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Integration AHP and MOORA for Sustainable Supplier Selection During the COVID-19 Pandemic Era: A Case Study

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Abstract. The global COVID-19 pandemic had a complex impact on the supply chain system. Manufacturing companies always strive to be able to face corporate competition and become superior with one of them through selecting the right supplier. Suppliers have the highest risk in a company, especially during the COVID-19 pandemic era, but with the correct selection of suppliers, the company can provide strength in global competition. The purpose of this research is to be able to solve the problem of sustainable supplier selection in a garment industry in Indonesia during the COVID-19 pandemic through the integration method between AHP and MOORA. AHP as a method that has been proven in many studies, in this study is used to determine the weight of each criterion. Furthermore, MOORA as a method that has good selectivity in choosing the best alternative will be used in the selection process. 12 criteria with 5 alternatives are used to determine the best supplier. The contribution of this research is the integration of the AHP and MOORA methods and the determination of important criteria in the era of the COVID-19 Pandemic. The results show that the criteria for the area with the level impact of COVID-19 (C12) have the greatest weight and supplier 3 becomes the first ranked supplier or the best supplier. The integration method between AHP and MOORA is easy to use and can choose the right sustainable supplier during the COVID-19 pandemic.

Keywords: AHP, MOORA, Pandemic COVID-19, Sustainable Supplier Selection

INTRODUCTION

Supplier selection as a multi-criteria decision-making problem is an important step in the supply chain management process and becomes a strategic issue in increasing company competitiveness [1-3]. Selection of the right supplier will have a positive impact on reducing costs, improving quality, and on-time delivery of products that will lead to strength in global competition [4, 5]. This becomes very complex when there is a disruption in the supply chain system caused by the COVID-19 pandemic. The global spread of the coronavirus, also known as the COVID-19 pandemic, has had a devastating impact on supply chains. The COVID-19 pandemic has disrupted the world economy tremendously. Even until there is a decline in retail sales that exceeds history and unemployment is rising rapidly. The current pandemic has created additional disruptions to the supply chain system [6]. Research conducted by Meyer, Walter [7] and Chowdhury, Paul [8] stated that the COVID-19 pandemic has greatly affected supply chains and their sustainability and one of the highest risks is from suppliers, so it must be mitigated properly.

In recent decades, sustainability has become a major concern for organizations due to increasing awareness about environmental degradation, depletion of natural resources, and climate change [9]. The concept of sustainability has become an important philosophy for various industrial sectors due to the increasing awareness of environmental protection and social responsibility. In addition, various social and environmental issues in developing countries raised by social organizations have forced organizations to focus on sustainable manufacturing practices. On the other

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hand, supply chain sustainability, which pays attention to environmental, economic, and social aspects, has always been highlighted in the evaluation process. Suppliers, which are the basic components of the supply chain, have a very important role in creating a sustainable supply chain [10]. A strategic step towards a sustainable supply chain is to select a sustainable supplier as well. This becomes a challenging problem because this decision-making must be faced with various conflicting criteria and the knowledge of the decision maker is not precise and unclear [11].

Researchers have conducted several studies on sustainable supplier selection. The use of the Analytical Hierarchy Process (AHP) method in the problem of sustainable supplier selection has been carried out by Mani, Agrawal [9]. The study pays attention to social parameters and makes decisions with AHP. Gold and Awasthi [12] using the fuzzy AHP approach in solving the problem of selecting a sustainable global supplier by considering the risks that occur. The fuzzy Technique For Others Reference by Similarity to Ideal Solution (TOPSIS) approach has also been used previously by Memari, Dargi [11] in the problem of selecting a sustainable supplier for the manufacture of automotive parts. Awasthi, Govindan [13] proposed the AHP method that is integrated by VIekriterijumsko KOmpromisno Rangiranje (VIKOR) method for solving sustainable supplier selection based on the encouragement of outsourcing business activities to geographically distant countries. The integration of the AHP and TOPSIS approaches in the selection of sustainable suppliers in the construction business has been carried out by Marzouk and Sabbah [14]. Other than that, Azimifard, Moosavirad [10] also use the AHP approach which is integrated with TOPSIS to solve the problem of selecting sustainable suppliers from the state-owned steel industry. Wang, Li [15] using the integration of Triangular fuzzy entropy and the MULTIMOORA method in the selection of sustainable battery suppliers at the battery exchange station in Beijing. Arabsheybani, Paydar [2] integrating fuzzy Multi-Objective Optimization on the basis of Ratio Analysis (fuzzy MOORA) with Failure Modes and Effects Analysis (FMEA) in selecting sustainable suppliers considering quantity discount and supplier's risk.

