A Hybrid Method of AHP and COPRAS-G for Supplier Selection: A Case Study in Indonesian Leather Industry

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Abstract. The aim of this research is to select suppliers using the Analytical Hierarchy Process (AHP) and Complex PRoportional Assessment of Alternatives with Gray Relations (COPRAS-G). The proposed technique for selecting criteria uses Delphi by considering objective and subjective factors. These criteria are then weighted by AHP and then used as the basis for selecting suppliers using COPRAS. The proposed model has been tested in the Indonesian leather industry for practical use. The suggested model can represent the dynamics of decision-making groups in supplier ranking. By using the selection of factors in this suggested model, decision makers can choose more wisely. The accuracy of the criteria set will determine the results of supplier selection. Therefore, to test the validity of the model, a sensitivity test to changes in parameters is used. The proposed method generates an effective outcome because it is not sensitive to parameter changes.

Keywords: supplier selection, criteria selection, AHP, COPRAS-G, Delphi

1 Introduction

In the manufacturing sector, raw materials are a crucial component that must be taken into account since without them, the system for producing items cannot function effectively. Extra consideration must be given to the caliber of suppliers in order to guarantee that the items are produced in accordance with the expectations and preferences of businesses or consumers [1]. As a result, selecting suppliers has come to be recognized as one of the major difficulties that firms must overcome in order to maintain a strategic competitive position [2]. Supplier is one of the success factors of the company.

A company called PT. Adi Satria Abadi (ASA) makes gloves out of animal skins. This company produces its goods using a long-term, sustainable make-to-order approach that enlists the help of medium- to large-sized businesses [3]. According to the company, each supplier has a very diverse personality when it comes to meeting the needs of raw materials. Because the suppliers couldn't meet the company's criteria, the company was let down by them numerous times [3]. The company is dissatisfied with the price, delivery delays, and product quality that it has received.

To compete in the industrial world, businesses must create efficient supply chains, one of which is to keep in touch with suppliers [4]. Supply chain management has a big impact on how

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well businesses perform and succeed [5]. As a result, it's crucial to maintain a strong supply chain and foster excellent connections with suppliers. The selection of suppliers is now a crucial component in managing industry relations [6]. To enhance business performance and lower PT ASA discontent, the company conducts an assessment to determine priority supplier selection. Every semester, a supplier assessment is carried out to evaluate the performance of each period's suppliers. The PT. ASA procurement section conducts the evaluation.

When choosing suppliers, research is necessary to lower the likelihood that the organization would be dissatisfied. By performing a factor analysis using the Delphi technique initially, the important factors to the company will be taken into account during the research. The Analytical Hierarchy Process (AHP) is used to weight the factors, and COmplex PRoportional ASsessment of Alternatives with Grey Relations (COPRAS-G) is used to pick the suppliers. One of the things looked at is sensitive data, thus it's crucial to conduct a sensitivity test to offer the business a clear idea of which providers to give priority to.

2 Method

Zavadskas et al. [7] introduced the COPRAS-G method for Multi Attribute Decision Making (MADM). Meanwhile, AHP is frequently utilized as an alternate weighting method when choosing suppliers [8]. So, in its development, the COPRAS-G approach and AHP were then merged in the supplier evaluation process. Zolfani et al. [9] uses AHP in calculating the weight of each criterion then COPRAS-G is adopted for ranking and selecting suppliers. To select suppliers in an Iranian manufacturing business, Mobin et al. [10] suggested integrating an AHP and CORPAS-G. Ajalli et al. [11] propose ABZARSAZI COMPANY's suppliers which were ranked using a mix of the AHP and COPRAS methods. Deretarla et al. [12] employs AHP and COPRAS to assess vendors and choose the best ones for manufacturing businesses. The decision-makers in the company offered the criteria that were taken into consideration in the prior study [13]. Most studies on supplier selection have only focused on methods for selecting alternative suppliers, they have not examined selection criteria in depth [14]. In actuality, a critical phase in the supplier selection process is selecting the criteria [15]. There are many methods for selecting criteria, for more details, see Ristono et al. [14].

