PAPER • OPEN ACCESS

Evaluation and Performance Analysis using ANP and TOPSIS Algorithm

Evaluation and Performance Analysis using ANP and TOPSIS Algorithm

Dana Marsetiya Utama*, Reza Putri Parameswari, Ahmad Mubin

Universitas Muhammadiyah Malang, Malang Indonesia

*dana@umm.ac.id

Abstract. Suppliers play an important role in supporting the supply chain within the company. Therefore, evaluation of suppliers in the company is a problem that is studied to improve the performance of the company's supply chain. The purpose of this study is to evaluate the performance of green suppliers using the Analytic Network Process (ANP)-Technique for order performance by similarity to ideal solution (TOPSIS). ANP is used to weigh each factor and criteria, and TOPSIS is used to evaluate the performance of green suppliers. This research is a case study on the construction industry in Indonesia. Six factors and fourteen sub-criteria are used to evaluate the performance of green suppliers. Based on the ANP method, the cost factor is the criterion that has the highest weight, which is 0.44318. The sub-criteria that has the highest weight is product price, with a weight of 0.2681. Furthermore, the order of green supplier performance based on TOPSIS shows that supplier B ranks first, followed by suppliers A, D, and C.

Keywords: Multi-criteria; ANP; TOPSIS; green supplier evaluation

1. Introduction

Suppliers are one of the most critical parts of the supply chain [1]. Suppliers ensure the availability of materials for the continuity of the company. In the supply chain, performance evaluation is essential because companies use it to assess the performance of their suppliers [2]. In addition, supplier evaluation can reduce risk and improve company performance [3] [4]. The construction industry requires raw materials to carry out its work. The costs of raw materials can reach 40% -70% of the planned needs [5]. In construction companies, one of the crucial factors that affect the supply chain is the supplier who provides goods [6]. Because construction projects have cost, quality, and time constraints, the right supplier is needed to support smoothness [7]. Several studies have been conducted in the selection or evaluation of suppliers in construction companies. Generally, supplier evaluation uses a multi-criteria decision-making approach [8]. Eshtehardian, Ghodousi and Bejanpour [9] and Cengiz, Aytekin, Ozdemir, Kusan and Cabuk [10] have offered the ANP method for supplier selection. A gray combined compromise solution (CoCoSo-G) method was proposed by Yazdani, Wen, Liao, Banaitis and Turskis [11] to select suppliers in the construction industry. The fuzzy Qualitative Flexible Multiple Criteria procedure was proposed by Liang [12]. The procedure for integrating the Decision Making Trial and Evaluation Laboratory and the evaluation based on distance from average solution was proposed by Yazdani, Chatterjee, Pamucar and Abad [13]. The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was offered by Safa, Shahi, Haas and Hipel [14]. In addition, Basar [15] proposed an analytic hierarchy process for supplier selection in the construction industry.

Based on previous research, several studies have investigated supplier evaluation or selection. One of the well-known studies was carried out by Safa, Shahi, Haas and Hipel [14]. They offer the TOPSIS method for the evaluation or selection of suppliers in the construction industry. Unfortunately, their study did not consider the relationship between criteria in evaluation or supplier selection. This study tries to evaluate the performance of green suppliers by considering the relationship between the criteria. Therefore, this study aims to Green Supplier Performance Evaluation (GSPE) using the ANP and TOPSIS approaches. In this study, the ANP method was used to obtain the weight of each criterion. The ANP method is a new approach to the qualitative method, which continues the previous method, namely the Analytic Hierarchy Process [16]. At the same time, the TOPSIS method is a technique for ordering preferences used to rank alternative suppliers [17] based on the results of processing the weights of the criteria in the ANP method.

2. Methods

2.1 ANP and TOPSIS procedures for Green supplier performance evaluation (GSPE)

In this section, we describe the GSPE framework that integrates ANP and TOPSIS. First, the ANP method is used to weigh the factors and criteria. Furthermore, the TOPSIS method assesses the performance of green suppliers based on the weighting criteria of the ANP procedure. The GSPE framework with the ANP and TOPSIS methods is shown in Figure 1.

