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A hybrid method of SWARA and ARAS for ranking of supplier: A case study at PT.Adi Satria Abadi (PT.ASA)

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ABSTRACT
The development of a suggested model for rating suppliers is the goal of this research. In this study, suppliers are rated and ranked using Additive Ratio Assessment (ARAS) and Stepwise Weight Assessment Ratio Analysis (SWARA). The suggested approach incorporates both objective and subjective criteria while applying Delphi to a subset of the criteria. To test the proposed model in a leather company for actual use, a case study is provided. The model can capture all objective and arbitrary criteria in the dynamics of the group of decision-makers when rating suppliers. To help in decision-making, this proposed model includes criteria selection. Because the results of the ranking of suppliers will depend on how accurately the criteria are chosen. The suggested approach produces a workable resolution because it is not sensitive to changes in the parameters.

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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 to guarantee that the items are produced by 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 to maintain a strategic competitive position [2]. One of the success criteria for the business is the supplier.

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 organization, 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, the delivery delays, and the product quality.

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 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 crucial in managing industry relations [6]. Each supplier has different advantages and disadvantages. Some suppliers have good quality criteria but are poor in other criteria. Some suppliers have good delivery criteria but are bad at other criteria. Likewise for other suppliers. No single supplier is superior in all criteria. To enhance business performance and lower PT ASA discontent, the company conducts an assessment to determine priority supplier selection. 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 Stepwise Weight Assessment Ratio Analysis (SWARA) is then used to weigh the variables, and the Additive Ratio Assessment (ARAS) is then used to choose the best supplier. 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. MATERIALS AND METHODS

2.1. Literature study

Zavadkas and Turskis [7] pioneered the ARAS method of supplier selection for the solid waste disposal sector. AHP is frequently utilized as an alternate weighting method when choosing suppliers [8]. As a result, in the process of developing it, the ARAS approach and modified AHP were integrated. Mavi [9] creates an AHP for weighting criteria in a fuzzy environment, then uses ARAS to choose green providers. Tamošaitiene et al. [10] utilize both AHP and ARAS to assess the suppliers of construction businesses. To evaluate watch suppliers, Liao et al [11] suggest new integrated fuzzy algorithms for the fuzzy AHP and fuzzy ARAS. Büyüközkan and Göçer [12] enhance the extended AHP-ARAS Methodology for supplier evaluation at airports in an interval-valued intuitionistic fuzzy environment. In order to identify the top caterers who adhere to airline requirements, Fu [13] combines the AHP with a type of performance evaluation that involves the determination of a utility level by ARAS and multi-choice goal programming (MCGP). In the research of Özdağoğlu et al. [14], the objective is to investigate the incorporation of techniques like the Hesitant Fuzzy Analytic Hierarchy Process (HF-AHP) and ARAS in the selection of vendors for water treatment facilities.

A method that is almost the same as AHP, but is said to be more efficient in evaluating criteria is Stepwise Weight Assessment Ratio Analysis (SWARA) [15]. Since this method is less difficult than AHP, it is not complicated [16]. When compared to the AHP approach, the SWARA method requires a great deal fewer pairwise comparisons and the SWARA method's computing process is also less complex [17]. The main feature of the SWARA method is the possibility to estimate experts or interest group's opinion about the significance ratio of the attributes in the process of their weights determination [18]. The SWARA approach can be applied to issues where a number of specified criteria have been determined based on the circumstance [18].

The SWARA method was only developed to determine the weight of each criterion used, so it is necessary to use other MCDM approach methods to determine alternative priority decisions [19]. So, in selecting suppliers, researchers combined SWARA with other MCDM methods. Alimardani et al. [20] proposed integrated SWARA and Vlse kriterijumska optimizacijai kompromisno resenje (Vikor) for agile supplier selection. Narayanan and Jinesh [21] introduce a new methodology for supplier selection comprising SWARA and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). In the context of supplier selection, this paper also explains how they might be used practically. While using Weighted Aggregated Sum Product Assessment (WASPAS) to assess various available options based on supplier selection indicators, Singh and Modgil [22] used SWARA to evaluate and weigh selection criteria. Tus and Aytac Adali [23] proposed a methodology that includes the combination of SWARA and Measurement Alternatives and Ranking according to the Compromise Solution (MARCOS) methods.