2.1 Delphi

Delphi is used in this study to choose the criterion. The benefit of using Delphi is that no precise sample size criterion has been specified in the literature because Delphi depends on group dynamics rather than statistical power to bring experts to consensus [16]. Delphi's capability to mix quantitative and qualitative data provides an additional benefit [17]. The ability to get expert opinions using an open questionnaire is the second benefit [18]. Researchers collected and examined expert perspectives topically before presenting them to the same panel of experts for their level of agreement or disagreement with the synthesis findings [18]. A consensus representing the aggregate expert opinion was obtained after several rounds of discussion [19]. In each round, experts can change their response. Following exposure to the viewpoints of other specialists or in order to clarify perspectives, modifications may take place [20]. The process was assisted by someone outside the panel, frequently a researcher, and the comments went unreported by other experts. Figure 1 depicts the Delphi phases used in this investigation, for more details, see Laupichler et al. [21].

2.2 Analytical Hierarchy Process (AHP)

After choosing the criteria, weight them using AHP. AHP not only helps with the analysis of arriving at the best decision but also provides a clear rational orientation to the made choices, involves the principles of decomposition pair-wise comparisons and the generation and synthesis of priority vectors [9]. Additionally, it is demonstrated that TOPSIS outperforms AHP, which necessitates an enormous number of paired comparisons, for large numbers of options [22]. However, the mathematical method is rather simple, and the reasoning of the AHP approach is reasonable and understandable [23]. As a result, AHP is mostly used to weight the criterion. In this study, COPRAS-G is used for supplier selection while AHP is used for criteria weighting. So that AHP can be applied to this problem to provide systematically appropriate weighting criteria, as well as to confirm the decision-making process [24].

AHP is often separated into three stages [25]. Defining the issue and creating a list of related issues is the first step [26]. This is the benefit of AHP, as the issue can now be exposed and thoroughly dissected during the construction of the hierarchical structure [27]. Hierarchy appraisal and decomposition of the problem separation make it possible to describe the problem [9]. The elements of hierarchy can relate to any aspect of the decision problem such as tangible or intangible, carefully measured or roughly estimated, well or poorly understood, i.e. anything that applies to the decision at hand. It has been well utilized in several fields

The next step is to rank the elements in order of importance, working up from pairwise comparisons to the relative weighting of the criterion [27]. Synthesis, or measuring the consistency ratio index, is the third stage. This seeks to determine the validity of the relative weighting outcomes of these criteria [28]. Figure 1 displays the AHP stages employed in this investigation, for more details, see Ristono et al. [29].

2.3. Copras-G

The concept behind the COPRAS-G approach and the interval-based criterion values [30],[31]. Decision makers constantly consider the future, hence it is impossible to precisely explain the values of criteria [7]. Many times, the outcomes of the possible courses of action cannot be known with confidence [7]. Instead of using the exact values for the criterion, this multi-criteria decision-making problem must be determined using fuzzy values or values picked from some intervals [30]. So, by applying the utility degree of each alternative and using criterion values presented in intervals, the COPRAS-G technique seeks the rational answer [9]. It is based on applications of the Grey system theory, which employs a stepwise ranking and assessing technique of options in terms of relevance and utility degree, in real-world decision-making situations [7]. In comparison to other data analysis techniques (such as probability statistics, fuzzy mathematics, and Bayesian methodology), the properties of grey systems theory simply call for a lower number of samples, and typical sample distribution is not required [32]. So, operating on a tiny sample has the side effect of allowing for the creation of incomplete and insufficient data [32].

