An Integrated Multi Criteria Decision Making Approach for Vendor Selection in the Indonesian Marble Industry

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Abstract. Effective vendor selection and strong relationship management are crucial for maintaining competitiveness and mitigating supply chain risks. However, unstructured selection processes can lead to inefficiencies, such as wasted time, resources, and financial losses. A marble industry in Indonesia faces similar challenges, particularly in selecting and evaluating bearing vendors, resulting in stock fluctuations and operational losses. This study aims to address these issues by integrating the AHP, COPRAS, and TOPSIS methods from the Multi-Criteria Decision-Making (MCDM) framework. Through this approach, four key criteria—price, quality, delivery duration, and service performance—were identified and appropriately weighted. The findings reveal that Asian Bearing was the most suitable vendor, achieving the highest utility value. This ensured a more stable and efficient supply chain while reducing operational risks and costs. Additionally, sensitivity analysis confirmed the robustness of the integrated methods, as vendor rankings remained stable even with changes in criterion weighting. The integration of AHP, COPRAS, and TOPSIS provides a systematic and reliable framework for vendor selection, improving the efficiency and reliability of the selection process and enhancing the company's competitiveness in a dynamic market.

Keywords: Vendor Selection, MCDM, AHP, COPRAS, TOPSIS.

1 INTRODUCTION

Supply chain management efficiency is not only the key to the survival and growth of a company in this era of globalization, but also plays an important role in determining its competitiveness in an increasingly complex and dynamic market. Amidst this complexity, several new challenges have emerged, particularly those further intensified by the impact of the Covid-19 pandemic. The pandemic has caused significant disruptions to global supply chains, thereby exposing vulnerabilities in the previously established supply chain management processes [1]. In response to this situation, companies around the world, including in Indonesia, are increasing them emphasize the importance of managing supply chain risks [2].

Industry experience shows that effective risk management not only reduces the impact of risks on day-to-day operations, but also has the potential to be a source of competitive advantage. One area where risk management is very important is in vendor selection and vendor relationship management [1]. Choosing the right vendor not only

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reduces operational risk, but can also improve supply chain flexibility, quality, and efficiency [3]. Vendors are regarded as the most valuable intangible assets for any organization [4].

Vendor assessment requires a variety of criteria that can describe the overall performance of the vendor [5]. The Multi-Criteria Decision-Making (MCDM) method provides a structured framework for making vendor selection decisions by taking multiple criteria into account and ensuring a thorough evaluation [6]. These techniques utilize mathematical models to aid decision making when it comes to considering conflicting criteria to assess potential solutions. The MCDM-based approach facilitates the identification of the most suitable alternatives by meticulously analyzing the weights assigned to each criterion [5].

Amid the ever-changing dynamics and complexity of MCDM's issues, this case study highlights one of Indonesia's leading natural stone producers facing a series of challenges in its supply chain management, particularly in vendor selection and evaluation. Despite having a variety of vendor partners, the vendor selection and evaluation process is not fully structured and well documented, leading to the absence of standard criteria for assessing and evaluating bearing vendors. This, coupled with delays and volatility in stock fluctuations, increases operational risks, especially concerning the reliability of production machinery. Bearing, as a critical component in production machinery, requires a consistent and reliable supply, and any disruptions caused by stock shortages or unreliable vendor performance can significantly affect operational stability. Historical data reveals that the company purchased 1,052 units of bearings during the period, with peaks in 2020 and 2022, and the total cost of bearing purchases from 2018 to 2023 amounted to Rp 655,446,313. Effective vendor selection is thus essential to ensure smooth production and minimize costs. Therefore, this study aims to address this challenge by employing AHP, COPRAS, and TOPSIS integration methods to set the weight of vendor selection criteria, evaluate quantitatively, and prioritize the best vendors among existing alternatives. The research seeks to optimize supply chain reliability, minimize operational risks, reduce costs, and enhance company value.

Although the Multi-Criteria Decision-Making (MCDM) method has been widely used in vendor selection, research specifically focusing on the marble industry in Indonesia, particularly in the selection of bearing vendors, remains limited. Furthermore, there is a significant gap in the literature regarding the comprehensive integration of AHP, COPRAS, and TOPSIS methods in this context. This gap is especially noticeable in the Indonesian marble industry, where the supply chain has unique characteristics.

There has been slight research on vendor selection in the marble industry, particularly with an integrated approach like this. Bearings, as a crucial component, play a vital role in ensuring smooth machinery operations. Any disruption in bearing supply can cause significant losses for companies. This method offers a new, more structured way to manage supply chains, which can provide a competitive advantage. This research not only contributes to the academic literature, but it is also beneficial for practitioners in the marble industry who want to improve the efficiency and reliability of their supply chains.

