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Selecting Suppliers in a Sustainable and Resilient Supply Chain Using an Integrated SWARA and COPRAS Approach

Mohsen Soleimani[1], Maryam Mozaffari[1,*]

Department of Industrial Engineering, South Tehran Branch, Islamic Azad University, Tehran, Iran; m_mozafari@iau.ac.ir.

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Abstract

This study aims to select suppliers within a sustainable and resilient supply chain using a hybrid multi-criteria decision-making approach composed of the Stepwise Weight Assessment Ratio Analysis (SWARA) and the Complex Proportional Assessment (COPRAS) methods. To this end, key indicators were first identified through a literature review and library-based studies. They were then screened using the Delphi method and subsequently classified through Exploratory Factor Analysis (EFA). Based on the results of this analysis, the indicators were grouped into two main categories: Sustainable supply chain and resilient supply chain. They were weighted and prioritized using the SWARA technique. In the exploratory analysis phase, 300 employees from the production and operations departments of Ilam Cement Company participated in the questionnaire survey using a census sampling approach. In addition, 10 experts and managers from Ilam Cement Company were involved in the Delphi process. The results indicated that among the sub-criteria, Environmental Management Systems (e.g., ISO 14001 certification) ranked first, on-time delivery ranked second, and environmental pollutant emissions ranked third. Finally, the shortlisted suppliers of Ilam Cement Company were evaluated and ranked using the COPRAS multi-criteria decision-making method. The results of applying the integrated SWARA–COPRAS approach demonstrate that the simultaneous integration of sustainability and resilience dimensions can provide a more accurate assessment of supplier capability in manufacturing industries.

Keywords: Supplier selection, Sustainable supply chain, Resilient supply chain, Multi-criteria decision-making.

1 | Introduction

In recent years, the selection of the most appropriate supplier within supply chains has become a critical strategic consideration. With the globalization of competition and companies' increasing focus on supply

Corresponding Author: m_mozafari@iau.ac.ir

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chain development, decisions related to sourcing have gained greater importance than ever, as, on average, approximately 60% of a manufacturing firm's transaction volume is allocated to the procurement of materials, goods, and services from suppliers. Globalization and the emergence of advanced corporations have led to a continuous increase in the outsourcing of components and services. This trend has compelled firms to pay greater attention to procurement processes and related decision-making activities [1]. Supplier selection is a critical task for organizational success.

The objective of supplier selection is to identify "appropriate" suppliers based on criteria such as cost, quality, and environmental performance. Given the pivotal role of suppliers in the supply chain and their impact on final products and services, decisions related to the evaluation and selection of this supply chain member are considered among the most consequential and strategic decisions for organizations. Large industries typically interact with diverse groups of suppliers.

Accordingly, clustering these suppliers into homogeneous groups facilitates the evaluation and selection process. The supplier evaluation and selection process plays a critical role in supply chain management.

In addition, appropriate supplier selection contributes to reducing procurement costs, increasing customer satisfaction, improving final product quality, and strengthening firms' competitiveness. Focusing solely on economic performance for cost optimization or return on investment cannot lead to sustainable development within the supply chain. The impacts of various supply chain activities on society and the environment, which ultimately contribute to sustainable development, must also be taken into account. Accordingly, sustainable supply chain management has emerged in order to incorporate social and environmental concerns alongside economic factors in supply chain planning.

In addition, government regulations, rising public awareness, and consumer pressure have compelled businesses to exercise greater caution and diligence regarding the environmental impacts of their operations. The growing emphasis on environmental and social issues within supply chains has further intensified the importance of sustainable supplier selection.

Since human well-being depends on having a healthy natural environment and a safe social context free from hazards, the concept of sustainability has been introduced to address environmental and social issues (such as natural resources, water and energy management, the development of infrastructure for pollution reduction, and the elimination of social inequalities including poverty, disabilities, and the rights of children, women, and minorities), alongside economic considerations, as a highly influential topic for the future of humanity by researchers.

Supply chains, by promoting responsible behavior across all stages and actors, can serve as an effective platform for advancing sustainability. The long-term selection of sustainable suppliers leads to the creation of competitive advantage across the entire supply chain. Sourcing sustainable raw materials has consistently been one of the key concerns of manufacturing companies. With increasing environmental and social awareness, the selection of sustainable suppliers has become a priority for organizations. In this regard, a considerable number of both domestic and international studies have been conducted.

Ebrahim Nia et al. [2] carried out a study entitled "Modeling a two-stage integrated problem for supplier selection and sustainable supply chain network design using D-number theory and robust possibilistic optimization."