A unique measure called COPRAS-G combines qualitative and quantitative elements including feature state and trust [33]. It presupposes that the relevance and usefulness level of the versions under investigation are directly and proportionally dependent on a system of characteristics that adequately describes the alternatives, values, and weights of the qualities [30],[34],[35]. Figure 1 depicts the COPRAS-G stages used in this study. COPRAS is a logical and systematic method that can handle the complicated and unstructured nature of vendor selection decisions as well as essentially multi-criteria problems in a real-time supply chain context [36].

With this approach, any problem may be thought of as a geometric system made up of *m* suppliers in an n-dimensional space, with each supply being evaluated according to *n* criteria. The following is a list of the COPRAS-G's steps [37] [38]:

Step-0: Obtaining the matrix of decision with grey number.

$$\otimes X = \begin{bmatrix} \otimes x_{11} & \cdots & \otimes x_{1n} \\ \vdots & \ddots & \vdots \\ \otimes x_{m1} & \cdots & \otimes x_{mn} \end{bmatrix} = \begin{bmatrix} [\underline{x}_{11}; \overline{x}_{11}] & \cdots & [\underline{x}_{1n}; \overline{x}_{1n}] \\ \vdots & \ddots & \vdots \\ [\underline{x}_{m1}; \overline{x}_{m1}] & \cdots & [\underline{x}_{mn}; \overline{x}_{mn}] \end{bmatrix} \quad (1)$$

Where $\otimes X$ is the matrix of decision and $\otimes x_{ij}$ is the grey number value obtained from the *i*-th supplier with the *j*-th criteria Notation $\overline{x}_{ij}$ is the highest value, and $\underline{x}_{ij}$ is the lowest value.

Step-1: Determining diagonal matrix of the criteria weights (significances of the criteria w_j) which result by AHP.

Step-2: Normalizing the decision-making matrix ($\otimes \check{X}$) using Eq. (2), (3), and (4).

$$\otimes \check{X} = \begin{bmatrix} [norm(\underline{x}_{11}); norm(\overline{x}_{11})] & \cdots & [norm(\underline{x}_{1n}); norm(\overline{x}_{1n})] \\ \vdots & \ddots & \vdots \\ [norm(\underline{x}_{m1}); norm(\overline{x}_{m1})] & \cdots & [norm(\underline{x}_{mn}); norm(\overline{x}_{mn})] \end{bmatrix} \quad (2)$$

Where:

$$norm(\overline{x}_{ij}) = \frac{\overline{x}_{ij}}{\frac{1}{2}[(\sum_{j=1}^{m} \overline{x}_{ij}) + (\sum_{j=1}^{m} \underline{x}_{ij})]}, \quad (3)$$

$$norm(\underline{x}_{ij}) = \frac{\underline{x}_{ij}}{\frac{1}{2}[(\sum_{j=1}^{m} \overline{x}_{ij}) + (\sum_{j=1}^{m} \underline{x}_{ij})]}, \quad (4)$$

Step-3: Weighting the normalized matrix ($\otimes \hat{\check{X}}$) using Eq. (5) and (6).

The weighting is done using an *n*n* diagonal matrix with the criteria weights, w_j, produced from the previous phase, as the major diagonal entries because the normalized matrix $\otimes \check{X}$ is of

$m*n$ dimension. The weighted normal matrix is then created by multiplying the diagonal weight matrix by the normal matrix:

$$\otimes\tilde{X} = \begin{bmatrix} \otimes n_{11} & \cdots & \otimes n_{1n} \\ \vdots & \ddots & \vdots \\ \otimes n_{m1} & \cdots & \otimes n_{mn} \end{bmatrix} * \begin{bmatrix} w_{11} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & w_{nn} \end{bmatrix}, \quad (5)$$

Where

$$\otimes n_{ij} = \left[norm(\underline{x}_{ij}), norm(\overline{x}_{ij})\right], \quad (6)$$

Step-3: Determining the sums P_i of the criterion values, whose larger values are more preferable by the Eq. (7).

$$P_i = \frac{1}{2}\sum_{j=1}^{k}\left[norm(\underline{x}_{ij})w_j + norm(\overline{x}_{ij})w_j\right] \qquad i = 1, 2, \dots, m \quad (7)$$

Step-4: Calculating the sums R_i of the criterion values, whose smaller values are more preferable by the Eq. (8).

$$R_i = \frac{1}{2}\sum_{j=k+1}^{n}\left[norm(\underline{x}_{ij})w_j + norm(\overline{x}_{ij})w_j\right] \qquad i = 1, 2, \dots, m \quad (8)$$

In Eq. (8), $(n - k)$ is the number of criteria which must be minimized.

