AHP and TOPSIS Integration for Green Supplier Selection: A Case Study in Indonesia

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Abstract. Recently, the problem of global warming arising from manufacturing activities has attracted attention. One of the triggers of global warming is the aspect of production. This aspect requires raw materials supplied by the supplier. The selection of the right supplier by considering environmental aspects can reduce the problem of global warming. The purpose of this study is to integrate the AHP and TOPSIS methods in green supplier selection. Eight criteria are used to select suppliers weighted by the AHP method. AHP weighting results are used to select suppliers with the TOPSIS method. A case study was applied to an offset printing company in Indonesia. The results show that the quality criteria have the highest importance. In addition, the results showed that the AHP and TOPSIS methods were easy to use in Green Supplier Selection.

Keywords: AHP, Supplier Selection, Green, TOPSIS

1. Introduction

Recently, a business's main challenge is achieving sustainable development by integrating environmental, economic, and social performance [1]. Increasing public awareness of environmental issues encourages companies to be competitive. Green issues are becoming increasingly crucial in supply chain management [2]. Several problems in the supply chain network contribute to environmental problems [3], such as suppliers [4], inventory [5] [6], production [7] [8], and distribution [9] [10]. One aspect of company sustainability is influenced by suppliers [11]. This problem has received much attention from researchers. Green Supplier Selection (GSS) is an issue of selecting suppliers that consider sustainability aspects. Some of the aspects considered in GSS are economic, environmental, and social aspects [12].

Researchers have carried out several studies on GSS. Azimifard, Moosavirad and Ariafar [13] proposed the Analytical Hierarchy Process (AHP) that is integrated by Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method for solving GSS based on the country in the steel industry. AHP and Vikor integration offered by Luthra, Govindan, Kannan, Mangla and Garg [14] on the GSS problem in automobile company companies. Furthermore, Freeman and Chen [15] developed AHP-Entropy-TOPSIS on supplier selection at an electronic machinery manufacturer. Fuzzy TOPSIS was developed by Shen, Olfat, Govindan, Khodaverdi and Diabat [16] to complete GSS in an automobile manufacturing company. Recently, Tirkolaee, et al. [17] proposed the Fuzzy Analytic Network Process that is combined by fuzzy Decision-Making Trial and Evaluation Laboratory-TOPIS in a central warehouse company.
Based on several studies, AHP and Topsis are popular and easy to use to solve GSS problems. This research tries to integrate AHP and Topsis to complete the GSS issue. To the best of our knowledge, only the research of Azimifard, Moosavirad and Ariaifar [13] used AHP and Topsis in GSS. The research was conducted to solve the GSS based on the country in the steel industry. However, no research uses AHP and Topsis to solve GSS problems in offset printing firms. This study aims to solve the GSS problem in offset printing firms using AHP and Topsis. This study contributes to the GSS problems, especially in the offset printing industry.

2. Methods

2.1. Proposed Methods

This research proposes a combination of the AHP and TOPSIS procedure to complete the GSS problem. AHP is a popular weighting method proposed by Saaty [18], based on pairwise comparisons between elements. In the GSS problem, AHP is proposed to give weight to the GSS criteria. Furthermore, the weight of the GSS criteria is utilized in the Topsis method for supplier selection. Topsis is a procedure offered by Hwang and Yoon [19] to complete multiple attribute decision-making issues. The proposed method framework can be seen in Figure 1.

Stage (1) in the GSS framework is the identification of GSS criteria. In this stage, the decision-maker identifies the criteria used in the GSS problem. Each criterion must also be identified as classification criteria based on benefit and cost criteria. Stage (2) is the decision-maker make a pairwise comparison of each GSS criterion. In this stage, the GSS criteria were compared using the pairwise comparison method. This study uses a scale of 1-9 levels of importance as follow: 1 shows that both criteria are equally important; 3 describes the criteria of Medium importance; 5 explains the criteria for Strong importance; 7 indicates Extreme importance; 9 describes the criteria of Extreme importance; and the values 2, 4, 6, 8 indicate the Intermediate scale.