Based on several previous studies, AHP and MOORA are popular and simple to use in solving sustainable supplier selection problems. As far as we know, there has never been a sustainable supplier selection taking into account supply chain disruption in the COVID-19 pandemic era. Thus, this study tries to integrate AHP and MOORA to solve the problem of selecting sustainable suppliers in the era of the COVID-19 pandemic, especially in Indonesia. The contribution of this research is the integration of the AHP and MOORA methods and the determination of important criteria in the era of the COVID-19 Pandemic. Additional criteria relevant to the situation at hand are sought through the literature. This study contributes to the sustainable supplier selection problem by considering the disruption of the supply chain system in the COVID-19 pandemic era.

METHODS

Proposed Methods

This study proposes an integration method between AHP and MOORA in solving the problem of sustainable suppliers selection in a garment industry in Indonesia during the COVID-19 pandemic. The Analytical Hierarchy Process method or better known by the abbreviation AHP, was first developed by Saaty [16]. AHP is one of the methods in the decision-making system by describing complex multi-criteria problems through a hierarchical structure. The AHP method has the best ability in determining the weighting of each criterion based on pairwise comparisons between criteria. It also takes into account the validity to the tolerance limit for the inconsistency of various criteria through an assessment based on a certain priority scale from the perspective of the party who is influential in decision making (commonly called the expert) to get the best criteria weight. Meanwhile, the Multi-Objective Optimization on the basis of Ratio Analysis (MOORA) method was first introduced by Brauers and Zavadskas [17] is a method of decision making as a multi-objective system that optimizes 2 or more conflicting attributes simultaneously. The MOORA method has good selectivity in choosing the best alternative. In problems related to the selection of sustainable suppliers of a garment industry during the COVID-19 pandemic, the author proposes the use of the AHP method in determining the weighting of each criterion and followed by the use of the MOORA method in selecting the best supplier. The framework of the proposed method can be seen in Figure 1.

The first stage in the framework of the proposed method is the decision maker to identify the criteria and alternatives used in the research problem. The second stage is to identify and classify each criterion into cost or benefit criteria. The third stage is the decision maker to determine the value of pairwise comparisons between criteria by making a pairwise comparison matrix between criteria and then normalizing the pairwise comparison matrix between criteria. The assessment on each criterion uses the priority scale developed by Saaty as shown in Table 1.

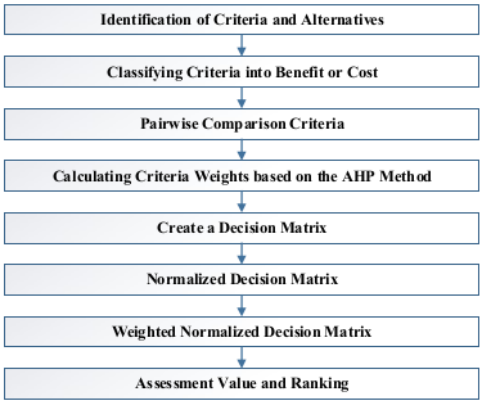

FIGURE 1. Integrated AHP and MOORA Framework

TABLE 1. Rating Scale

Level of Interest	Definition
1	Equally important (equal)
3	Quite important (moderate)
5	More important (strong)
7	Very more important (very)
9	Absolute more important (extreme)
2,4,6,8	Values that fall between 2 adjacent considerations

Then, the fourth stage is to calculate the weighting of each criterion using the AHP method. This stage begins with calculating the weight value of each criterion by dividing the number of normalized pairwise comparison matrix values per row by the number of criteria. Next, calculate the Consistency Ratio value and it is said to be consistent if CR ≤ 0.1.