Step-5: Calculating the relative significance of each supplier by Q_j using Eq. (9).

$$Q_i = P_i + \frac{\sum_{i=1}^{m} R_i}{R_i \sum_{i=1}^{m} \frac{1}{R_i}}, \quad (9)$$

Step-6: Calculating the utility degree (N_i) of each supplier using Eq. (10).

$$N_i = \frac{Q_i}{Q_{max}} x100\%, \quad (10)$$

Step-7: Ranking the supplier:

Finally, the options are ranked based on the N_i in descending order.

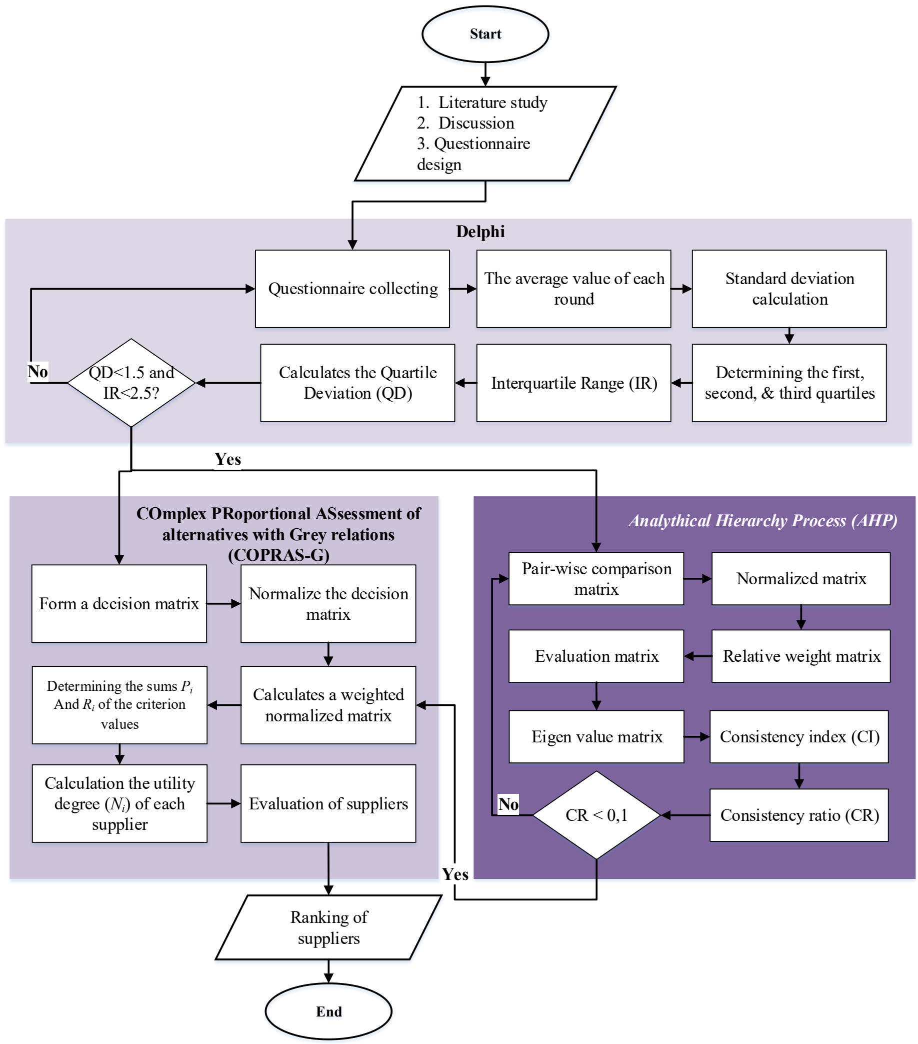

Fig. 1. Structure of the proposed method.