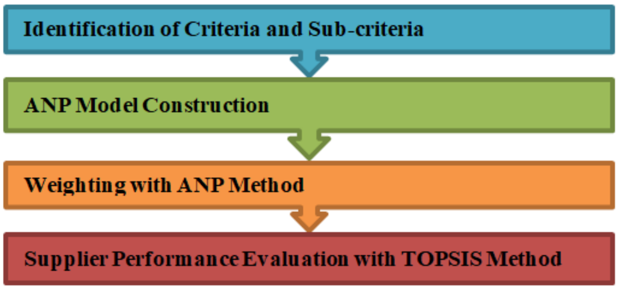

Figure 1. GSPE Framework with ANP and TOPSIS Methods

The first stage of GSPE is the identification of factors, aspects, and criteria. Identification of initial factors and criteria is based on previous studies and actual case observations. Furthermore, the initial factors were assessed for use in the GSPE. Assessment is based on a Likert scale from 1 (very unimportant) to 5 (very important). This study proposes the factors and criteria used based on the natural cut-off point (NCP). NCP value factors and criteria used are at least 3. If the factors and criteria have a score of at least 3, they are used in the GSPE. The second stage is to construct the ANP model. It is based on the focus group discussion of the criteria used. The third stage is weighting using the ANP method. Based on the second stage, the factors and criteria are compared in a pairwise comparison matrix (A). Paired comparison assessment based on a scale of 1 (equal importance) to 9 (absolutely more important). The next step is to form a supermatrix, as shown in equation (1). The weighted supermatrix is formulated in equation (2) which is generated through equations (3), (4), (5). Where α shows the relationship between criteria, and ci is the number of rows. Furthermore, the Ts matrix is multiplied by the A matrix to produce the weighted supermatrix (Aw) presented in equation (6). The last step is to calculate the limiting supermatrix based on equation (7). Based on the limiting supermatrix, the weights of the factors and criteria are generated.

$$A = \begin{matrix} & \begin{matrix} C1 & C2 & \cdots & Cn \end{matrix} \\ \begin{matrix} C1 \\ C2 \\ Cn \end{matrix} & \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{12} & a_{22} & \cdots & a_{2n} \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \end{matrix} \quad (1)$$

$$\text{T}\alpha = \begin{bmatrix} t_{11}^{\propto} & t_{1j}^{\propto} & t_{1n}^{\propto} \\ t_{i1}^{\propto} & t_{ij}^{\propto} & t_{in}^{\propto} \\ t_{n1}^{\propto} & t_{nj}^{\propto} & t_{nn}^{\propto} \end{bmatrix} \tag{2}$$

$$c_i = \sum_{j=1}^{n} t_{ij}^{\propto} \tag{3}$$

$$\text{Ts} = \begin{bmatrix} t_{11}^{\propto}/_{c1} & t_{1j}^{\propto}/_{c1} & t_{1n}^{\propto}/_{c1} \\ t_{i1}^{\propto}/_{ci} & t_{ij}^{\propto}/_{ci} & t_{in}^{\propto}/_{ci} \\ t_{n1}^{\propto}/_{c3} & t_{nj}^{\propto}/_{c3} & t_{nn}^{\propto}/_{c3} \end{bmatrix} \tag{4}$$

$$\text{Ts} = \begin{bmatrix} t_{11}^{s} & t_{1j}^{s} & t_{1n}^{s} \\ t_{i1}^{s} & t_{ij}^{s} & t_{in}^{s} \\ t_{n1}^{s} & t_{nj}^{s} & t_{nn}^{s} \end{bmatrix} \tag{5}$$

$$\text{A}w = \begin{bmatrix} t_{11}^{s}\ x\ a_{11} & t_{1j}^{s}\ x\ a_{12} & \cdots & t_{1n}^{s}\ x\ a_{1n} \\ t_{i1}^{s}\ x\ a_{12} & t_{ij}^{s}\ x\ a_{22} & \cdots & t_{in}^{s}\ x\ a_{2n} \\ t_{n1}^{s}\ x\ a_{n1} & t_{nj}^{s}\ x\ a_{n2} & \cdots & t_{nn}^{s}\ x\ a_{nn} \end{bmatrix} \tag{6}$$

