Integration of AHP-MOORA Algorithm in Green Supplier Selection in the Indonesian Textile Industry

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Abstract. In selecting suppliers, one approach that can be used to solve this problem is Multi-Criteria Decision Making (MCDM). MCDM involves several criteria with both quantitative and qualitative assessments. This research attempts to solve the Green Supplier Selection (GSS) problem by using the integration of Analytical Hierarchy Process (AHP) and Multi-Objective Optimization On The Basis Of Ratio Analysis (MOORA). AHP is used as the weighting of the GSS criteria and sub-criteria. Furthermore, MOORA is used to rank the best suppliers. This research was conducted in the textile industry in Indonesia. Eight criteria and 15 sub-criteria GSS are used to select eight suppliers. The results show that the product price has the most excellent weight in supplier selection. In addition, the AHP-MOORA method can be used in solving GSS problems.

Keywords: AHP, Green, Supplier Selection, MOORA

1. Introduction

Recently, the problem of the green supply chain has become a concern of researchers [1]. This problem must consider environmental aspects in solving the problem. One of the causes of green supply chain problems is supplier selection [2]. Green supplier selection (GSS) problems have received much attention from researchers [3] [4]. One of the challenges faced in the Green supply chain is the difficulty of choosing the right supplier of raw materials [5]. The right supplier can positively impact the producer, such as minimizing costs and maximizing service. In addition, reliable suppliers can improve the production process carried out [6].

Several studies on GSS have been carried out. Several integration procedures have proposed for GSS problems such as Analytical Hierarchy Process (AHP)-Simple Additive Weighting [7], AHP-Vikor [8], AHP-Entropy-Technique for order performance by similarity to ideal solution (TOPSIS) [9], Fuzzy AHP-Fuzzy Topsis [10], Fuzzy Topsis-Electre [11], Fuzzy AHP-Taguchi loss function [12], and analytic network process and improved gray relational analysis [13]. One of the critical sectors to be investigated is the textile industry. Several GSS studies with Multi-Criteria Decision Making (MCDM) were found in this sector, such as AHP [14], Topsis [15], grey system [16], and fuzzy topsis [17].

Based on previous research, GSS research in the textile industry sector is still rarely investigated. This research attempts to propose integrating the Analytical Hierarchy Process (AHP) method and the Multi-Objective Optimization on the Basis of Ratio Analysis (MOORA) on GSS problems in the textile industry. The use of the AHP-MOORA method is effective in solving the problems of welding process selection [18], material selection [19], and risk assessment [20]. Unfortunately, AHP-MOORA has never been used to solve GSS problems. It is what motivates researchers to use AHP-MOORA for
GSS. In this study, AHP was chosen as a weighting method, while MOORA was used to determine alternative rankings suppliers.

2. Methods

2.1 Proposed GSS Procedure

In this section, the article outlines the proposed AHP-MOORA procedure for solving GSS problems. The AHP is used to weigh the criteria and sub-criteria. AHP weights are used in the MOORA method for determining supplier rankings. The AHP-MOORA integration framework for GSS problems can be seen in Figure 1.

The first stage in the GSS is the identification of the criteria and sub-criteria. Identification of criteria and sub-criteria based on GSS problems in the company. In addition, at this stage, the criteria and sub-criteria are identified for the type of criteria (benefit or cost). The second stage is to make a Pairwise Comparison for each criterion and sub-criterion. Pairwise comparison is used as input weighting of GSS AHP criteria and sub-criteria. The pairwise comparison rating scale used was 1-9 (1 indicating equal importance to 9 indicating absolute importance). The third stage is supplier assessment based on criteria and sub-criteria. Stage 4 is weighting the criteria and sub-criteria using AHP. The result of the pairwise comparison is made a matrix. The resulting matrix is normalized. From this normalization process, we can then know the weight of each criterion/sub-criterion ($W_{ij}$), according to equations (1). $W_{ij}$ shows the weighted results. $atj$ describes the row normalization matrix. $n$ denotes the number of criteria being compared.

$$W_{ij} = \frac{a_{ij}}{n}$$  

(1)

Each weighting must be calculated the consistency test. The consistency test procedure is obtained by determining the value of the consistency ratio (CR). The formula for determining CR is presented in equation (2)-(4). Data is consistent if the CR value is less than 10% (0.1). $\lambda_{max}$ shows the maximum eigenvector. $n$ denotes the number of criteria being compared. $CI$ describes the consistency index. $RI$ is the random consistency index.