The findings from this study are also applicable to other industries that face similar challenges in supply chain management, particularly those that rely on critical components for smooth production processes. Industries such as manufacturing, electronics, and automotive, which share the need for high-quality, timely vendor performance, can benefit from applying these methodologies to optimize their vendor selection and reduce operational risks.

2 LITERATURE REVIEW

The combination of AHP and COPRAS in supplier selection was employed by [6], driven by the complexity of vendor selection and supplier evaluation involving multiple criteria. These criteria often intersect, further complicating the vendor selection process. The study uses AHP to assess the relative importance of each criterion, while COPRAS is applied to evaluate vendor models by comparing alternatives, indicating the quality of these alternatives through their utility levels. The study's criteria include cost, quality, delivery time, and service performance across five alternative vendors. The study found that Vendor E was the best supplier, while Vendor B ranked the lowest.

In the study [8], they analysed and compared three multi-criteria decision-making methods (MCDM), namely TOPSIS, VIKOR, and COPRAS in the context of regional safety assessments during the COVID-19 pandemic. The goal is to evaluate and determine the best method to measure the security of the area during a health crisis. The criteria used include aspects such as health risks, infrastructure, and government response. The results show that each method has advantages in different contexts, but COPRAS is considered superior in providing a more balanced evaluation.

Furthermore, in the research [9] develop a new approach that integrates AHP and COPRAS under the Pythagorean fuzzy set for the selection of digital supply chain partners. This research aims to improve the partner selection process by considering criteria such as quality, cost, flexibility, and innovation. The results of this study show that the proposed method can provide a more comprehensive and appropriate solution in the selection of supply chain partners.

Another study [1] was conducted a study on the selection of strategic suppliers for renewable energy supply chains using the BWM-WASPAS-COPRAS hybrid fuzzy approach. The goal is to optimize supplier selection based on criteria such as cost, sustainability, capacity, and environmental risk. The results of this study show that the hybrid approach used can effectively identify the suppliers that best suit the strategic needs of the renewable energy supply chain.

MCDM method is also used in the study [10] to evaluating crop residues for gasification in Ghana using integrated multi-criteria decision-making techniques. This study aims to determine the best plant residues for the gasification process based on criteria such as energy content, cost, environmental impact, and availability. The results show that the integrated multi-criteria approach used can provide more informative and reliable decisions in the context of renewable energy.

In another research by [11] develop a multi-criteria decision-making approach to overcome barriers in green supply chain management and prioritize alternative solutions. The purpose of this study is to identify and assess key barriers as well as possible solutions based on criteria such as cost, environmental impact, and implement ability. The results show that this approach is effective in prioritizing the most practical solutions and has a positive impact on green supply chain management.

In their study, [12] tackle the issue of asphaltene deposition in oil fields and wells, a significant challenge in oil production operations. The study seeks to quantify and rank the risks associated with asphaltene deposition in oil fields and wells by employing the Fuzzy TOPSIS method alongside AHP. The methodology involves identifying relevant criteria and sub-criteria for risk assessment, followed by the application of Fuzzy TOPSIS to prioritize these risks. The findings suggest that this approach is effective in pinpointing and ranking the oil fields and wells most susceptible to asphaltene deposition, thus supporting more precise decision making.

Research by [13] developed a new approach to selecting the most suitable type of oilseed for biodiesel production. The purpose of this study is to identify and assess various oilseed alternatives based on criteria such as oil content, production cost, availability, and environmental impact. The AHP method is used to determine the weight of the criteria, while TOPSIS is used to determine the final ranking of oilseed alternatives. The results show that this integrated method is effective in identifying the most suitable oilseeds for biodiesel production, by providing a more accurate and comprehensive ranking.

Furthermore, the study [14] explores the application of the Fuzzy AHP-TOPSIS method in the selection process of human resource managers. The goal is to improve the decision-making process in selecting the best candidates for manager positions, considering criteria such as work experience, management skills, communication skills, and leadership. The AHP Fuzzy method is used to determine the weight of the criteria by considering uncertainty and ambiguity in the assessment, while TOPSIS is used to rank candidates. The results show that the Fuzzy AHP-TOPSIS approach provides a more flexible and accurate evaluation, thus helping companies in selecting the best candidates.

And research by [15] the Fuzzy AHP-TOPSIS approach was used to analyse green management practices in the hospitality industry in Oman. The purpose of this study is to evaluate and prioritize green management initiatives based on criteria such as energy efficiency, waste management, environmental awareness, and economic sustainability. The AHP fuzzy is used to determine the weight of each criterion's importance, while TOPSIS is used to evaluate and rank green management practices. The results of the study show that this integrated approach helps in identifying the most effective green management practices that can be adopted by the hospitality industry in Oman to improve their environmental sustainability.