$$\lim_{k\to\infty} W_w^k \tag{7}$$

The TOPSIS approach is used to evaluate the performance of green suppliers at the fourth stage.. The decision-maker assesses each supplier (i) on each criterion (j) denoted as aij. Using Equation (8), the assessment matrix is then normalized. After the ANP procedure, step (9) is determining the weights of the decision matrix for each of the criteria j. Equations (10) and (11) present negative and positive ideal solutions. For positive and negative ideal solutions, the A^+ value is calculated based on the highest yij value. According to the other criteria, A^-values are determined by the lowest yij values. Benefit criteria A^-values are determined by the lowest yij value. As per the cost criteria, however, A^+ is calculated based on the highest yij value. Equations (12) and (13) show the difference between the positive and negative ideal solution values for each supplier (13). Lastly, preference values for each provider are calculated. On the basis of the distance of the ideal positive and negative solution from each value source, each value supplier's preference is computed Using Equation (14), determine the rank order preference value (C^+). Furthermore, the supplier with the highest performance is obtained from the highest C^+ value.

$$r_{ij} = \frac{xij}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \qquad \text{where i = 1, 2, 3, . . . , m; and j = 1, 2, 3, . , n} \tag{8}$$

$$v_{ij} = w_i r_{ij} \tag{9}$$

$$A^+ = (y_1^+, y_2^+, \dots \dots . y_n^+) \tag{10}$$

$$A^- = (y_1^-, y_2^-, \dots \dots . y_n^-) \tag{11}$$

$$S_i^+ = \sqrt{\sum_j^n = 1\ \left(v_{ij} - v_j^+\right)^2} \tag{12}$$

$$S_i^- = \sqrt{\sum_j^n = 1\,(v_{ij} - v_j^-)^2} \tag{13}$$

$$C_i^+ = \frac{S_i^-}{(S_i^- + S_i^+)}, 0 \leq C_i^+ \leq 1 \tag{14}$$

2.2 A case study

The research was conducted on the construction industry in Indonesia, which is located in Tulungagung, East Java. Four suppliers were selected with supplier codes SA, SB, SC, and SD. The decision-maker in this research is the procurement manager. The results of the identification of factors, aspects, and criteria are presented in table 1. This result is an assessment based on the NCP value. Furthermore, the decision-maker makes the pairwise comparison matrix between the criteria and the green supplier performance assessment. Finally, the weighting of the criteria is carried out by using super decision software.

Table 1. Factors and criteria for Gree Supplier Performance Evaluation

No	Factors	Aspect	Criteria	Code	Classification
1	Company Profile (A)	Economy	Approval	A1	Benefit
			Performance History	A2	Benefit
2	Quality (B)	Economy	Quality	B1	Benefit
			Rejection rate	B2	Cost
			Conformance to specifications	B3	Benefit
3	Cost (C)	Economy	Price	C1	Cost
			Discount	C2	Benefit
			Delivery cost	C3	Cost
4	Service (D)	Social	Defective product replacement	D1	Benefit
			Flexibility	D2	Benefit
5	Delivery (E)	Economy	Lateness	E1	Cost
			Delivery of products on demand	E2	Benefit
6	Environmental Issues (F)	Environment	Environmental standards	F1	Benefit
			Eco-friendly packaging	F2	Benefit

3. Result and Discussions

3.1 A case study

Figure 2 shows the weight of each factor in the GSPE. Sequentially, the factors that have the highest to the lowest weight are the cost of 0.44318, quality of 0.343794, delivery of 0.082044, company profile of 0.061375, service of 0.034968, and environmental issues of 0.03464. The factor that has the highest weight in this study is cost. Referring to previous research, Baroto and Utama [18] stated that cost has the highest weight compared to other criteria. The criteria for environmental issues have the lowest weight because the company does not prioritize environmental aspects. The results of this study show the same results from the research conducted by Utama, Asrofi and Amallynda [19]. Companies must prioritize environmental criteria in the face of global warming. Because environmental criteria are still used in supplier selection, environmentally sound selection will have a higher value.