$$W_j = \frac{1}{n}\sum_j a_{ij} \quad (1)$$

Notation:
W_j : criteria weight value
n : number of criteria
i : column
j : row
a_{ij} : pairwise comparison matrix value

$$CI = \frac{(t-n)}{(n-1)} \quad (2)$$

Notation:
CI : consistency Index value
t : consistency value
n : number of criteria

$$CR = \frac{CI}{IR_n} \quad (3)$$

Notation:
CR : consistency ratio value
CI : consistency index value
IR : random index value (based on number of criteria)
n : number of criteria

The fifth stage is making a decision matrix from the assessment of each alternative against each criterion consisting of i criteria and j alternatives. Decision makers who provide an assessment of each alternative against each criterion. Next, the sixth step is to calculate the normalization of the decision matrix which aims to unite each element of the matrix so that it has a uniform value for each element. The seventh stage is to calculate the optimization of the attribute value by reducing the number of multiplication values of the criteria weights to the maximum attribute values and the total multiplication values of the criteria weights to the minimum attribute values. Then, the eighth stage is ranking to get the best supplier solution with the highest y_i value.

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1i} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots & \iddots & \vdots \\ x_{j1} & \cdots & x_{ji} & \cdots & x_{jn} \\ \vdots & \iddots & \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mi} & \cdots & x_{mn} \end{bmatrix} \quad (4)$$

Notation:

x_{ji} : alternative value j on criterion i

X :decision matrix

$$X_{ij}^{*} = \frac{x_{ij}}{\sqrt{\left[\sum_{j=1}^{m} x_{ij}^{2}\right]}} \quad (5)$$

Notation:

X_{ij}^{*} : alternative normalization matrix j on criterion i

x_{ij} : alternative value j on criterion

$$y_i = \sum_{j=1}^{j=g} W_j X_{ij}^{*} - \sum_{j=g+1}^{i=n} W_j X_{ij}^{*} \quad (6)$$

Notation:

i : 1, 2, …, g is an attribute or criterion with maximum status status

j : g+1,g+2, g+3, …, n is an attribute or criterion with a minimum status

W_j : the value of weight against alternative j

y_i : the value of the assessment that has been optimized from alternative j on all attributes/criteria

Data Collection

This research raises a case study on a garment company in Indonesia. The company in this case selects a supplier of cotton fabric which is the main raw material for its products. Five suppliers were selected as alternative suppliers to be used. In this study, experts are sought who have an interest in making decisions. The members of the decision-makers team include the company owner, the head of the procurement department, the head of the production section, and the warehouse supervisor. Determination of the criteria used in this problem is done by studying literature in previous studies. The list of criteria that has been obtained is then submitted to the decision-makers members. After that, a focus group discussion was conducted to determine the criteria used. In detail, the criteria used in this study can be seen in Table 2. The selected criteria related to the COVID-19 pandemic used are represented in criteria 8 to 12. The COVID-19 pandemic in Indonesia has led to the emergence of several new criteria related to government conditions and regulations. The government's policy by urging companies to implement Work From Home (WFH) for certain sectors has led to the selection of criteria for remote working conditions to be considered. The criteria for safety and health practices were also chosen because they are important practices in avoiding viruses. In addition, the policy of Enforcement of Community Activity Restrictions (PPKM) also causes Area criteria to be important and considered. Health and safety practices, the wellbeing of employees, efficient communication strategies in healthcare, community safety, remote working conditions, and skill improvement are some of the social sustainability initiatives adopted by corporations for diminishing the negative effects of the epidemic and preserving the social sustainability of supply chains [18].

After the list of criteria is formed, then the decision-making team performs a pairwise comparison of the criteria. Table 3 is a presentation of the results of pairwise comparisons between criteria. Subsequently, the five suppliers were assessed by the decision-making team. The assessment of the price criteria (C1) is based on quantitative data. For other criteria, the assessment is based on a Likert scale (scores 1-5). 1 means very bad and a score of 5 means very

good criteria. Table 4 is a decision matrix that shows the results of the assessment of the five suppliers against each criterion.