This summary provides an overview of how various multi-criteria decision-making methods such as AHP, COPRAS, and TOPSIS are used in different contexts to address challenges in supply chain management, supplier selection, and risk evaluation, with the primary goal of improving efficiency, reducing costs, and maximizing benefits.

Based on previous research and preliminary observations, while there is a strong understanding of the importance of risk management in the supply chain and the strategic role of vendor selection in the process, there are some gaps that have not been addressed. First, while extensive research has been conducted on vendor selection using Multi-Criteria Decision-Making (MCDM) methods, very few studies have focused on the marble industry in Indonesia, particularly in the context of bearing vendor selection. Second, the integration of AHP, COPRAS, and TOPSIS methods for vendor selection in the marble industry has not been extensively explored, resulting in a lack of practical guidance for companies to effectively implement this approach. Third, this study also highlights the absence of standardized criteria in bearing vendor evaluation, which can increase operational risks and costs, yet this issue has not been sufficiently addressed in prior research. Therefore, this study aims to fill these gaps by providing a comprehensive approach that integrates AHP, COPRAS, and TOPSIS methods for more effective vendor selection in the Indonesian marble industry.

2.1 Case study

This research was conducted in Jakarta, Indonesia, focusing on a company within the marble and natural stone industry. The company has faced significant losses due to the lack of standardized criteria for assessing and evaluating bearing vendors, compounded by delays and stock fluctuations. Given the critical role of bearing spare parts in maintaining operational efficiency in the marble industry, selecting the most suitable vendor is essential. To address this issue, relevant criteria were identified through an extensive literature review. The key criteria emerging from the literature include:

C1: Cost/Price
C2: Lead Time
C3: Delivery
C4: Quality
C5: Payment Terms
C6: Service Performance
C7: Vendor Proximity
C8: Rating Profile
C9: Digital Competency
C10: Technology
C11: Relationship
C12: Agility
C13: Economic
C14: Social/Urban impact
C15: Environment Impact
C16: Other criteria

To address this issue, relevant criteria were identified through a comprehensive literature review, including insights from [6], [7], and [16], as well as observations and interviews with company experts. The experts have many years of experience in the field of supply chain management, particularly in the marble manufacturing industry. They are made up of operational managers, supply chain managers, and technicians who understand the complexities in the maintenance of production machinery and the supply chain of critical components such as bearings. To ensure consistency of evaluation from experts involves testing consistency using a consistency ratio (CR) below 0.1 in the AHP method. From this comprehensive analysis, four key criteria were prioritized for vendor evaluation:

C1: Cost/Price

In the marble industry, profit margins are very sensitive to operating costs, so price is a critical factor.

C2: Quality

Quality is also considered very important because poor bearing quality can cause damage to production machines, resulting in downtime and increased maintenance costs.

C3: Delivery Time

Delivery time is important to ensure smooth production, given that delays in the delivery of bearings can result in disruptions to the production line.

C4: Service Performance

Service performance includes vendors' responsiveness to company requests, their ability to handle issues, and after-sales service. Vendors who have good after-sales service help the company in ensuring operational resilience. These criteria emerged as the most significant based on both the academic literature and practical insights from industry experts. The prioritization of these criteria is intended to streamline the vendor selection process, ensuring that the company can mitigate risks, reduce losses, and enhance its overall supply chain efficiency.

3 RESEARCH METHODOLOGY

Selecting the appropriate vendor is a fundamental aspect in reducing uncertainties and ensuring the seamless functioning of supply chain activities [17]. This study begins with the identification of the problem statement, followed by data collection through observation, expert interviews, and a literature review. These methods provide the necessary input to establish assessment criteria and identify alternative bearing vendors [18]. AHP is used to assign criteria weights because of its ability to handle complexity in making decisions by involving many criteria. COPRAS was chosen for its ability to evaluate vendor performance based on favourable and unfavourable criteria. This allows companies to evaluate vendors in a more proportionate and comprehensive manner, resulting in more balanced decisions in terms of preferences. TOPSIS was chosen because this method allows vendor assessment by comparing the best and worst vendor alternatives by providing a clear perspective in decision-making based on vendor performance against specified criteria. The integration of AHP, COPRAS, and TOPSIS methodologies is then applied within a Multi-Criteria Decision-Making (MCDM) framework to evaluate these alternatives. Finally, sensitivity analysis is conducted to assess the robustness of the results [19]. By adopting this systematic approach, the study aims to pinpoint comprehensive vendor evaluation criteria, establish a structured evaluation framework, and incorporate the AHP-COPRAS-TOPSIS techniques into decision-making processes. This initiative is poised to effectively mitigate risks, enhance the reliability of the supply chain, and augment the overall value of the organization.