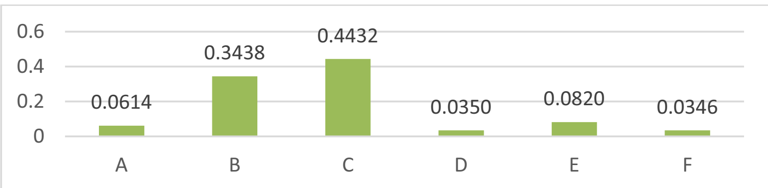

Figure 2. Weight of each factor in GSPE

The results of the weighting of the GSPE criteria are presented in Figure 3. The results show that the five highest weighting criteria in a row are price criteria of 0.2681, product Conformance to specifications of 0.187, a discount of 0.122, quality of 0.1024, lateness of 0.0604. The weight that has the highest value is the price criteria. The results of this study are from previous research conducted by Pujotomo, Puspitasari and Rizkiyani [20]. According to their findings, product price is the most important criterion because it can reduce its operating costs and increase its revenue. The reduction in operating costs is another benefit of low product prices. It allows low production costs while maintaining high-quality standards in product production [21]. Furthermore, the criterion that has the lowest weight is eco-friendly packaging. It is the same as the previous study investigated by Utama [22]. Therefore, this criterion has at least a relationship with other criteria. In addition, environmentally friendly packaging is not a crucial problem for companies that focus on price and product quality. Therefore, this criterion has little impact on the company's production results. However, if there are suppliers with better eco-friendly packaging, suppliers will be considered to choose them.

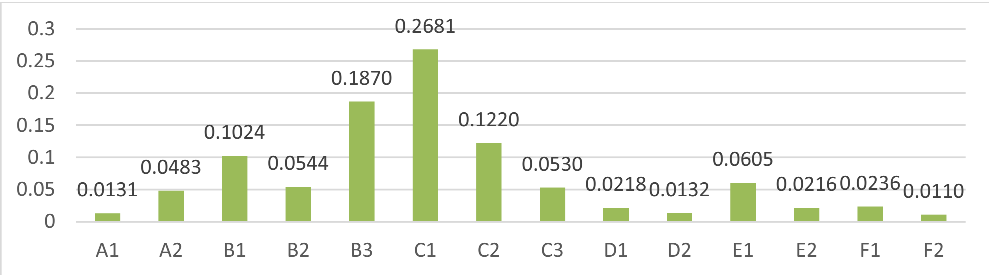

Figure 3. GSPE criteria weighting results

3.2 Green supplier Performance Evaluation Results using TOPSIS

The results of the green supplier performance evaluation assessment are shown in Figure 4. Based on the TOPSIS method, the priority supplier is Supplier B, with a value of 79.04%. Supplier A has a value of 48.55%, then Supplier D with a percentage of 37.12%, and the last one is Supplier C with 37.21%. The percentage of alternative suppliers is strongly influenced by the criteria indicators. Supplier B has the greatest value because this company has a good performance, especially on criteria indicators with the highest weight, such as affordable prices and product conformance to specifications.

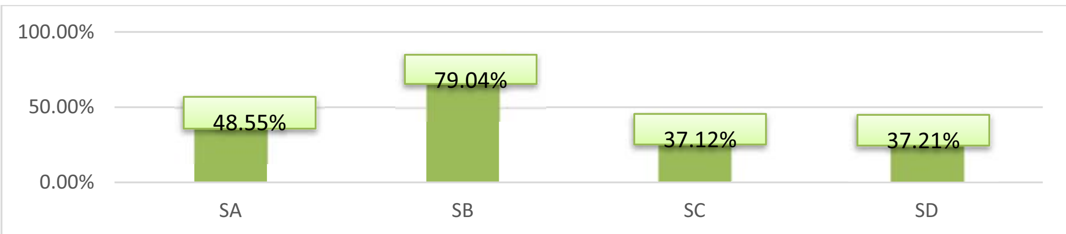

Figure 4. The results of the green supplier performance evaluation assessment

4. Conclusion

The main objective of this study is to evaluate the performance of green suppliers using the ANP and TOPSIS methods. The weighting of green suppliers with ANP shows that there are three highest factor weights out of 6 factors, namely the criteria of cost, quality, and delivery. Five criteria have the highest value out of 14 criteria, namely price, conformity of material with specifications, price discounts, quality, and lateness. The results of the green supplier performance evaluation based on TOPSIS show that suppliers that have the highest to lowest values are supplier B, supplier A, supplier

D, and supplier C. This study has limitations that assume the assessment has crisp data characteristics. Future research needs to consider fuzzy characteristics in GSPE in construction companies.