In this study, an uncertain model of the supply chain network problem was developed; therefore, transportation cost parameters and customer product demand were considered uncertain and represented using trapezoidal fuzzy numbers. To handle these uncertainties, a fuzzy robust optimization approach was employed. Given the tri-objective nature of the model, a multi-objective decision-making framework was used as a comprehensive criterion for solving the model, resulting in six efficient (Pareto-optimal) solutions. For analyzing the output variables of the problem, the NSGA-II, MOPSO, and MOALO algorithms were applied.

Furthermore, Ardavan et al. [3] conducted a study entitled "Sustainable Supplier Selection Using Grey System Theory: A Case Study of the Steel Industry." Supplier selection plays a significant role in supply chain management. The growing emphasis on sustainability in supply chains has made supplier selection an increasingly challenging issue.

Moreover, in the relevant literature, various methods, primarily based on linear programming, multi-objective programming, goal programming, integer programming, and similar approaches, have been employed for supplier evaluation. However, most evaluation criteria are inherently vague, qualitative, and linguistic in nature. In this regard, a novel approach based on Grey System Theory has been proposed for supplier evaluation, which can be effectively applied under conditions of uncertainty and ambiguity, thereby supporting managerial decision-making in supplier selection. In this study, based on expert opinions, economic, environmental, and social indicators were identified for supplier evaluation, and then Grey System Theory was employed to assess and rank the suppliers.

Among the international studies, Esrikumar and Rajmohan [4] conducted a study entitled "evaluation of supply chain strategy decisions for sustainable development using an integrated multi-criteria decision-making approach." From a sustainability perspective, the results indicate that the second strategy set, with an objective coefficient of 0.5, represents the best option among the alternatives considered. The robustness of the results was also analyzed to account for uncertainty in the final ranking.

The consistency of the final ranking was evaluated based on different values of the objective factor. This approach provides a flexible framework for decision-makers, enabling them to incorporate an appropriate balance of subjectivity and objectivity into their decisions according to their level of expertise.

Amindoost [5] proposed a study titled "a supplier selection model based on flexibility using a hybrid intelligent approach." In this research, a fuzzy-based approach was employed for supplier selection. In addition, a modular Fuzzy Inference System (FIS) was designed to compute supplier dependency indices with respect to flexibility and sustainability issues.

Furthermore, a modular FIS framework was employed to develop a comprehensive supplier selection model capable of supporting any number of criteria and suppliers. Subsequently, the outputs obtained from the proposed modular FIS were integrated with the Assurance Region Data Envelopment Analysis (AR-DEA) method to determine the weights of criteria for supplier ranking. Finally, the results indicated that Supplier No. 3 was identified as the best option.

Ajali [6] conducted a study on the evaluation of key factors in sustainable supply chain management and the ranking of suppliers using an integrated multi-criteria decision-making approach. The findings of this study showed that the factor "sustainability training for managers" had the highest weight, indicating its greater importance compared to other factors.

Additionally, the factor "implementation of environmental management systems" ranked second in terms of importance in sustainable supply chain management within the country's gas industry. Tavasoli et al. [7] introduced a bi-fuzzy model for evaluating the sustainability of supply chains and employed the α-cut approach to solve the proposed models.

In another study [8], the authors used stochastic and fuzzy Data Envelopment Analysis (DEA) to evaluate suppliers' sustainability indicators. Izadi Khah et al. [9] applied DEA for clustering suppliers, thereby identifying and eliminating non-qualified suppliers. In their study, a new algorithm was proposed for supplier selection that integrates a fuzzy screening system with the DEA method.

In 2022, the authors in study [10] conducted a comprehensive review of the literature on the application of DEA in sustainable supplier selection. Furthermore, Yarahmadi and Sakinia [11] proposed an intelligent model for sustainable supplier selection.

In this context, and in light of previous studies and the existing theoretical literature, it can be stated that in the past decade, the identification of the most appropriate supplier has increasingly been recognized as a strategic factor in supply chain management. If important parameters such as sustainability are also considered essential for continued operations, the selection process will no longer be straightforward.

Today, no company can afford to ignore supply chain management and still expect to survive [12]. Environmental performance has been recognized as a core component in measuring and assessing corporate sustainability.

According to the latest reports and information from the World Health Organization, environmental health, and particularly human health, is in a critical and hazardous condition [13]. On the other hand, a resilient supply chain must be able to respond to market fluctuations and changing customer needs in order to attract customers in a highly competitive environment.

Therefore, selecting appropriate suppliers based on the level of supply chain flexibility and sustainability can significantly assist managers in addressing deficiencies and enhancing competitive advantage. The economic development of companies operating in the cement industry, when accompanied by unsustainable exploitation of the environment, has posed serious threats to sustainable development.