3 Research Findings and Disucussion

The first stage is called Delphi. Gathering important parameters for the firm is the aim of this step. At this stage, the submission of surveys was managed by knowledgeable specialists.

The input and results from the Delphi stages are presented in Tables 1 and 2. the criterion is evaluated using convergence. If the standard deviation and interquartile range are both smaller than 1.5 and 2.5, the instrument is considered to have converged. According to Table 2, there are seven factors taken into account when choosing a supplier: quality, delivery, pricing, communication, service, flexibility, and complaint method. Making pairwise comparisons between the seven criteria is the following stage. Decision makers from the company, who we regard as experts, compile tables of pairwise comparisons between criteria. This is demonstrated in Table 3. Using a pairwise comparison with AHP, the weight of the criteria was determined to be as given in the right-hand column of Table 3. Calculating the consistency ratio (CR) validates the proportional importance of these criteria. These computations' findings show that the consistency ratio is less than 0.1, hence it is deemed valid.

Table 1. Assessment of criteria.

No	Criteria	Assessment of criteria			Mean	Deviation standard
		Respondent 1	Respondent 2	Respondent 3		
1	Quality	5	5	5	5	0
2	Delivery	5	5	5	5	0
3	Price	5	4	3	3.915	0.580
4	Communication	5	4	4	4.309	0.469
5	Complaint procedure	3	4	3	3.302	0.334
6	Service	4	5	4	4.309	0.334
7	Flexibility	4	3	5	3.915	0.580

Table 2. Results of the Delphi stage.

first quartile	second quartile	third quartile	Interval of Range (IR)	Quartile Deviation
3.915	4.309	5	1.085	0.542566

Table 3. Pair wise comparison.

	Criteria	Criteria							
		Quality	Delivery	Price	Communication	Complaint procedure	Service	Flexibility	Weight
1	Quality		1.00	1.28	1.16	1.51	1.16	1.28	0.1681
2	Delivery	1.00		1.28	1.16	1.51	1.16	1.28	0.1681
3	Price	0.78	0.78		0.91	1.19	0.91	1.00	0.1316
4	Communication	0.86	0.86	1.10		1.30	1.00	1.10	0.1448

	Criteria	Criteria Quality	Delivery	Price	Communication	Complaint procedure	Service	Flexibility	Weight
5	Complaint procedure	0.66	0.66	0.84	0.77		0.77	0.84	0.1110
6	Service	0.86	0.86	1.10	1.00	1.30		1.10	0.1448
7	Flexibility	0.78	0.78	1.00	0.91	1.19	0.91		0.1316

The data needed by COPRAS-G for supplier evaluation is the evaluation of each supplier for each criterion. The first phase in the COPRAS-G process is this one. Using Eq. (1), the choice matrix can be produced. Table 4 contains the data's specifics. In accordance with the type of criterion, the data is split into two categories. The two sorts are non-benefit criteria (pricing, delivery, communication, service, flexibility, and complaint procedure) and benefit criteria (quality). The choice matrix will then be normalized using Equations (2), (3), and (4). The weight for each criterion (the result of the AHP) is then multiplied by this matrix using Eq. (5). The P_i sums of the criterion values, whose higher values are preferred by Eq. (7), comprise the third stage. Calculating the sums R_i of the criterion values, whose smaller values are preferred by Eq. (8), is the fourth step. The next step is to use Eqs. (9) and (10), to determine the relative importance and utility degree of each provider by Q_i. Tables 5, 6, and 7 show the specifics of each step's outcomes in more detail.

Table 4. Decision matrix.