$$\lambda_{max} = \frac{\Sigma a_{ij}}{n}$$  

(2)

$$CI = \frac{(\lambda_{max} - n)}{(n-1)}$$  

(3)

$$CR = \frac{CI}{RI}$$  

(4)
In stage five is the ranking using MOORA. Supplier assessment in each criterion based on stage 3 is made a decision matrix. The MOORA decision matrix is shown in equation (5). Furthermore, the matrix that has been created is carried out Normalization (equation (6)), determination of the multi-objective optimization value (equation (7)), and followed by determining supplier rankings. $x_{ij}$ shows the Alternative matrix $i$ on criterion $j$, $i$ describe as the sequence number of attributes or criteria, $j$ denotes the supplier, and $m$ represents the number of alternatives. $W_{ij}$ shows the weight of the AHP calculation.

$$X = \begin{bmatrix} x_{11} & x_{12} & \ldots & x_{1n} \\ x_{21} & x_{22} & \ldots & x_{2n} \\ \vdots & \vdots & & \vdots \\ x_{m1} & x_{m2} & \ldots & x_{mn} \end{bmatrix}$$  \hspace{1cm} (5)

$$X'_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{m} x_{ij}^2}}$$  \hspace{1cm} (6)

$$Y_i = \sum_{j=1}^{g} w_{ij} X'_{ij} - \sum_{j=g+1}^{n} w_{ij} X'_{ij}$$  \hspace{1cm} (7)

### 2.2 Data collection

The research was conducted on Indonesia's textile industry, which is located in Tulungagung, East Java. Eight suppliers were selected with supplier code A1 - A8. Respondents of this research are procurement managers who are also decision-makers. The GG criteria used can be seen in Table 1. The results of the pairwise comparison of criteria and sub-criteria can be seen in Table 2 to Table 8. Furthermore, supplier assessment data for each sub-criteria is presented in Table 9.

#### Table 1. Criteria for GSS problems

| No | Criteria | Criteria code | Sub-criteria | Sub-Criteria Code | Type |
|----|----------|---------------|--------------|-------------------|------|
| 1  | Company Profile | CP | a) Relation | CP1 | Benefit |
|    |          |               | b) Performance history | CP2 | Benefit |
| 2  | Quality | Q | a) Conformity of raw materials to specifications | Q1 | Benefit |
|    |          |               | b) Packaging neatness | Q2 | Benefit |
| 3  | Cost | C | a) Price | C1 | Cost |
|    |          |               | b) Delivery Cost | C2 | Cost |
|    |          |               | c) Payment Method | C3 | Benefit |
|    |          |               | d) Discount | C4 | Benefit |
| 4  | Delivery | D | a) The accuracy of the order quantity | D1 | Benefit |
|    |          |               | b) On-time delivery | D2 | Benefit |
|    |          |               | c) Distance | D3 | Cost |
| 5  | Service | S | a) Replacement of damaged items | S1 | Benefit |
|    |          |               | b) Flexibility | S2 | Benefit |
| 6  | Environment | E | a) Use of environmentally friendly materials | E1 | Cost |
|    |          |               | b) Environmental certification | E2 | Benefit |
3. Result and Discussions

Based on calculations using the AHP method, the results of the global weighting of each sub-criterion are presented in Figure 2. These results indicate that the C1 sub-criterion (price) has the highest weight, followed by the Q1 sub-criteria (Conformity of raw materials to specifications) and D1 (Accuracy of order quantity) and D2 (On-time delivery). These results confirm the research conducted by Baroto and Utama [7], which states that product prices have the most excellent supplier selection weight. Industries in developing countries are concerned with product prices because it is crucial for the industry's continuity. In addition, price affects short-term business profits. Furthermore, the criterion that has the next most significant weight is Conformity of Raw Materials to Specifications. Although low prices are an option, the industry also considers raw materials' suitability with specifications in selecting raw materials. Furthermore, environmental criteria are the criteria with the least weight. This research proves that the textile industry pays less attention to environmental aspects. It stands to reason that industry in developing countries has not yet paid attention to environmental aspects as the main criterion.

Table 2. Criteria Pairwise Comparison

| Criteria | C | D | Q | CP | S | E |
|----------|---|---|---|----|---|---|
| C        | 1 | 2 | 2 | 5  | 5 | 7 |
| D        | 0.5| 1 | 3 | 4  | 4 | 7 |
| Q        | 0.5| 0.33| 1 | 5  | 3 | 5 |
| CP       | 0.2| 0.25| 0.2| 1  | 3 | 5 |
| S        | 0.2| 0.25| 0.33| 0.33| 1 | 3 |
| E        | 0.14| 0.14| 0.2| 0.2 | 0.33| 1 |

Table 3. Sub-Criteria Cost Pairwise Comparison

| Sub-Criteria Cost | C1 | C2 | C3 | C4 |
|-------------------|----|----|----|----|
| C1                | 1  | 4  | 4  | 2  |
| C2                | 0.25| 1 | 1  | 1  |
| C3                | 0.25| 1 | 1  | 2  |
| C4                | 0.5 | 1  | 0.5| 1  |