Water and air pollution are among the key environmental challenges that have been intensified by industrialization and increased energy consumption. Today, achieving sustainable development requires attention to industries that, through the responsible utilization of resources and adherence to environmental principles, contribute to improving the quality of life for society without creating serious risks for future generations.

Moreover, supply chain flexibility is an operational capability that enables a disrupted or failed supply chain to recover and become stronger than before. Ilam Cement Company, in its pursuit of obtaining the IMS quality management system certification in the fields of quality, environment, and safety, became the first cement company in the country in 2010 to successfully acquire the ISO/IEC 17025 standard, related to "General requirements for the competence of testing and calibration laboratories", as an international benchmark for validating laboratory testing and calibration competence from the German accreditation body DAkkS.

This achievement reflects the company's strong commitment to sustainability components. Therefore, proposing a framework that integrates sustainable and resilient supply chain management for supplier selection at Ilam Cement Company would represent an important step toward the company's development.

2|Research Methodology

The present study is a descriptive–survey study in terms of its nature and methodology. In the first phase, supplier selection criteria within the context of sustainable and resilient supply chains are identified through a review of the literature and library-based research.

Then, the Delphi technique is employed with a panel of experts to eliminate non-essential criteria, and the final list of valid indicators is obtained through expert consensus. In the next stage, these criteria are categorized using Exploratory Factor Analysis (EFA). The weighting of criteria and sub-criteria is performed using the Stepwise Weight Assessment Ratio Analysis (SWARA) method, and based on these weights, suppliers are ranked using the Complex Proportional Assessment (COPRAS) technique.

2.1|Identification of Sustainable Supplier Selection Criteria Using the Delphi Technique

In the first phase, the most frequently used criteria related to sustainable and resilient supply chains for supplier selection were identified through a review of the literature and library-based research. These criteria are presented in *Table 1*.

Table 1. Extracted criteria from the literature.

Criteria	Source
Financial position and market share	[14], [15], [16]
Use of renewable and non-renewable energy	[21]
Revenue from green products	[16], [17], [18], [19], [20], [21]
Logistics management cost	[20], [22], [23]
Quality and safety of components and material	[5], [18], [24], [25], [26], [27]
Order fulfillment completeness	[21], [23], [23]
Supplier flexibility level	[21], [22]
Use of clean technologies	[28], [29], [30], [31]
After-sales service	[22], [23]
Number of skilled and trained employees	[32], [15], [24]
Order cost and product pricing	[22], [23]
Environmental pollutant emissions	[5], [16], [27], [28], [29], [33], [34], [35], [36], [37], [38], [39]
Customer satisfaction	[18], [40]
Fast responsiveness	[5], [41], [23]
Interaction with local communities	[16], [33]
Backup supplier contract	[5], [23], [23]
Information transparency (level of openness toward stakeholders)	[5], [18], [26], [31]
Participation	[5], [22]
Service flexibility	[22], [41]
Environmental management system (ISO 14001 certification, etc.)	[26], [27], [31], [35], [42]
Supplier capacity	[5], [22]
Inventory level	[5], [23]
Green transportation	[14], [37], [38], [39], [43]
Technological systems	[22], [23], [23]
Ethical principles (ethical environment regulations, etc.)	[44]
Financial risk	[22], [41]
Employee health and safety	[5], [19], [37], [38], [33]
Geographical location	[5], [23], [23]
Facility capacity	[5], [35]
Ease of communication	[22], [41]
Cost reduction capability	[22], [41]
Green Research and Development (Green R&D)	[35], [37], [38], [39]
Product reliability	[5], [22], [41]

The Delphi technique is defined as a research approach aimed at achieving consensus through a series of questionnaires and controlled feedback provided to experts in the relevant field. In this study, a comprehensive theoretical framework is adopted for the application of the Delphi method. Saaty [45] argues that a panel of 10 experts is sufficient for studies based on pairwise comparisons. Similarly, Khorramshahgol and Moustakis [43] emphasize that the number of experts should not be excessively large and recommend a range of 5 to 15 participants. Accordingly, in this study, the opinions of 10 experts and managers from Ilam Cement Company were purposively collected and used in the Delphi process.

In the first round of the Delphi technique, several criteria, including renewable and non-renewable energy consumption, interaction with local communities, backup supplier contracts, inventory level, technological systems, and ethical principles (ethical environmental regulation, etc.), received scores below 4 and were therefore eliminated from further analysis. Additionally, “on-time delivery” was introduced by the experts as a new criterion and, along with the remaining indicators, entered the second Delphi round for further evaluation.

In the second round, all criteria obtained scores higher than 4; consequently, to achieve greater consistency and expert consensus, the indicators were re-evaluated in a third round. Ultimately, the Delphi process concluded after the third round with a final set of 27 criteria, following the attainment of full agreement among the experts.