No	Supplier	Criteria Quality	Delivery	Price	Communication	Complaint procedure	Service	Flexibility
1	Cianjur (min)	70	0	0	10	0	0	0
	Cianjur (max)	110	35	40	50	40	40	25
2	Kediri (min)	50	0	10	10	0	10	0
	Kediri (max)	90	40	50	50	40	50	40
3	Lumajang (min)	65	0	0	0	0	0	0
	Lumajang (max)	105	30	40	40	40	40	30
4	Cirebon (min)	60	0	20	5	0	10	15
	Cirebon (max)	100	35	60	45	40	50	55
5	Jombang (min)	40	10	10	10	0	20	25
	Jombang (max)	80	50	50	50	40	60	65
6	Wonogiri (min)	45	20	0	10	0	0	10

	Wonogiri (max)	85	60	40	50	40	30	50
7	Sidoarjo (min)	70	0	0	10	0	10	20
	Sidoarjo (max)	100	40	35	50	40	50	60
8	Rembang (min)	40	10	5	15	0	20	25
	Rembang (max)	80	50	45	55	40	60	65

Table 5. Decision matrix normalized.

No	Supplier	Criteria						
		Quality	Delivery	Price	Communi cation	Complaint procedure	Service	Flexibility
1	Cianjur (min)	0.118	0.000	0.000	0.043	0.000	0.000	0.000
	Cianjur (max)	0.185	0.184	0.198	0.217	0.250	0.178	0.103
2	Kediri (min)	0.084	0.000	0.049	0.043	0.000	0.044	0.000
	Kediri (max)	0.151	0.211	0.247	0.217	0.250	0.222	0.165
3	Lumajang (min)	0.109	0.000	0.000	0.000	0.000	0.000	0.000
	Lumajang (max)	0.176	0.158	0.198	0.174	0.250	0.178	0.124
4	Cirebon (min)	0.101	0.000	0.099	0.022	0.000	0.044	0.062
	Cirebon (max)	0.168	0.184	0.296	0.196	0.250	0.222	0.227
5	Jombang (min)	0.067	0.053	0.049	0.043	0.000	0.089	0.103
	Jombang (max)	0.134	0.263	0.247	0.217	0.250	0.267	0.268
6	Wonogiri (min)	0.076	0.105	0.000	0.043	0.000	0.000	0.041
	Wonogiri (max)	0.143	0.316	0.198	0.217	0.250	0.133	0.206
7	Sidoarjo (min)	0.118	0.000	0.000	0.043	0.000	0.044	0.082
	Sidoarjo (max)	0.168	0.211	0.173	0.217	0.250	0.222	0.247
8	Rembang (min)	0.067	0.053	0.025	0.065	0.000	0.089	0.103
	Rembang (max)	0.134	0.263	0.222	0.239	0.250	0.267	0.268

Table 6. Decision matrix weighted.

No	Supplier	Criteria						
		Quality	Delivery	Price	Communi cation	Complaint procedure	Service	Flexibility
1	Cianjur (min)	0.020	0.000	0.000	0.006	0.000	0.000	0.000
	Cianjur (max)	0.031	0.031	0.029	0.031	0.033	0.023	0.011
2	Kediri (min)	0.014	0.000	0.007	0.006	0.000	0.006	0.000
	Kediri (max)	0.025	0.035	0.036	0.031	0.033	0.029	0.018
3	Lumajang (min)	0.018	0.000	0.000	0.000	0.000	0.000	0.000
	Lumajang (max)	0.030	0.027	0.029	0.025	0.033	0.023	0.014
4	Cirebon (min)	0.017	0.000	0.014	0.003	0.000	0.006	0.007
	Cirebon (max)	0.028	0.031	0.043	0.028	0.033	0.029	0.025
5	Jombang (min)	0.011	0.009	0.007	0.006	0.000	0.012	0.011
	Jombang (max)	0.023	0.044	0.036	0.031	0.033	0.035	0.030
6	Wonogiri (min)	0.013	0.018	0.000	0.006	0.000	0.000	0.005
	Wonogiri (max)	0.024	0.053	0.029	0.031	0.033	0.018	0.023
7	Sidoarjo (min)	0.020	0.000	0.000	0.006	0.000	0.006	0.009
	Sidoarjo (max)	0.028	0.035	0.025	0.031	0.033	0.029	0.027
8	Rembang (min)	0.011	0.009	0.004	0.009	0.000	0.012	0.011
	Rembang (max)	0.023	0.044	0.032	0.035	0.033	0.035	0.030