In previous studies, the company's decision-makers provided the factors that were taken into account. [24]. The majority of supplier selection research has not looked further into selection criteria, and those studies simply concentrate on methods for choosing alternative suppliers. [25]. An essential phase in the supplier selection process is the determination of criteria [26]. There are numerous techniques for choosing criteria, for more details, see Ristono et al. [25]. So, Yazdi et al. [27] select Critical Success Factors (CSFs) and utilize a conventional Delphi methodology to determine the partial supplier rankings utilizing Complex Proportional Assessment (COPRAS) utility functions along with SWARA-derived criteria weights for each CSF.

2.2. Proposed Method

This study develops Yazid et al. [27] research by replacing COPRAS with ARAS, because the computational procedure of the ARAS method is simpler compared to the computational procedures of some prominent MCDM methods such as TOPSIS, VIKOR, WASPAS, MARCOS, and COPRAS [16]. So, this study introduces a new methodology of the integration of Delphi, SWARA, and ARAS. In this research, the proposed model is divided into three stages (see Figure 1).

The first stage is criteria selection using Delphi. The benefit of Delphi is that the method focuses on group dynamics rather than statistical power to bring experts to an agreement, hence no explicit sample size criterion has been accepted in the literature [28]. Delphi's capability to mix quantitative and qualitative data provides an additional benefit. [29]. The ability to get expert opinions using an open questionnaire is the second benefit. [30]. 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 [30]. A consensus representing the aggregate expert opinion was obtained after several rounds of discussion [31]. In each round, experts can change their responses. Following exposure to the viewpoints of other specialists or to clarify perspectives, modifications may take place [32]. The process was assisted by someone outside the panel, frequently a researcher, and the comments went unreported by other experts. The Delphi stages used in this study can be seen in Figure 1, for more details, see Laupichler et al. [33] and Wahyuningsih et al. [3].

The second stage is weighting criteria using SWARA. The following steps can be used to accurately illustrate how the SWARA approach determines the relative weights of criteria [17]:

1. First step. Based on their anticipated significance, the criteria are arranged in descending order.
2. Second step. The answer specifies, for each specific criterion, the relative importance of criterion j with respect to the preceding (*j-1*) criterion starting with the second criterion. According to Kersuliene et al. [15], the Comparative Importance of Average Value is the name given to this ratio, s_j.
3. Step 3. Calculate the coefficient k_j as follows:

$$K_j = \begin{cases} 1 \;, & j = 1 \\ S_j + 1 \,, & j > 1 \end{cases} \tag{1}$$

4. Step 4. Determine the recalculated weight q_j as

$$q_j = \begin{cases} 1 \;, & j = 1 \\ \dfrac{q_{j-1}}{Kj} , & j > 1n \end{cases} \tag{2}$$

5. Step 5. The following is how the evaluation criteria's respective weights are determined:

$$W_j = \frac{q_j}{\sum_{k=1}^{n} q_k} \tag{3}$$

where w_j denotes the relative weight of criterion *j*.

In this study, ARAS is used for supplier selection. The utility value function, which is an advantage of the ARAS technique, determines the relative effectiveness of workable alternatives in direct proportion to the importance and weight of the criteria taken into account [34]. The ARAS stages used in this research can be seen in Figure 1, for more details, see Zavadskas et al. [34] and Zavadskas et al. [35].

In the evaluation of every supplier for every criterion makes up the information needed by ARAS. The initial step of ARAS is to form the decision matrix by using Eq. (4) [34]. The next step is to normalize the decision matrix using Eq. (5) for the criteria of benefits and Eq. (6) for the criteria of non-benefits, and then multiplied by the weight for each criterion (output from SWARA) using Eq. (7) [35]. The optimality function (S_i) value will be determined by adding these values for each criterion (see Eq. (8)). The degree of utility is the basis for supplier evaluation. This utility's level is determined by dividing its value by the ideal optimality function for each supplier [34,35].