2.2 | Stepwise Weight Assessment Ratio Analysis Technique

In many multi-criteria decision-making problems, the weighting of criteria represents one of the most critical stages of the process. Accordingly, experts play a fundamental role in evaluating the criteria and determining their corresponding weights, and their involvement constitutes an indispensable part of the decision-making process. The SWARA method enables decision-makers to select, evaluate, and assign weights to criteria in a structured manner.

One of the main advantages of this method compared to similar approaches is its ability to capture and reflect the precision of experts' judgments regarding the assigned weights throughout the procedure. Moreover, experts are allowed to interact and consult with one another, and such interaction enhances the accuracy and reliability of the results compared to other multi-criteria decision-making techniques.

Step 1 (ranking the criteria). In the first step, the criteria are identified, and then, based on expert opinions, the most important criteria are screened and ranked according to their degree of importance. Accordingly, the most important criterion is placed in the first position. In this study, the criterion "sustainable supply chain" was identified as the most significant based on expert judgments, followed by the "resilient supply chain" criterion as the next most important.

Step 2 (determining the relative importance of main criteria (S_j)). In this stage, the relative importance of each criterion is evaluated and scored with respect to the more important criterion. In the SWARA method, this value is denoted by S_j. A group of experts determines the importance of the criteria, and the average values are reported.

Step 3 (calculation of the coefficient K_j). In this step, the coefficient K_j is calculated as a function of the relative importance value of each criterion, using the following equation:

$$K_j = S_j + 1,$$

Step 4 (calculation of the initial weight and subsequent weights). In this step, the initial weight is computed, and the weights of the criteria are determined sequentially relative to the previous criterion. The weight of each criterion is calculated using the following relationship:

$$Q_j = \frac{Qj - 1}{K_j},$$

Step 5 (normalization of weights). In this step, the normalized weights of the criteria are obtained using the following equation:

$$w_j = \frac{Q_j}{\sum Q_j},$$

2.3 | Complex Proportional Assessment Technique

In this phase, supplier ranking is carried out using the weighted criteria and sub-criteria obtained in the previous phase by applying the COPRAS technique. According to the COPRAS method, priority is given to the option that has the greatest distance from negative factors and the smallest distance from positive factors. The steps of this method are as follows:

Step 1 (identification of criteria and suppliers). The main indicators (criteria) and alternatives have been identified. Therefore, the decision matrix of alternatives based on the criteria has been constructed. For scoring each criterion, a nine-point Likert scale has been used. The score assigned to each indicator is evaluated according to the experts' opinions.

Step 2 (preparing the normalized matrix). In the second step, considering the final weights of the sub-criteria and indicators obtained from the previous stage and using the SWARA technique, the existing matrix is normalized. The weight of each criterion calculated by the SWARA method is denoted by q_i. Based on the following normalization relation:

$$d_{ij} = \frac{q_i}{\sum_{j=1}^{n} x_{ij}} x_{ij},$$

where the denominator is equal to the sum of the sub-criteria and indicator values for each option. **Step 3 (calculating the sum of positive and negative indicators).** In the third step, after normalizing the sub-criteria and indicators, the values Σsj+ and Σsj− are calculated. For this purpose, the positive and negative indicators of each option are computed separately.

Step 4 (calculating Qj). Qj is calculated based on the beneficial and non-beneficial sub-criteria and indicators through the following equation:

$$Q_j = S_j{}^+ + \frac{S^-_{min} \sum_j^n = 1 S_j^- x}{S_j^- \sum_j^n = 1 \frac{S^-_{min}}{S_j^-}} = S_j{}^+ + \frac{\sum_j^n = 1 S_j^-}{S_j^- \sum_j^n = 1 \frac{1}{S_j^-}}.$$

Step 5 (ranking the alternatives). The alternative with the best status among the available alternatives is identified. The higher the value of Qj for an alternative, the higher its value of Nj will be. This value is expressed as a percentage; that is, its overall value is calculated on a scale from 0 to 100.

$$N_j = \frac{Q_j}{Q_{max}} \times 100$$

The ranking is performed based on the value of Q_j; therefore, the alternative with the highest values of Q_j and N_j is considered the most appropriate alternative.

3 | Results and Findings

In this study, a total of 300 employees from the production and operations departments of Ilam Cement Company participated in the survey through a census sampling approach and responded to the questionnaire items. To classify the indicators identified through the Delphi method, an EFA was conducted using SPSS software. By generating a correlation matrix, factor analysis reveals clusters of variables that exhibit strong intercorrelations within each cluster while remaining relatively uncorrelated with variables in other clusters. These clusters were interpreted as the key dimensions associated with sustainable supply chain and resilient supply chain practices for supplier selection. The variables within each cluster represent the measurement items corresponding to that specific dimension.