3.1 Analytical Hierarchy Process

The AHP method, developed by Thomas L. Saaty around 1970, serves as a framework for effective decision-making on complex problems. AHP employs a more precise pairwise comparison than traditional scoring methods [6]. As one of the most extensively employed multi-criteria decision-making (MCDM) methodologies, the Analytic Hierarchy Process (AHP) is conventionally utilized to ascertain the weights of criteria predicated on pairwise evaluations of both alternatives and criteria, thereby computing the relative importance of alternatives, rank them, and select the best alternative [19]. Below is a description of the AHP method stages:

1. Generating the hierarchical structure model from observation, interview expert, and literature review four important criteria and four alternative vendors hierarchical modelled.

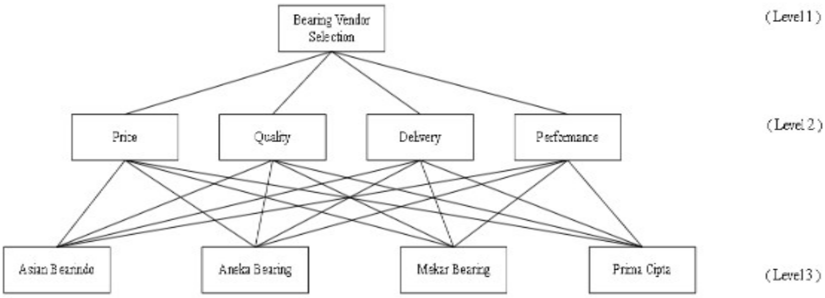

Fig. 1. Hierarchical Structure of the problem

2. Generating pairwise comparison matrix with following equation

$$GM = \sqrt[n]{(x_1)(x_2)\ldots(xn)} \quad (1)$$

$$A = \begin{bmatrix} 1 & a & b \\ \frac{1}{a} & 1 & c \\ \frac{1}{b} & \frac{1}{c} & 1 \end{bmatrix}$$

GM : Geometric Mean
x_1 : 1st person rate
x_2 : 2nd person rate
xn : N person rate
A : Comparison Matrix
n : Number of appraisers

3. Determining the eigen vector priority value with formula

$$w = \frac{1}{n}\sum_{j=1}^{n} aj \quad (2)$$

w : Priority Value
n : Total criteria or alternatives
aj : Coloumn – j comparison matrix

4. Calculating the eigen vector's consistency with formula

$$CR = CI/RI \quad (3)$$

$$CI = \frac{\lambda\max - n}{n-1} \quad (4)$$

CR : Consistency Ratio
CI : Consistency Index
RI : Random Index
λmax : Eigen Value
n : Total criteria or alternatives

Consistent if CR is less than 0.10. The comparison would be inconsistent otherwise.

5. Obtaining result of the hierarchical structure

3.2 Complex Proportional Assessment (COPRAS)

The Complex Proportional Assessment (COPRAS) is a multi-criteria decision-making technique that systematically assesses both quantitative and qualitative dimensions

[20], [21]. This methodology was devised by Zavadskas and Kaklauskas in 1996 at the Gediminas Technical University in Vilnius. This framework evaluates alternatives and yields a ratio that signifies the comparative performance of an alternative relative to its peers. The selection of the optimal alternative is achieved through the consideration of both ideal and non-ideal solutions. In COPRAS, the relative importance of an alternative is determined by considering both beneficial and non-relevant characteristics. The stages of the COPRAS method are as follows [1]:

1. Generating matrix from the alternative data obtained. The results of this first stage will produce a table or matrix containing each alternative along with each value on the predetermined criteria.
2. Normalize the matrix results using the following equation.

   $$R = [r_{ij}]m = x_{ij} \,/ \sum_{i=1}^{m} x_{ij} \quad (5)$$

   R : Normalized matrix
   x_{ij} : Decision value for the-i alternative on the criteria-j
   m : Total alternatives

   The results of the second stage will be created a new matrix or table containing the normalization results of each criterion in each alternative.
3. Determining of the weighted normalized decision matrix, D, by using the following equation.

   $$D = [yij] = rij \,.\, wij, i = 1, \dots, m, j = 1, \dots, n \quad (6)$$

   D : Weighted normalized decision matrix

   The results of the third stage will create a new matrix or table that contains the results of multiplying the weight values with each of the criteria that have been normalized. The search for weights can be done using the analytical hierarchy process (AHP) method.
4. Calculating favourable and disadvantageous criteria

   $$S_{+i} = \sum_{j=1}^{n} y+ \,, S_{-1} = \sum_{j=1}^{n} y- \quad (7)$$

   S_{+i} : Aggregate Favorable Criteria
   S_{-1} : Aggregate Disadvantageous Criteria