Furthermore, step (3) is the weighting criteria based on AHP. In AHP, the matrix of pairwise comparison \((A)\) is normalized by dividing the column value by the number of columns [20]. The principle of the vector Eigen \((\lambda_{\text{max}})\) can be seen in Equation (1). In AHP, the matrix of pairwise comparison is considered consistent if the Consistency Ratio \((CR)\) value is \(\leq 10\%\). The \(CR\) coefficient is calculated based on Equation (2), and the Consistency Index \((CI)\) is formulated in Equation (3).

\[
A \cdot w = \lambda_{\text{max}} \cdot w
\]  

(1)
\[ CR = \frac{CI}{RI} \]  
\[ CI = \frac{\lambda_{max} - n}{n - 1} \]

Stage (4) is to create a decision matrix and normalize the decision matrix. It consists of m suppliers and n criteria. The decision-maker provides an assessment of each supplier (\( i \)) in each criterion (\( j \)). The decision-maker assessment for each supplier in each criterion is notated as \( a_{ij} \). Furthermore, the decision matrix is normalized using Equation (4).

Step (5) calculates the weight of the decision matrix and the negative and positive ideal solutions. The decision matrix weight calculation (\( V_{ij} \)) is based on Equation (5). The weight for each criterion \( j \) is generated from the AHP procedure. Furthermore, the negative and positive ideal solutions are presented in Equations (6) and (7). On assessing positive and negative ideal solutions, if the criteria is a benefit, \( V^+ \) value is based on the largest \( V_{ij} \) value. Conversely, if the criteria cost, \( V^- \) value is based on the smallest \( V_{ij} \) value. The value of \( V^- \) for the benefit criteria is based on the smallest \( V_{ij} \) value. However, if the criteria cost, \( V^- \) is based on the largest \( V_{ij} \) value.

Stage (6) determines the distance between each supplier's value and the positive and negative ideal solution matrix. The distance calculation formula is presented in Equations (8) and (9). The last stage is the Determination of preference values for each supplier. At this stage, each supplier preference value is calculated based on the ideal positive and negative solution distance of each supplier. The determination of preference value (\( P_i \)) is based on Equation (10). Furthermore, the best supplier of GSS problems results from the greatest preference value.

\[ r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{k=1}^{m} a_{ij}^2}} \quad i = 1, 2, \ldots, m \quad \text{ve} \quad j = 1, 2, \ldots, n \]  
\[ V_{ij} = w_j \times r_{ij} \forall i, j, w_j \text{ is criteria weight } j \]  
\[ V^+ = (\max_i V_{ij} | j \in J), (\min_i V_{ij} | j \in J) \]  
\[ V^- = (\min_i V_{ij} | j \in J), (\max_i V_{ij} | j \in J) \]  
\[ D_i^+ = \frac{\sqrt{\sum_{j=1}^{n} (V_{ij} - V^+)^2}}{i = 1, 2, 3, \ldots, m} \]  
\[ D_i^- = \frac{\sqrt{\sum_{j=1}^{n} (V_{ij} - V^-)^2}}{i = 1, 2, 3, \ldots, m} \]  
\[ P_i = \frac{D_i^-}{(D_i^- + D_i^+)} \quad i = 1, 2, 3, \ldots, m \]

2.2. Data Collection

A case study was conducted at an offset printing company in Indonesia. 6 suppliers were selected as suppliers of ink raw materials. This study formed a decision-maker team consisting of procurement, production, and warehouse managers. Focus group discussion was conducted by decision-maker members to determine the criteria used in the problem. The criteria utilized in this study are presented in Table 1.

Furthermore, the decision-making team conducted a pairwise comparison of the criteria. The pairwise comparison results are presented in Table 2. The decision-making team also assessed the six suppliers for each criterion. The assessment of price (C1) and distance (C5) was based on quantitative data. For other criteria, the assessment was based on a scale of Likert (1-5 values). 1 indicates very bad, and a score of 5 indicates excellent criteria. The assessment results of 6 suppliers for each criterion are presented in the decision matrix Table 3.
3. Result and Discussions

Based on pairwise comparisons between criteria, the weighting criteria based on the AHP method are presented in Figure 2. It shows that quality (C2) produces the greatest weight in GSS problems, followed by price criteria (C1), reputation (C4), Delivery (C3), Distance (C5), Use of Green Materials (C7), environmental management systems (C6), and Use of Green Packaging (C8). Offset printing companies give priority to quality (C2) criteria. The final product quality depends on the raw material quality supplied by the supplier. This study proves the research conducted by Freeman and Chen [15] and Lee, Kang, Hsu and Hung [21]. Price (C1) takes second place with a weighted value of 0.258. This weight has a relatively small difference with the quality criteria (C2). These show that Price (C1) is also the biggest priority of GSS problems.