Variables that do not demonstrate meaningful correlations with other variables should be excluded from the analysis, as factor analysis requires each variable to exhibit a reasonable degree of association with at least some of the other variables under investigation. One of the most widely used measures for assessing the adequacy of sample size for factor analysis is the Kaiser–Meyer–Olkin (KMO) statistic, also referred to as the Measure of Sampling Adequacy (MSA). A KMO value greater than 0.70 indicates that the correlation structure is sufficiently robust and appropriate for factor analysis.

The computed KMO value was 0.782, confirming the suitability of the correlation matrix for conducting EFA. Furthermore, the results of the EFA used to identify the sub-criteria associated with the sustainable and resilient supply chain clusters in supplier selection are presented in *Table 2*.

Table 2. Cluster elements for supplier selection in a sustainable and resilient supply chain.

Indicators		**Factors**	
		1 **Sustainable Supply Chain**	**2** **Resilient Supply Chain**
Financial position and market share	Q1	0.589	
Revenue generated from green products	Q2	0.652	
Logistics management cost	Q3		0.678
Quality and safety of parts and materials	Q4	0.596	
Order fulfillment completeness	Q5		0.547
Supplier flexibility level	Q6		0.538
Adoption of clean technologies	Q7	0.707	
After-sales services	Q8		0.661
Number of skilled and trained employees	Q9	0.572	
Ordering costs and product prices	Q10		0.599
Environmental pollutant emissions	Q11	0.854	
Customer satisfaction	Q12	0.621	
Responsiveness and prompt reaction	Q13		0.558
Information and transparency (extent of information disclosure to stakeholders)	Q14	0.912	
Collaboration and partnership	Q15		0.538
Service flexibility	Q16		0.529
Environmental management system (e.g., ISO 14001 certification)	Q17	0.515	
	Q18		0.602
Supplier capacity			
	Q19	0.569	
Green transportation practices			
	Q20		0.568
Financial risk			
	Q21	0.874	
Employee health and safety			
	Q22		0.555
Geographical location			
	Q23		0.773
Ease of communication			
	Q24		0.888
Cost reduction capability			
	Q25	0.934	
(Green R&D)			
	Q26		0.521
Product reliability			
	Q27		0.525
On-time delivery			

Accordingly, the indicators identified in this study can be systematically classified into criteria and sub-criteria, as presented in *Table 3*.

Table 3. Classification of identified indicators into criteria and sub-criteria.

Criteria	Symbol	Sub-Criteria	Symbol
Sustainable supply chain	C1	Financial position and market share	S11
		Revenue generated from green products	S12
		Quality and safety of parts and materials	S13
		Adoption of clean technologies	S14
		Number of skilled and trained employees	S15
		Environmental pollutant emissions	S16
		Customer satisfaction	S17
		Information transparency (extent of information disclosure to stakeholders)	S18
		Environmental management system (e.g., ISO 14001 certification)	S19
		Green transportation practices	S110
		Employee health and safety	S111
		Green R&D	S112
Resilient supply chain	C2	Logistics management cost	S21
		Order fulfillment completeness	S22
		Supplier flexibility	S23
		After-sales services	S24
		Ordering costs and product prices	S25
		Responsiveness	S26
		Collaboration and partnership	S27
		Service flexibility	S28
		Supplier capacity	S29
		Financial risk	S210
		Geographical location	S211
		Ease of communication	S212
		Cost reduction capability	S213
		Product reliability	S214
		On-time delivery	S215

The relative importance of each main criterion was calculated using the parameters S_j, k_j, the initial weight, and the normalized weight in the SWARA method, as presented in *Table 4*. According to the results, the Sustainable Supply Chain ranks first with a weight of 0.631, while the Resilient Supply Chain ranks second with a weight of 0.369.

Table 4. Normalized weights of the main criteria.

Criteria	Average Relative Importance of Each Criterion (S_j)	Kj=Sj+1	Initial Weight of Each Criterion (q_j)	Normalized Weight (w_j)
Sustainable supply chain	1.00	2.00	2.000	0.631
Resilient supply chain	0.71	1.71	1.170	0.369
			3.170	1.000

The relative importance of the sub-criteria associated with the sustainable supply chain criterion was calculated using the parameters S_j, k_j, the initial weight, and the normalized weight, as presented in *Table 5*.

Table 5. Relative importance and normalized weights of sustainable supply chain sub-criteria.

Sub-Criteria	Average Relative Importance of Each Sub-Criterion (S_j)	Kj=Sj+1	Initial Weight of Each Sub-Criterion (q_j)	Normalized Weight (w_j)
Environmental management system (e.g., ISO 14001 certification, etc.)	1.00	2.000	2.000	0.430
Environmental pollutant emissions	0.810	1.810	1.105	0.237
Quality and safety of parts and materials	0.730	1.730	0.639	0.137
Financial position and market share	0.710	1.710	0.374	0.080

Table 5. Continued.