   The favourable criteria for S+i and the detrimental criteria for S-i, y is a criterion value from a table or matrix that has been normalized and multiplied by weights. The result of this fourth stage will produce S+i and S-i values, on each criterion.
5. Determining of the relative significance of the alternative, Qi, using the following equation.

   $$Qi = S_{+i} + \frac{1 \cdot \Sigma_{i=1}^{m} \cdot S_{-i}}{S_{-i} \cdot \Sigma_{i=1}^{m} [1/S_{-i}]}, i = 1, \cdots m \quad (8)$$

   Qi : Significance relative for alternative- i

   The results of this fifth stage will produce a Q value for each alternative. The value of Q will be in the form of a decimal number.
6. Calculate of quantitative utility, Ui, for i-th alternative using the following equation.

   $$Ui = \left[\frac{Q_i}{Q_{max}}\right] \cdot 100\% \quad (9)$$

   Ui : Utility value of alternatives- i
   Q_{max} : Maximum significance relative

The greater the value of Ui, the higher the priority of the alternative. Based on the value of alternative utilities, a complete ranking of competitive alternatives can be obtained.

3.3 Technique for Order Performance of Similarity to Ideal Solution (TOPSIS)

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is among the most utilized MCDM methodologies. Its core tenet posits that the most favourable alternative should manifest the minimal distance from the ideal solution while simultaneously maintaining the maximal distance from the anti-ideal solution [23]. The TOPSIS method is a multi-criteria and sub-criteria decision-making technique where the identified alternative has the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution from a geometric perspective using Euclidean distance. However, an alternative with the shortest distance from the positive ideal solution does not always have the farthest distance from the negative ideal solution [24]. Here are the steps in TOPSIS [12]:

1. Determining a normalized decision matrix based on criteria assessment

$$Rij = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}^2} \quad (10)$$

Rij : Normalized decision matrix
x_{ij} : Decision value for the alternative- i
m : Total alternatives

2. Determining a normalized decision matrix weighted with

$$Yij = Wij.Rij \quad (11)$$

Yij : Weighted normalized matrix
Wij : Weight of each criterion

3. Identify the positive ideal solution matrix and the negative ideal solution matrix; the positive ideal solution matrix is for benefit attributes, while the negative one is for cost attributes.

$$A^+ = (Y_1^+, Y_2^+, Y_3^+, \ldots, Y_n^+) \quad (12)$$

$$A^- = (Y_1^-, Y_2^-, Y_3^-, \ldots, Y_n^-)$$

$A+$: Positive ideal solution
$A-$: Negative ideal solution

4. Calculate the distance between the value of each alternative and the positive ideal solution matrix, as well as the negative ideal solution matrix.

$$D_i^+ = \sqrt{\sum_{j=1}^{n} (y_j^+ - Y_{ij})\, 2} \quad (13)$$

$$D_i^- = \sqrt{\sum_{j=1}^{n} (Y_{ij} - y_j^-)\, 2}$$

$Di+$: Distance between positive ideal solution
$Di-$: Distance between negative ideal solution

5. Determining the preference value for each alternative (see table 14).

$$Vi = \frac{D_i^-}{D_i^- + D_i^+} \quad (14)$$

3.4 Sensitivity Analysis

Sensitivity analysis is an approach used to evaluate options by measuring how stable and consistent the outcome is against changes in factors such as weights or priority sequences that may change due to changes in decision-making [25]. The sensitivity analysis was carried out after the AHP & COPRAS calculation process was completed [7]. The sensitivity analysis in this study aims to get the optimal solution of a decision-making process. Sensitivity analysis is used here to compare two or more approaches and identify which is more sensitive to a change in ranking in the final ranking result [26]. It does this by measuring the influence of a change in the weight of the criterion [24]. The steps in sensitivity analysis are:

1. Identify the Initial Base Value The initial base value was obtained from the results of the integration of AHP-COPRAS and AHP-TOPSIS. These values are obtained from the results of the utility (Ui) and preference (Vi) calculations of each vendor alternative that have been calculated.
2. Variation in the weight of the criteria Change sensitive criteria weights in the range of 0.5 to 1. The sensitivity test was carried out by varying the weights of initial base value criteria in the range of 0.5 to 1 consecutively. In each simulation, the weight of the criteria is changed, and the ranking change of each alternative is noted.
3. Recalculate the vector weight criteria
4. Recalculate alternative scores
5. Analysed ranking changes
6. Calculate the percentage of ranking change in each method analyse

   $$\frac{T}{i.a} x\ 100\% \quad (15)$$

   T : Final total of ranking changes
   i : Total if iterations
   a : Number of attributes used
7. Visualize results with tables or graphs
   The output of the sensitivity analysis results is a comparison of the vendor's priority ranking with the change in the weight of the input criteria from the AHP–COPRAS-TOPSIS results before the sensitivity analysis is carried out.