References

[1] Ibrahim M F, Putri M M and Utama D M 2020 A literature review on reducing carbon emission from supply chain system: drivers, barriers, performance indicators, and practices *IOP Conference Series: Materials Science and Engineering* **722** 012034
[2] Utama D M, Baroto T, Ibrahim M F and Widodo D S 2021 Evaluation of Supplier Performance in Plastic Manufacturing Industry: A Case Study *Journal of Physics: Conference Series* **1845** 012016
[3] Natalia C, Surbakti I P and Oktavia C W 2020 Integrated ANP and TOPSIS Method for Supplier Performance Assessment *Jurnal Teknik Industri* **21** 34-45
[4] Utama D M 2021 AHP and TOPSIS Integration for Green Supplier Selection: A Case Study in Indonesia *Journal of Physics: Conference Series* **1845** 012015
[5] Banaeian N, Mobli H, Nielsen I E and Omid M 2015 Criteria definition and approaches in green supplier selection–a case study for raw material and packaging of food industry *Production & Manufacturing Research* **3** 149-68
[6] Hoseini S A, Fallahpour A, Wong K Y, Mahdiyar A, Saberi M and Durdyev S 2021 Sustainable Supplier Selection in Construction Industry through Hybrid Fuzzy-Based Approaches *Sustainability* **13** 1413
[7] Stević Ž, Pamučar D, Vasiljević M, Stojić G and Korica S 2017 Novel integrated multi-criteria model for supplier selection: Case study construction company *Symmetry* **9** 279
[8] Ho W, Xu X and Dey P K 2010 Multi-criteria decision making approaches for supplier evaluation and selection: A literature review *European Journal of operational research* **202** 16-24
[9] Eshtehardian E, Ghodousi P and Bejanpour A 2013 Using ANP and AHP for the supplier selection in the construction and civil engineering companies; Case study of Iranian company *KSCE Journal of Civil Engineering* **17** 262-70
[10] Cengiz A E, Aytekin O, Ozdemir I, Kusan H and Cabuk A 2017 A Multi-criteria Decision Model for Construction Material Supplier Selection *Procedia Engineering* **196** 294-301
[11] Yazdani M, Wen Z, Liao H, Banaitis A and Turskis Z 2019 A grey combined compromise solution (CoCoSo-G) method for supplier selection in construction management *Journal of Civil Engineering and Management* **25** 858-74
[12] Liang R 2019 A hybrid group decision model for green supplier selection: a case study of megaprojects *Engineering, Construction and Architectural Management* **26** 1712-34
[13] Yazdani M, Chatterjee P, Pamucar D and Abad M D 2019 A risk-based integrated decision-making model for green supplier selection: A case study of a construction company in Spain *Kybernetes*
[14] Safa M, Shahi A, Haas C T and Hipel K W 2014 Supplier selection process in an integrated construction materials management model *Automation in Construction* **48** 64-73
[15] Basar P 2018 The analytic hierarchy process method to design strategic decision making for the effective assessment of supplier selection in construction industry *Research Journal of Business and Management* **5** 142-9
[16] Saaty T L 2004 Decision making—the analytic hierarchy and network processes (AHP/ANP) *Journal of systems science and systems engineering* **13** 1-35
[17] Jadidi O, Firouzi F and Bagliery E 2010 TOPSIS method for supplier selection problem *World Academy of Science, Engineering and Technology* **47** 956-8
[18] Baroto T and Utama D M 2021 Integrasi AHP dan SAW untuk Penyelesaian Green Supplier Selection *Prosiding SENTRA (Seminar Teknologi dan Rekayasa)* 38-44
[19] Utama D M, Asrofi M S and Amallynda I 2021 Integration of AHP-MOORA Algorithm in Green Supplier Selection in the Indonesian Textile Industry *Journal of Physics: Conference Series* **1933** 012058

[20] Pujotomo D, Puspitasari N B and Rizkiyani D 2016 Integrasi Metode ANP dan TOPSIS Dalam Evaluasi Kinerja Supplier dan Penentuan Prioritas Supplier Bahan Baku Utama Cetak Koran Pada PT Masscom Graphy Semarang *J@ ti Undip: Jurnal Teknik Industri* **11** 151-60

[21] Utama D M, Maharani B and Amallynda I 2021 Integration Dematel and ANP for The Supplier Selection in The Textile Industry: A Case Study *Jurnal Ilmiah Teknik Industri* **20** 119-30

[22] Utama D M 2021 Penyelesaian Green Supplier Selection Menggunakan Integrasi AHP dan VIKOR *Prosiding SENTRA (Seminar Teknologi dan Rekayasa)* 31-7