Sub-Criteria	Average Relative Importance of Each Sub-Criterion (S_j)	Kj=Sj+1	Initial Weight of Each Sub-Criterion (q_j)	Normalized Weight (w_j)
Customer satisfaction	0.700	1.700	0.220	0.047
Green transportation	0.690	1.690	0.130	0.028
Revenue generated from green products	0.680	1.680	0.077	0.017
Green R&D	0.660	1.660	0.047	0.010
Use of clean technology	0.630	1.630	0.029	0.006
Employee health and safety	0.610	1.610	0.018	0.004
Number of skilled and trained employees	0.590	1.590	0.011	0.002
Information transparency (degree of information disclosure to stakeholders)	0.570	1.570	0.007	0.002
			4.656	1.000

The sub-criterion environmental management system (e.g., ISO 14001 certification, etc.) ranked first with a weight of 0.430, followed by Environmental Pollutant Emissions with a weight of 0.237 and Quality and Safety of Parts and Materials with a weight of 0.137, ranking second and third, respectively. In contrast, the sub-criterion Information Transparency (the degree of information disclosure to stakeholders) ranked twelfth (the lowest priority) with a weight of 0.002. The bar chart illustrating the weights of the sub-criteria is presented in *Fig. 1*.

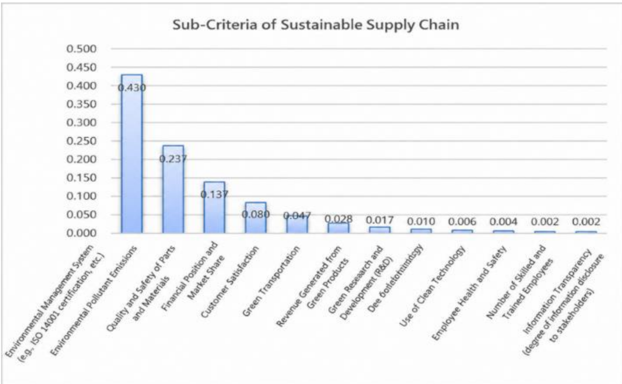

Fig. 1. Normalized weights of the sustainable supply chain sub-criteria.

Using the same approach, the relative importance of the sub-criteria associated with the "flexible supply chain" criterion is derived according to *Table 6*. As shown in *Table 6*, the sub-criterion "on-time delivery," with a weight of 0.423, ranks first. This is followed by "rapid responsiveness," with a weight of 0.236, and "service flexibility," with a weight of 0.137, which rank second and third, respectively. In contrast, the sub-criterion "information transparency" (i.e., the degree of openness of information toward stakeholders) with a weight of 0.0004 is ranked fifteenth, the lowest priority. *Fig. 2* illustrates the bar chart of the weights of the sub-criteria under the flexible supply chain criterion.

Table 6. Weights and ranking of flexible supply chain sub-criteria.

Sub-Criteria	SJ (Average Relative Importance)	Kj = SJ + 1	Initial Weight qj	Normalized Weight wj
On-time delivery of goods	1.000	2.000	2.000	0.423
Rapid responsiveness	0.790	1.790	1.117	0.236
Service flexibility	0.720	1.720	0.650	0.137
Product reliability	0.690	1.690	0.384	0.081
Supplier flexibility level	0.680	1.680	0.229	0.048

Table 6. Continued.

Sub-Criteria	SJ (Average Relative Importance)	Kj = SJ + 1	Initial Weight qj	Normalized Weight wj
Order cost and product price	0.670	1.670	0.137	0.029
Ease of communication	0.660	1.660	0.083	0.017
Financial risk	0.650	1.650	0.050	0.011
Cost reduction capability	0.630	1.630	0.031	0.006
After-sales service	0.610	1.610	0.019	0.004
Supplier capacity	0.590	1.590	0.012	0.003
Logistics management cost	0.580	1.580	0.008	0.002
Order completeness	0.570	1.570	0.005	0.001
Geographical location	0.530	1.530	0.003	0.001
Participation	0.510	1.510	0.002	0.000

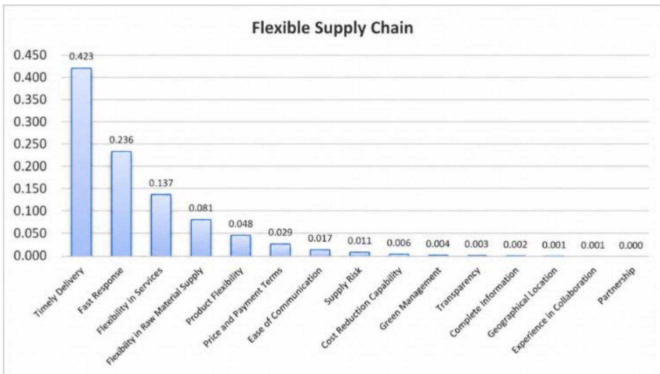

Fig. 2. Normalized weights of sub-criteria related to the flexible supply chain criterion.