4 RESULT AND DISCUSSION

Based on observations, interviews with expert of the company and literature review, four alternative vendors and four criteria were obtained to meet the bearing needs. The criteria are price, quality, delivery, and service. The alternative vendors are Asian Bearing, Aneka Bearing, Mekar Bearing, Primacipta Bearing.

4.1 Analytical Hierarchy Process (AHP)

After obtaining the criteria and vendor alternatives, the next step is to determine the weight of each criterion with AHP, by recapitulating the weight value of each criterion produced, namely:

Table 1. Pairwise Comparison Matrix of Criteria

Criteria	Price	Quality	Delivery	Service
Price	1	2	5.48	6.48
Quality	0.5	1	3.87	2.45
Delivery	0.18242	0.26	1	2.45
Service	0.154321	0.20	0.5	1
Total	1.836803	3.458	10.85	12.38

Table 2. Normalized Matrix of Criteria

Criteria	Price	Quality	Delivery	Service
Price	0.544424	0.578302	0.5050691	0.523425
Quality	0.272212	0.289151	0.356682	0.1979
Delivery	0.099347	0.074716	0.0921659	0.1979
Service	0.084016	0.05783	0.0460829	0.080775
Total	1	1	1	1

Table 3. Weight & Consistency Ratio of Criteria

Criteria	Weight	P. Vector	Eigen		
Price	0.537805	2.151	0.987	4.0432	λ
Quality	0.278986	1.115	0.964	0.0144	**CI**
Delivery	0.116032	0.464	1.258	0.89	**RI**
Service	0.067176	0.268	0.831	**0.01621**	**CR**

Furthermore, the calculation of AHP is continued to calculate the weight of each alternative against the weight of the previously calculated criteria.

Table 4. Pairwise Comparison Matrix of Alternative

		Based on Price		
	Asian	Aneka	Mekar	Prima
Asian	1	0.289017	0.2	0.289017
Aneka	3.46	1	0.5	0.408163
Mekar	5	2.00	1	0.5
Prima	3.46	2.45	2	1
Total	12.92	5.739017	3.7	2.197181
		Based on Quality		
	Asian	Aneka	Mekar	Prima
Asian	1	0.289017	0.350877	0.2
Aneka	3.46	1	0.408163	0.5
Mekar	2.85	2.45	1	0.408163
Prima	5	2	2.45	1
Total	12.31	5.739017	4.20904	2.108163
		Based on Delivery		
	Asian	Aneka	Mekar	Prima
Asian	1	0.223714	0.289017	0.25
Aneka	4.47	1	0.5	0.404858
Mekar	3.46	2	1	0.5
Prima	4	2.47	2	1
Total	12.93	5.693714	3.789017	2.154858
		Based on Service		
	Asian	Aneka	Mekar	Prima
Asian	1	0.289017	0.223714	0.223714
Aneka	3.46	1	0.5	0.5
Mekar	4.47	2.00	1	0.5
Prima	4.47	2	2	1
Total	13.4	5.289017	3.723714	2.223714

Table 5. Normalized Matrix of Alternative

		Based on Price		
	Asian	Aneka	Mekar	Prima
Asian	0.077	0.050	0.054	0.132
Aneka	0.268	0.174	0.135	0.186
Mekar	0.387	0.348	0.270	0.228
Prima	0.268	0.427	0.541	0.455
Total	1	1	1	1
		Based on Quality		
	Asian	Aneka	Mekar	Prima
Asian	0.081	0.050	0.083	0.095
Aneka	0.281	0.174	0.097	0.237
Mekar	0.232	0.427	0.238	0.194
Prima	0.406	0.348	0.582	0.474
Total	1	1	1	1
		Based on Delivery		
	Asian	Aneka	Mekar	Prima
Asian	0.077	0.039	0.076	0.116
Aneka	0.346	0.176	0.132	0.188
Mekar	0.268	0.351	0.264	0.232
Prima	0.309	0.434	0.528	0.464
Total	1	1	1	1
		Based on Service		
	Asian	Aneka	Mekar	Prima
Asian	0.075	0.055	0.060	0.101
Aneka	0.258	0.189	0.134	0.225
Mekar	0.334	0.378	0.269	0.225
Prima	0.334	0.378	0.537	0.450
Total	1	1	1	1