Table 7. Evaluation of utility degree.

No	Supplier	R_j	P_j	$1/R_j$	Q_j	Q_{max}	N_j	Priority
1	Cianjur	0.083	0.025	12.11	0.153		93.25%	2
2	Kediri	0.101	0.020	9.88	0.123		75.48%	4
3	Lumajang	0.075	0.024	13.30	0.164		100.00%	1
4	Cirebon	0.110	0.023	9.10	0.118		72.21%	5
5	Jombang	0.127	0.017	7.85	0.099		60.74%	8
6	Wonogiri	0.108	0.018	9.30	0.116		70.88%	6
7	Sidoarjo	0.101	0.024	9.86	0.127		77.94%	3
8	Rembang	0.127	0.017	7.88	0.100		60.91%	7
		0.832	0.168	79.297	1.000	0.164		

To ensure that the results of the suggested model were accurate, a sensitivity study was done. A sensitivity analysis was performed due to potential changes. Results are subject to potential changes because human judgment directly affects them. For example, external factors like transportation costs or taxation laws can affect the weights of the criteria. This section does a sensitivity study to evaluate the robustness of the ranking technique. To do this, 4 situations are chosen, and the ranking is completed while taking the new weights into consideration. The cost criterion was determined to be the most significant one, thus we focused on it in this section. The price criterion weight is increased by 10% in each situation. Figures 3, 4, 5, and 6 show the graph with the results, where the left side shows the percentage weight of the criteria and the right side shows the weighted solutions for each case. Nevertheless, Fig. 2 depicts the currently investigated scenario using the current weights. The ranks of solutions are the same in all created scenarios, as seen by the numbers presented. Since the most crucial pricing criterion's weight cannot be changed by more than 40% without significantly changing the method's output, the findings of the performed proposed model process are therefore trustworthy enough to be used to a real circumstance.

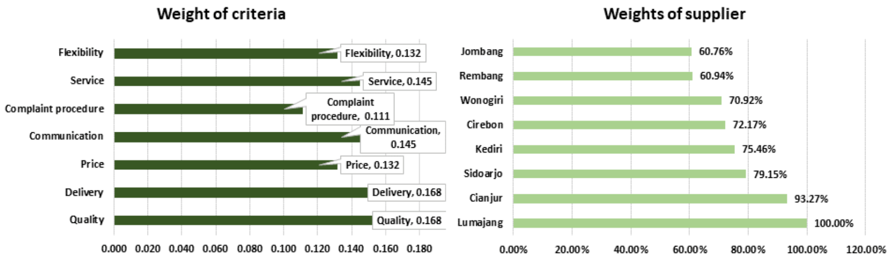

Fig. 2. Current scenario.

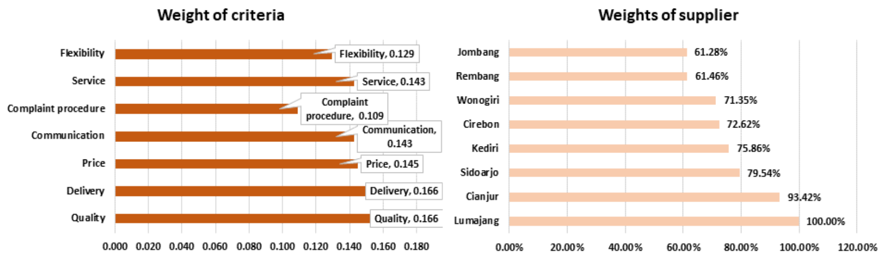

Fig. 3. Scenario 1.