Finally, to calculate the final weights of the sub-criteria, the weight of each main criterion was multiplied by the weights of its corresponding sub-criteria at the subsequent level of the hierarchy. The resulting final weights of all sub-criteria are presented in *Table 7*.

Table 7. Final weights of the sub-criteria.

Criterion Code	Criterion	Criterion Weight	Sub-Criterion Code	Sub-Criterion	Sub-Criterion Weight	Final Weight	Rank
			S11	Financial position and market share	0.0802	0.0506	7
			S12	Revenue from green products	0.0166	0.0105	13
			S13	Quality and safety of parts and materials	0.1372	0.0866	4
			S14	Use of clean technology	0.0061	0.0039	17
C1	Sustainable supply chain	0.631	S15	Number of skilled and trained employees	0.0024	0.0015	21
			S16	Environmental emissions	0.2373	0.1498	3
			S17	Customer satisfaction	0.0472	0.0298	9
			S18	Information transparency (degree of openness to stakeholders)	0.0015	0.0010	22
			S19	Environmental management system (ISO 14001 certification, etc.)	0.4296	0.2711	1
			S110	Green transportation	0.0279	0.0176	11
			S111	Health and safety of employees	0.0038	0.0024	19
			S112	Green R&D	0.0100	0.0063	15

Table 7. Continued.

Criterion Code	Criterion	Criterion Weight	Sub-Criterion Code	Sub-Criterion	Sub-Criterion Weight	Final Weight	Rank
			S21	Logistics management cost	0.0016	0.0006	24
			S22	Order completeness	0.0010	0.0004	25
			S23	Supplier flexibility level	0.0484	0.0179	10
			S24	After-sales service	0.0040	0.0015	20
			S25	Order cost and product price	0.0290	0.0107	12
			S26	Rapid responsiveness	0.2363	0.0872	5
			S27	Participation	0.0004	0.0002	26
			S28	Service flexibility	0.1374	0.0507	6
			S29	Supplier capacity	0.0025	0.0009	23
			S210	Financial risk	0.0106	0.0039	16
			S211	Geographical location	0.0007	0.0002	27
C2	Flexible supply chain	0.369	S212	Ease of communication	0.0175	0.0064	14
			S213	Cost reduction capability	0.0065	0.0024	18
			S214	Product reliability	0.0813	0.0300	8
			S215	On-time delivery of goods	0.4229	0.1561	2

To rank the suppliers of Ilam Cement Company, the COPRAS technique was employed. First, a decision-making matrix was constructed in which A, B, C, and D represent the four main suppliers of the company. The values presented in the matrix indicate the performance scores of each supplier with respect to each sub-criterion. To obtain the normalized decision matrix, each element of the decision matrix was divided by the sum of its corresponding column. Subsequently, the resulting normalized matrix was multiplied by the weights derived from the SWARA technique. This process yielded the weighted normalized decision matrix, which is presented in *Table 8*.

Table 8. Normalized decision matrix.

	A	B	C	D
S11	0.0118	0.0124	0.0135	0.0129
S12	0.0024	0.0025	0.0030	0.0026
S13	0.0218	0.0247	0.0184	0.0218
S14	0.0011	0.0008	0.0008	0.0012
S15	0.0004	0.0003	0.0004	0.0004
S16	0.0399	0.0346	0.0381	0.0372
S17	0.0076	0.0067	0.0082	0.0072
S18	0.0002	0.0003	0.0003	0.0002
S19	0.678	0.652	0.0704	0.0678
S110	0.0049	0.0050	0.0044	0.0033
S111	0.0006	0.0007	0.0005	0.0006
S112	0.0013	0.0020	0.0018	0.0013
S21	0.0001	0.0002	0.0002	0.0001
S22	0.0001	0.0001	0.0001	0.0001
S23	0.0038	0.0053	0.0040	0.0046
S24	0.0003	0.0004	0.0005	0.0003
S25	0.0025	0.0026	0.0032	0.0024
S26	0.0230	0.0249	0.0216	0.0177
S27	0.0000	0.0000	0.0000	0.0000
S28	0.0100	0.0120	0.0161	0.0126
S29	0.0001	0.0002	0.0003	0.0002
S210	0.0008	0.0011	0.0010	0.0010
S211	0.0001	0.0001	0.0001	0.0001

Table 8. Continued.