Table 6. Consistency Ratio of Alternative

Based on Price			
P. Vector	Eigen		
0.313354	1.012132	4.176115	λ
0.76295	1.094645	0.058705	CI
1.233323	1.140824	0.89	RI
1.690373	0.928514	0.065961	CR
Based on Quality			
P. Vector	Eigen		
0.309827	0.953492	4.187259	λ
0.789464	1.132688	0.06242	CI
1.089616	1.14656	0.89	RI
1.811093	0.95452	0.070134	CR
Based on Delivery			
P. Vector	Eigen		
0.308925	0.998601	4.186688	λ
0.841182	1.197362	0.062229	CI
1.114814	1.056012	0.89	RI
1.735079	0.934712	0.069921	CR
Based on Service			
P. Vector	Eigen		
0.289953	0.971344	4.103753	λ
0.806404	1.066271	0.034584	CI
1.205122	1.121883	0.89	RI
1.698521	0.944256	0.038859	CR

Table 7. Alternative Weight Values

	Final Weight	Rank
Asian	0.077571	4
Aneka	0.195586	3
Mekar	0.294396	2
Prima	0.432447	1

Furthermore, calculations are carried out for each alternative based on previously calculated criteria. Based on the results of the calculation with the AHP method, the weight of each alternative is 0.077 for Asian Bearing, then 0.195 for Aneka Bearing, 0.294 for Mekar Bearing, and 0.432 for Primacipta.

4.2 AHP – COPRAS

The COPRAS approach is used to rank the alternatives following the AHP method's computation of the pertinent criterion weights in supplier selection. The greatest vendor possibilities that are appropriate for choosing are likewise found using this strategy. After the matrix weights are found, the next step is to calculate the favourable (S+i) and disadvantage (S-i) criteria of each alternative. It then calculates the relative significance of the existing vendor alternatives (Qi). This value is used to calculate the performance utility value of each vendor alternative, so that it can be known which vendor has the best performance utility value. The following are the applications of the AHPCOPRAS method:

Table 8. Normalized Decision Matrix COPRAS

	Criteria			
Alternative	Price	Quality	Delivery	Service
Asian	0.07834	0.07746	0.07723	0.07249
Aneka	0.19074	0.19737	0.21030	0.20160
Mekar	0.30833	0.27240	0.27870	0.30128
Prima	0.42259	0.45277	0.43377	0.42463

Table 9. Normalized Weighted Decision Matrix

	Criteria			
Alternative	Price	Quality	Delivery	Service
Asian	0.042131	0.021609	0.008961	0.004869
Aneka	0.10258	0.055062	0.024401	0.013543
Mekar	0.165822	0.075997	0.032339	0.020239
Prima	0.227273	0.126318	0.050331	0.028525

Table 10. Utility of each alternative vendor (Ui)

Alternative	S+-i	S-i	1/ S-i
Asian	0.03544	0.042131	23.73561
Aneka	0.093006	0.10258	9.74853
Mekar	0.128574	0.165822	6.030566
Prima	0.205174	0.227273	4.399997
	Total	0.537805	43.9147

Alternative	S+-i	S-i	1/ S-i
Asian	0.32612	100	1
Aneka	0.212393	65.12703	3
Mekar	0.202428	62.07167	4
Prima	2.259059	79.43656	2
Total	0.32612		

The integration of AHP-COPRAS assessment results show that Asian Bearing is the most suitable vendor based on the criteria that have been set. Based on the results of the table 10 utility value data above, the best vendor is Asian Bearing with a utility value of 100%, then in the second position is occupied by the Primacipta Bearing with a utility value of 79% and successively the vendor with the lowest performance utility value, namely Aneka and Mekar Bearing at 65% and 62%.

4.3 AHP – TOPSIS

One of the MCDM techniques that is used the most is TOPSIS. Its basic tenet is that the optimal course of action ought to be the one that is closest to the ideal solution and furthest from the anti-ideal one [26]. Matrix from the value of the alternative weights to the criteria of the previous normalized AHP method (see table 5). The following are the applications of the AHP-TOPSIS method:

Table 11. Normalized Decision Matrix TOPSIS

	Criteria			
Alternative	Price	Quality	Delivery	Service
Asian	0.211197	0.224388	0.215983	0.196081
Aneka	0.514221	0.571759	0.588105	0.545331
Mekar	0.831248	0.78914	0.779413	0.814964
Prima	1.139295	1.311659	1.213065	1.148625

Table 12. Weighted Normalized Decision Matrix

	Criteria			
Alternative	Price	Quality	Delivery	Service
Asian	0.113583	0.062601	0.025061	0.013172
Aneka	0.276551	0.159513	0.068239	0.036633
Mekar	0.447049	0.220159	0.090437	0.054746
Prima	0.612719	0.365935	0.140755	0.07716

Table 13. Preference Value for Each Alternative (Vi)

Alternative	A+-i	A-i	D+1
Asian	0.113583	0.612719	0.330894
Aneka	0.365935	0.062601	0.275807
Mekar	0.140755	0.025061	0.368082
Prima	007716	0.013172	0.499136

Alternative	D-	Vi	Rank
Asian	0.499136	0.601347	1
Aneka	0.353293	0.561585	2
Mekar	0.241399	0.396073	4
Prima	0.330894	0.398653	3

From the results of the calculation with the integration of AHP-TOPSIS, the preference value of each of the existing vendor alternatives is found in table 13, with the best vendor alternative Asian Bearing with a preference value of 0.60134.