TABLE 2. Criteria for Sustainable Supplier Selection during Pandemic

No.	Criteria	Code	Classification	References
1.	Price	C1	Min	[19] [20] [21] [22] [23]
2.	Quality	C2	Max	[19] [23] [24] [25]
3.	Delivery	C3	Max	[15] [23] [24] [25] [26]
4.	Service	C4	Max	[23] [25] [27]
5.	Environmental Management System (EMS)	C5	Max	[20] [23] [28] [29]
6.	Use of Environmental-Friendly Materials	C6	Max	[30] [31]
7.	Use of Green Packaging	C7	Max	[30] [32] [33]
8.	Safety and Health Practices	C8	Max	[34] [35] [36]
9.	The Wellbeing of Employees	C9	Max	[34] [37]
10.	Communication Strategies in Healthcare	C10	Max	[18]
11.	Remote Working Conditions	C11	Max	[34] [35] [37]
12.	Area (Covid-19 Impact Level)	C12	Min	[36]

TABLE 3. Pairwise Comparison Between Criteria

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
C1	1	1/3	3	3	1/3	1	1	1/5	1/3	1/5	1/5	1/7
C2	3	1	3	3	1/3	1	1	1/3	1	1	1/2	1/3
C3	1/3	1/3	1	2	1/3	1/5	1/3	1/5	1/2	1/2	1/5	1/7
C4	1/3	1/3	1/2	1	1/5	1/3	1/2	1/5	1	1/2	1/5	1/7
C5	3	3	3	5	1	1	3	1	2	1/3	1/5	1/7
C6	1	1	5	3	1	1	3	1	1	1	1/5	1/7
C7	1	1	3	2	1/3	1/3	1	1/3	3	1/3	1/5	1/7
C8	5	3	5	5	1	1	3	1	5	1	1	1/5
C9	3	1	2	1	1/2	1	1/3	1/5	1	1/5	1/5	1/7
C10	5	1	2	2	3	1	3	1	5	1	1/5	1/5
C11	5	2	5	5	5	5	5	1	5	5	1	1/5
C12	7	3	7	7	7	7	7	5	7	5	5	1

TABLE 4. Assessment

Criteria	Suppliers				
	Supplier 1	**Supplier 2**	**Supplier 3**	**Supplier 4**	**Supplier 5**
C1	1,350,000	1,500,000	1,400,000	1,300,000	1,350,000
C2	4	4	5	4	5
C3	3	4	5	4	5
C4	4	4	5	4	4
C5	3	4	4	3	2
C6	4	4	5	4	4
C7	3	4	4	4	4
C8	2	3	3	2	3
C9	5	5	4	5	4
C10	3	4	3	3	3
C11	2	5	5	3	3
C12	2	4	3	5	3

RESULTS AND DISCUSSION

After completing the pairwise comparison matrix through the process of discussion and filling out the questionnaire, the weights between criteria were obtained using the AHP method. It was found that Area (C12) was the criteria with the greatest weight, which was 29.5%. Then, the next position was occupied by Remote Working Conditions (C11) and Safety and Health Practices (C8) with weights of 16.1% and 10.6%, respectively. The three

criteria with the highest weight are criteria related to the ongoing COVID-19 pandemic. Next, followed by the criteria for Communication Strategies in Healthcare (C10), EMS (C5), Environment-Friendly Materials (C6), Quality (C2), Green Packaging (C7), Welbeing of Employees (C9), Price (C1), Delivery (C3), and Service (C4). Obtaining Area (C12) as the criterion that has the highest weight can be related to the implementation of Community Activity Restrictions (PPKM) by the government in areas affected by the pandemic. That way, the Area criteria become very important to maintain the continuity of a company's supply. Because, the PPKM implemented is considered to have an impact on the company. One of them is due to the dissolution of the workplace in the affected area as described in Andriani [38] and Buditomo [39].

In further analysis, the criteria related to the environment also remain an important criterion even though it is in a slightly lower position. For example, the EMS criteria (C5), Environment-Friendly Materials (C6), and Green Packaging (C7) are also important criteria with weights of 7.6%, 6.2%, and 4.2% respectively. Surprisingly, basic criteria such as price, delivery, and even service have become criteria that are considered less important in these conditions. This shows how big the environmental problems are coupled with the COVID-19 pandemic. In detail Figure 2 shows the weights for each criterion.