Table 4. Sub-Criteria Delivery Pairwise Comparison

| Sub-Criteria Delivery | D1 | D2 | D3 |
|-----------------------|----|----|----|
| D1                    | 1  | 1  | 3  |
| D2                    | 1  | 1  | 3  |
| D3                    | 0.33| 0.33| 1  |

Table 5. Sub-Criteria Quality Pairwise Comparison

| Sub-Criteria Quality | Q1 | Q2 |
|----------------------|----|----|
| Q1                   | 1  | 2  |
| Q2                   | 0.5| 1  |

Table 6. Sub-Criteria Company Profile Pairwise Comparison

| Sub-Criteria Company Profile | CP1 | CP2 |
|------------------------------|-----|-----|
| CP1                          | 1   | 3   |
| CP2                          | 0.33| 1   |

Table 7. Sub-Criteria Service Pairwise Comparison

| Sub-Criteria Service | S1 | S2 |
|----------------------|----|----|
| S1                   | 1  | 1  |
| S2                   | 1  | 1  |
Table 8. Sub-Criteria Environment Pairwise Comparison

| Sub-Criteria Environment | S1 | S2 |
|--------------------------|----|----|
| E1                       | 1  | 1  |
| E2                       | 1  | 1  |

The results of AHP weighting are used to determine supplier rankings based on MOORA. The results of MOORA’s assessment for each supplier are presented in Table 10. The multi-objective value used by MOORA is the value of $Y_i$. The $Y_i$ value is used to rank the alternatives based on the criteria used. The higher the $Y_i$ value, the better the ranking of the alternatives. Based on Table 10, supplier A6 is first, while the last rank is filled by supplier A8. This study shows that supplier A6 is the selected supplier, followed by Supplier A7. A6 is a supplier that is close to the home industry. In addition, the raw material prices and shipping costs offered by A6 suppliers are competitive.

Figure 2. Sub-criteria weighting results with AHP

Table 9. Supplier assessment on each Sub-Criteria

| Alternatives | A1  | A2  | A3  | A4  | A5  | A6  | A7  | A8  |
|--------------|-----|-----|-----|-----|-----|-----|-----|-----|
| C1           | 65.300 | 60.500 | 68.300 | 59000 | 63.700 | 60000 | 64000 | 62.500 |
| C2           | 218.000 | 120.000 | 122.000 | 120.000 | 195.000 | 125.000 | 115.000 | 210.000 |
| C3           | 5   | 3   | 4   | 4   | 3   | 4   | 4   | 4   |
| C4           | 0.1 | 0   | 0.15 | 0   | 0.15 | 0.15 | 0   | 0   |
| D1           | 3   | 5   | 3   | 4   | 4   | 4   | 5   | 3   |
| D2           | 4   | 4   | 3   | 4   | 3   | 4   | 3   | 4   |
| D3           | 30  | 20  | 22  | 19  | 30  | 20  | 22  | 31  |
| Q1           | 5   | 3   | 4   | 4   | 5   | 4   | 3   | 4   |
| Q2           | 3   | 3   | 3   | 3   | 3   | 3   | 5   | 3   |
| CP1          | 3   | 3   | 4   | 4   | 3   | 3   | 4   | 3   |
| CP2          | 4   | 3   | 4   | 4   | 4   | 4   | 3   | 4   |
| S1           | 3   | 3   | 4   | 5   | 3   | 4   | 4   | 4   |
| S2           | 3   | 3   | 4   | 4   | 5   | 4   | 4   | 3   |
| E1           | 2   | 2   | 2   | 2   | 2   | 2   | 2   | 2   |
| E2           | 2   | 2   | 2   | 2   | 2   | 2   | 2   | 2   |

Table 10. The Rankings GSS alternative

| Alternative | Max  | Min  | Yi   | Rank |
|-------------|------|------|------|------|
| A1          | 0.244| 0.112| 0.132| 7    |
| A2          | 0.250| 0.090| 0.159| 4    |
| A3          | 0.244| 0.100| 0.145| 5    |
| A4          | 0.253| 0.088| 0.165| 3    |
| A5          | 0.252| 0.108| 0.144| 6    |
| A6          | 0.265| 0.091| 0.175| 1    |
| A7          | 0.261| 0.094| 0.167| 2    |
| A8          | 0.232| 0.109| 0.123| 8    |
4. Conclusion

This study aimed to develop procedures for selecting GSS using AHP and MOORA. The results showed that this study succeeded in proposing the AHP-MOORA integration procedure for GSS problems in Indonesia's textile industry. The results showed that the product price has the highest weight, followed by the suitability of raw materials with specifications. The results of the supplier ranking with MOORA show that supplier A6 gives the highest rating. These results indicate that the AHP-MOORA method can be used to solve the GSS. One of the limitations of this study is that the information for AHP and MOORA data is considered crisp. For further research, it can be developed for the characteristics of Fuzzy information.

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