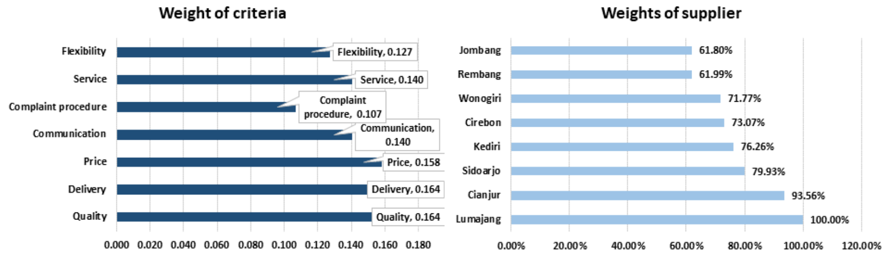

Fig. 4. Scenario 2.

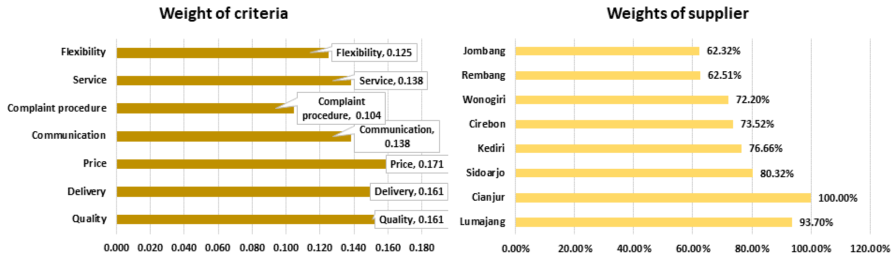

Fig. 5. Scenario 3.

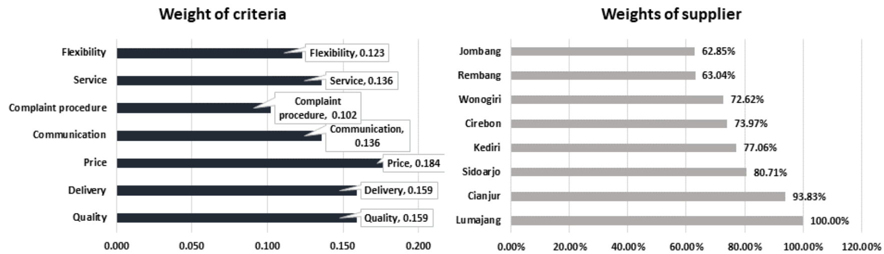

Fig. 6. Scenario 4.

4 Conclusion

Dynamic business environments help firms choose the finest suppliers, who are crucial to their success. The foundation of supply chain cooperation, which appears to be an MCDM issue comprising several tasks (evaluation criteria), is the supplier selection model. The MCDM method has been developed into a hybrid model in this study. The COPRAS-G method for performance evaluation and AHP for weighing seven evaluation factors make up the suggested model. The issue of choosing a supplier firm at the national level is the subject of research.

The suggested methodology can also serve as a guide for other overseas businesses choosing their suppliers effectively during the decision-making process. The best supplier for the leather industry has been confirmed based on the computed outcomes of the AHP and COPRAS-G methodologies. Applying calculation results, the following ranking was reached throughout the supplier selection process: Lumajang, Cianjur, Sidoarjo, Kediri, Cirebon, Wonogiri, Rembang, and Jombang. A sensitivity analysis was ultimately carried out to ascertain the implications of probable changes in the weights of the criteria on the ranks of the best solutions. The results demonstrated the validity of the proposed model and the robustness of the ranks to changes in the criterion weights.

5 Conflict of Interest

The authors declare no conflict of interest.

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