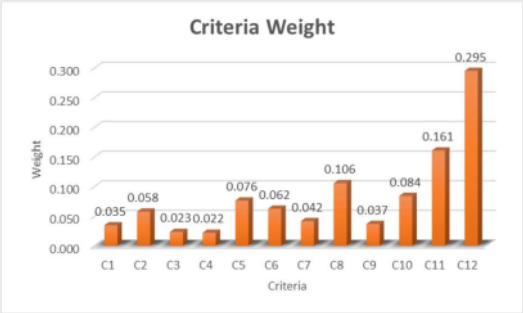

FIGURE 2. Criteria Weight Based on AHP Method

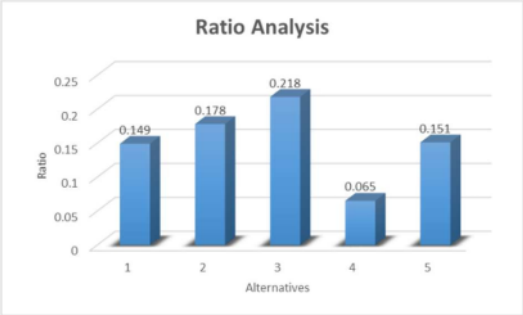

FIGURE 3. Ratio Analysis Based on MOORA Method

The weight of the criteria shown in Figure 2 is then used in the process of determining the best supplier using the MOORA method. Ratio Analysis shows the best alternative or in this case is the best supplier. The results show that Supplier 3 has the largest ratio value of 0.218. Then followed by Supplier 2 and Supplier 5 with a ratio value of 0.178 and 0.151, respectively. Furthermore, in the 4th position is occupied by Supplier 1 with a ratio value of 0.149. The last position is occupied by Supplier 4 with a ratio value of 0.065. In a more in-depth analysis, it was found that Supplier 3 as the best supplier had superior scores on the criteria of EMS (C5), Environment-Friendly Materials (C6), and Green Packaging (C7) when compared to other alternative suppliers. In addition, supplier 3 is also one of the suppliers that has the highest score on the criteria for Safety and Health Practices (C8) and Remote Working Conditions (C11). That way, Supplier 3 is very worthy of being the best supplier because all of the criteria previously mentioned are mostly criteria with high weights. On the other hand, we try to analyze the last alternative supplier position, namely Supplier 4. It can be seen from the data collected, Supplier 4 is the highest on the Area (C12) criteria which is the criterion with the highest weight. However, Supplier 4 has a low score on the criteria for Safety and Health Practices (C8) and Remote Working Conditions (C11). In addition, it also has a fairly low score on EMS (C5), Environment-Friendly Materials (C6), and Green Packaging (C7) which are environmental criteria. This shows that all criteria have been well considered in this method. The assessment carried out is not only focused on criteria related to the COVID-19 pandemic, but also considers the priority of sustainability. The graph of the ratio analysis as well as the ranking of each of the best alternative suppliers to be selected is presented in Figure 3.

Determining decisions with multiple assessment criteria is indeed a dilemma for decision makers. Moreover, when decision makers are faced with various environmental conditions that interfere with stability. It was found that a high score on one very important criterion did not necessarily lead the supplier to become the best supplier. However, the proposed method is able to solve the problem of sustainable suppliers selection in the era of the COVID-19 pandemic. These results indicate that the integration of AHP and MOORA can be used efficiently to solve the problem of sustainable suppliers selection in the era of the COVID-19 pandemic.

CONCLUSIONS

This study aims to solve the problem of sustainable supplier selection in the era of the COVID-19 pandemic. The contribution of this research is the integration of the AHP and MOORA methods and the determination of important criteria in the era of the COVID-19 Pandemic. The integration of AHP and MOORA succeeded in solving the problems encountered. This research uses a case study from a garment industry in Indonesia. The criteria used are based on previous research and focus group discussions to determine the criteria used. Fabric suppliers are selected by considering twelve criteria, five of which are criteria related to the COVID-19 pandemic. There are five alternative prospective suppliers being considered. The results showed that the criteria Area (C12) had the greatest weight and Supplier 3 became the supplier with the first rank. The results of this study also show the ease of use of the AHP and MOORA integration methods in solving sustainable supplier selection problems in the COVID-19 pandemic era. In future research, the relationship between criteria can be analyzed more focused.

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