4.4 Sensitivity Analysis

Sensitivity analysis is an approach used to evaluate options by measuring how stable and consistent the outcome is against changes. Sensitivity analysis is used here to compare two or more approaches and identify which is more sensitive to a change in ranking in the final ranking result [26]. The following are the applications of the sensitivity analysis:

Table 14. Ranking Changes of Alternatives

Simulation	Changes (AHP-COPRAS)	Changes (AHP-TOPSIS)
1	11	10
2	14	14
3	14	12
4	15	15
5	11	11
6	14	10
Total	79	72

The ranking change shows that the 4th simulation (with a weight addition of 0.8) gives the largest number of changes in vendor rankings. This shows that the criteria given higher weight have a greater influence on the result.

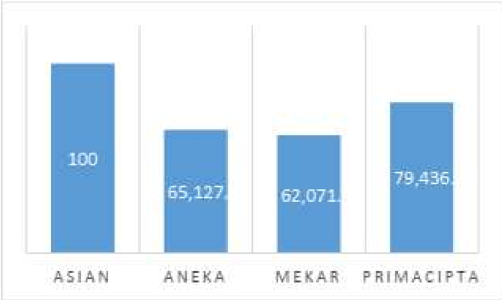

Fig. 2. Ranking of alternatives Ui values before sensitivity analysis

Fig. 3. Ranking of alternatives Ui values after sensitivity analysis

Fig. 4. Ranking of alternatives Vi values before sensitivity analysis

Fig. 5. Ranking of alternatives Vi values after sensitivity analysis

The results of this weight change are represented in a graph showing the number of rating changes in each simulation for both the COPRAS and TOPSIS methods (See Fig.2,3,4, and 5). The sensitivity analysis showed that the percentage change by Eq. (15) in vendor ranking with AHP-COPRAS was 3.29% while AHP-TOPSIS was worth 3%. The relatively small change in ranking shows that the vendor selection results are quite stable despite changes in the weighting of sensitive criteria. Despite the change in criterion weights, both methods (AHP-COPRAS and AHP-TOPSIS) showed consistency in their results, with less significant changes in vendor rankings. This shows that both methods are quite reliable in providing robust decisions against changes in criterion weights.

5 CONCLUSIONS

This study aimed to address the challenges in vendor selection and evaluation faced by one of Indonesia's leading natural stone producers, particularly in the context of bearing purchases. Through the integration of AHP, COPRAS, and TOPSIS methods, the research successfully identified and weighted the key criteria—price, quality, delivery duration, and service performance—that are critical for the company's supply chain management. The results demonstrated that vendor Asian Bearing, emerged as the most suitable vendor with the highest utility value, ensuring a stable and efficient supply chain while minimizing operational risks and costs.

Furthermore, the sensitivity analysis confirmed the robustness of the selected methods, as the vendor rankings remained relatively stable despite changes in the weighting of criteria. This indicates that the integration of AHP, COPRAS, and TOPSIS provides a reliable decision-making framework for vendor selection in the natural stone industry. The study not only addressed the specific problem faced by the company but also contributed valuable insights into the broader field of supply chain risk management, particularly in the Indonesian manufacturing sector.

For future research, it is recommended to explore the application of the AHP-COPRAS-TOPSIS integration in different industries and contexts to validate its effectiveness and adaptability. While this study focused on the marble industry in Indonesia, applying these methods in other sectors could provide valuable insights into their broader applicability such as SMEs (Small and Medium Enterprises). SMEs with limited resources and data can use a simpler version of this model, for example by reducing the number of criteria used or using an Excel-based decision-making tool to calculate the weight of criteria and alternative evaluations. Additionally, SMEs can rely on simple historical data to implement these methods without the need for sophisticated software or complex systems. The implementation of this simpler model will still provide more structured vendor decisions and reduce operational risks faced by SMEs. This could help in understanding the relative strengths and weaknesses of different MCDM methods in vendor selection. Moreover, expanding the scope to include sustainability criteria, such as environmental impact or corporate social responsibility, could provide a more holistic approach to vendor evaluation in the supply chain management process.

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