	A	B	C	D
S212	0.0019	0.0016	0.0015	0.0014
S213	0.0007	0.0006	0.0005	0.0005
S214	0.0095	0.0064	0.0072	0.0070
S215	0.0400	0.0400	0.0360	0.0400

Subsequently, the sums of the beneficial (positive) and non-beneficial (negative) criteria for each supplier were calculated separately, as presented in *Table 9*. In the final step of the COPRAS method, the relative significance index (Qj) and the utility degree (Nj) for each supplier were determined. The results are reported in *Table 10*.

Table 9. Sums of positive and negative criteria for each supplier.

Supplier	Sj+	Sj-
Supplier A	0.20930	0.04334
Supplier B	0.21214	0.03844
Supplier C	0.20967	0.04249
Supplier D	0.20395	0.04067
Total / maximum	0.083505	0.016495

Table 10. Prioritization of alternatives using the Q_j and N_j indices.

Suppliers of Ilam Cement Company	Sj+	Sj−	Qj	Nj	Rank
Supplier A	0.20930	0.04334	0.24844	96.941	3
Supplier B	0.21214	0.03844	0.25628	100.000	1
Supplier C	0.20967	0.04249	0.24961	97.394	2
Supplier D	0.20395	0.04067	0.24567	95.857	4
Total / maximum	0.83505	0.16495	0.25628	_	_

4 | Discussion

This study aimed to develop a comprehensive framework for supplier selection within a sustainable and flexible supply chain context. The results obtained from applying the integrated SWARA–COPRAS approach show that considering sustainability and flexibility simultaneously leads to a more holistic and realistic evaluation of supplier capabilities in manufacturing industries. The weighting results of the main criteria indicate that sustainability, with a weight of 0.631, is more important than flexibility, with a weight of 0.369. This suggests that in industries such as cement manufacturing, environmental considerations are prioritized due to the significant ecological impacts of production activities. This finding is consistent with previous research in sustainable supply chain management, which highlights that environmentally intensive industries tend to place greater emphasis on environmental performance in their strategic decisions.

At the sub-criterion level, the environmental management system emerged as the most important factor, achieving the highest overall weight (0.2711). This highlights the critical role of structured environmental practices, such as ISO 14001 certification, in supplier evaluation. Among the remaining sub-criteria, on-time delivery (0.1561) and environmental emissions (0.1498) ranked second and third, respectively, indicating that both operational reliability and environmental impact are key determinants in supplier assessment. Overall, these findings suggest that manufacturing firms attempt to balance environmental responsibility with operational performance when selecting suppliers. However, less emphasis was placed on softer factors such as information transparency and participation, which may indicate a managerial preference for more tangible and measurable criteria. Despite this, strengthening relational and institutional aspects in the long term can enhance supply chain resilience and maturity.

The results of the COPRAS ranking further confirmed the effectiveness of the proposed model, as Supplier B achieved the highest utility value (Qj = 0.25628) and ranked first, followed by Suppliers C, A, and D. The relatively small differences among the utility values indicate a highly competitive environment among suppliers. In contrast, the model successfully differentiated between the alternatives. Based on these findings, it can be concluded that in industries with significant environmental impacts, certified environmental management systems should be considered a prerequisite for supplier collaboration. In addition, on-time delivery and responsiveness remain critical factors in ensuring supply chain flexibility and supplier performance. Overall, the integrated SWARA–COPRAS approach proves to be an effective decision-making tool for supplier selection in complex multi-criteria environments under real organizational conditions.

5 | Conclusion

The main innovation of this study lies in the simultaneous integration of two dimensions, supply chain sustainability and supply chain flexibility, within a multi-criteria decision-making framework. While many previous studies have focused on only one of these dimensions, this research combines both perspectives to provide a more comprehensive evaluation approach. In addition, the use of the hybrid SWARA–COPRAS methodology strengthens the robustness and reliability of the proposed model. Overall, the findings indicate that supplier selection in manufacturing industries cannot be based solely on economic criteria; rather, the integration of environmental, social, and operational indicators is essential for achieving sustainable competitive advantage. The proposed model can serve as a practical decision-making framework for similar industrial organizations and facilitate the transition toward more sustainable and flexible supply chains.

From a practical perspective, it is recommended that supplier evaluation systems be periodically revised, and sustainability indicators be formally incorporated into contractual agreements. Furthermore, providing environmental training for suppliers and requiring the reporting of green performance metrics can enhance firms' competitive advantage. For future research, the use of fuzzy approaches or uncertainty-based models is suggested to improve decision-making accuracy and better reflect real-world complexity.

Conflict of Interest

The authors declare no conflict of interest.

Data Availability

All data are included in the text.

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