Criteria for the use of Green Materials (C7), environmental management systems (C6), and Use of Green Packaging (C8) is less of a priority in GSS problems. These show that the offset printing company does not give priority to environmental aspects. Increasing the global warming problem encourages companies to give priority to environmental criteria.

Table 1. Criteria for GSS problems

| No | Measure       | Indicator | Classification | References |
|----|---------------|-----------|----------------|------------|
| 1  | Price         | C1        | Cost           | [22] [23] [12] [24] |
| 2  | Quality       | C2        | Benefit        | [22] [15] [21] |
| 3  | Delivery      | C3        | Benefit        | [22] [23] |
| 4  | Reputation    | C4        | Benefit        | [25] [26] |
| 5  | Distance      | C5        | Cost           | [27] [28] |
| 6  | Environmental management system | C6 | Benefit | [29] [23] [2] |
| 7  | Use of Green Material | C7 | Benefit | [21] [30] |
| 8  | Use of Green Packaging | C8 | Benefit | [21] [31] [32] |

Table 2. Pairwise comparison between criteria

| Criteria | C1  | C2  | C3  | C4  | C5  | C6  | C7  | C8  |
|----------|-----|-----|-----|-----|-----|-----|-----|-----|
| C1       | 1   | 1   | 2   | 3   | 4   | 5   | 5   | 7   |
| C2       | 1   | 1   | 3   | 3   | 4   | 5   | 5   | 7   |
| C3       | 1/2 | 1/3 | 1   | 1/2 | 3   | 3   | 3   | 3   |
| C4       | 1/3 | 1/3 | 2   | 1   | 3   | 4   | 4   | 5   |
| C5       | 1/4 | 1/4 | 1/3 | 1/3 | 1   | 3   | 3   | 5   |
| C6       | 1/5 | 1/5 | 1/3 | 1/4 | 1/3 | 1   | 1   | 3   |
| C7       | 1/5 | 1/5 | 1/3 | 1/4 | 1/3 | 1   | 1   | 3   |
| C8       | 1/7 | 1/7 | 1/3 | 1/5 | 1/5 | 1/3 | 1/3 | 1   |

Table 3. Assessment of 6 suppliers on each criterion

| Suppliers      | Criteria          |
|----------------|-------------------|
|                | C1  | C2  | C3  | C4  | C5  | C6  | C7  | C8  |
| Supplier 1     | RP. 650,000      | 3   | 5   | 4   | 20 km | 4   | 4   | 4   |
| Supplier 2     | Rp. 600,000      | 5   | 5   | 4   | 25 km | 3   | 4   | 4   |
| Supplier 3     | Rp. 625,000      | 4   | 3   | 4   | 30 km | 4   | 3   | 3   |
| Supplier 4     | Rp. 700,000      | 5   | 3   | 3   | 50 km | 4   | 3   | 3   |
| Supplier 5     | RP. 620,000      | 3   | 4   | 3   | 30 km | 3   | 3   | 4   |
| Supplier 6     | RP. 620,000      | 3   | 5   | 4   | 30 km | 3   | 4   | 3   |
The weighted criteria in Figure 2 are used in the Topsis method to assess supplier preferences. The results of each supplier's preference assessment using the Topsis method are shown in Figure 3. It indicates that supplier 2 produces the largest preference value, followed by supplier 3, supplier 4, supplier 1, supplier 6, and supplier 5. As critical criteria, price and quality have the highest percentage. It is reasonable that supplier 2 is the priority because criteria and prices are more competitive than other suppliers. These results indicate that the AHP and Topsis integration efficiently is utilized to solve the GSS problem.

4. Conclusion
This research aimed to propose the integration of AHP and Topsis to solve GSS problems. AHP and Topsis integration can be used to solve GSS problems. This study used eight criteria with six suppliers. The results showed that the quality criteria produced the greatest weight. This study's results indicate that the integration of AHP and Topsis is easy to use to solve the GSS problem. In this study, the relationship between the criteria was not investigated. In future studies, researchers need to examine the relationship between criteria as the criterion weight.

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