors with higher Ri values have a greater impact on other factors, while factors with higher Ci values are more influenced by the other factors. Analyzing the Ri and Ci values assists decision-makers in understanding the significance of factors, prioritizing actions, and comprehending the dynamics of the decision-making problem.

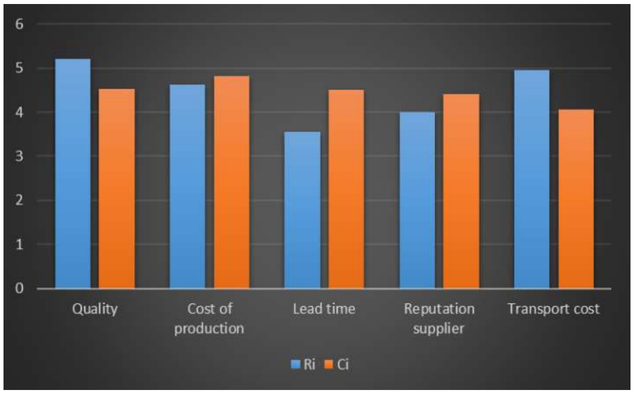

FIGURE 2. Ri and Ci values

Figure 2 illustrates the Ri and Ci values, which represent the Row Sum and Column Sum, respectively, for various factors. The Ri values reflect the overall influence of a factor on all other factors, while the Ci values indicate the total influence received by a factor from the remaining factors. These values provide valuable insights into the relative importance and influence of each factor within the system. Factors with higher Ri values exert a greater impact on other factors, while factors with higher Ci values are more influenced by the other factors. Analyzing the Ri and Ci values aids decision-makers in gaining a deeper understanding of factor significance, prioritizing actions, and comprehending the intricacies of the decision-making process.

TABLE 6. Ri + Ci, Ri – Ci and ranks

	Ri + Ci	Ri - Ci	Rank	Identity
Quality	9.739269	0.678325	1	cause
Cost of production	9.443031	-0.19979	2	effect
Lead time	8.06006	-0.96732	5	effect
Reputation supplier	8.422893	-0.41017	4	effect
Transport cost	9.004593	0.898958	3	cause

Table 6 displays the Ri + Ci, Ri - Ci, Rank, and Identity values for various factors. The Ri + Ci column represents the total influence and impact of each factor, considering both its influence on other factors (Ri) and the influence it receives from others (Ci). The Ri - Ci column shows the net influence of each factor, obtained by subtracting the influence it receives from the influence it exerts. The Rank column indicates the ranking of the factors based on their combined influence and impact, with 1 denoting the highest rank. The Identity column specifies whether each factor is considered a cause or an effect within the system. For instance, Quality has an Ri + Ci value of 9.739269 and a Ri - Ci value of 0.678325. It is ranked 1, indicating that it has the greatest combined influence and impact among the factors. Quality is classified as a cause within the system. Similarly, Cost of production has an Ri + Ci value of 9.443031 and a Ri - Ci value of -0.19979. It is ranked 2 and categorized as an effect within the system. Lead time has an Ri + Ci value of 8.06006 and a Ri - Ci value of -0.96732. It is ranked 5 and considered an effect. Reputation supplier has an Ri + Ci value of 8.422893 and a Ri - Ci value of -0.41017. It is ranked 4 and classified as an effect. Transport cost has an Ri + Ci value of 9.004593 and a Ri - Ci value of 0.898958. It is ranked 3 and identified as a cause. Examining the Ri + Ci and Ri - Ci values, along with the ranks and identities of the factors, assists decision-makers in comprehending the relative influence, impact, and roles of each factor within the system.

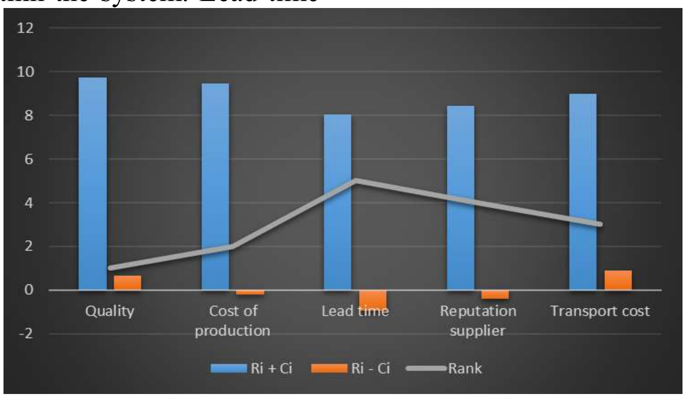

FIGURE 3. Ri + Ci, Ri – Ci and ranks

Figure 3 presents a visual representation of the Ri + Ci, Ri - Ci, Rank, and Identity values for different factors. These values are useful for evaluating the influence and impact of each factor within the system. Quality stands out as a significant cause with a high Ri + Ci value and a positive Ri - Ci value, ranking first. Cost of production is more influenced as an effect, with a lower Ri + Ci value and a negative Ri - Ci value, ranking second. Lead time is ranked fifth as an effect, with a relatively lower Ri + Ci value and a negative Ri - Ci value. Reputation supplier is ranked fourth as an effect, with an Ri + Ci value and a negative Ri - Ci value. Transport cost is a significant cause, positioned at rank three with an Ri + Ci value and a positive Ri - Ci value. Analyzing these values aids decision-makers in understanding the relative influence, impact, and roles of each factor, facilitating processes such as prioritization and resource allocation.

CONCLUSION

In conclusion, the process of choosing environmentally sound supplier nations for Iran's steel industry is crucial to ensuring the sector's long-term viability, economic growth, and environmental sustainability. Iran can make decisions that are in line with its goals and objectives by taking into account variables such resource availability, geopolitical stability, environmental rules, social responsibility, economic considerations, and technological breakthroughs. Data on resource assessments, geopolitical studies, environmental restrictions, and economic indicators are all collected thoroughly as part of the selecting process. In order to define the selection criteria and give them the proper weight, taking into account the priorities and viewpoints of many stakeholders, stakeholder consultation is essential. Potential supplier nations are evaluated and ranked according to how well they perform in comparison to the established criteria using a score system and evaluation methodology. Sensitivity evaluation enables Comparative ranking analysis is done as part of the decision-making process, taking into account the advantages and disadvantages of each potential supplier nation. The decision is ultimately guided by strategic factors, risk evaluations, and alignment with the goals and objectives of Iran's steel sector. The continual performance evaluation of chosen supplier nations is ensured by the establishment of a system for monitoring and continuous evaluation. The sustainability and dependability of the supply chain are maintained through routine assessments and adjustments depending on modifications to environmental laws, labourpractises, resource availability, and technology improvements. In general, resource security, environmental sustainability, social responsibility, and economic viability are all supported by the process of choosing sustainable supplier nations for Iran's steel sector. Iran can guarantee the ongoing development and competitiveness of its steel sector by making educated judgements and building long-term relationships with sustainable suppliers.

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