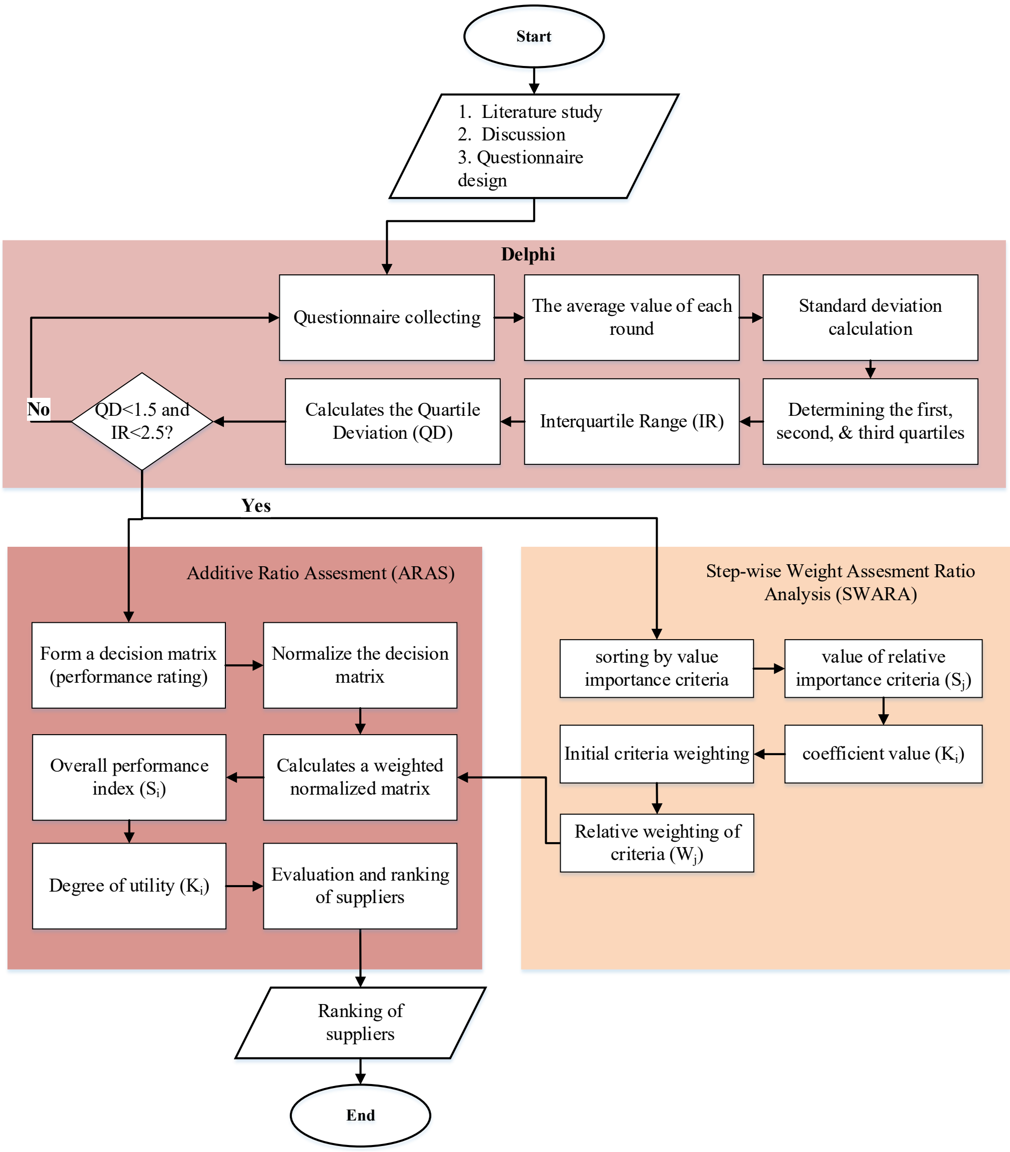

Figure 1 The proposed model

$$X_{ij} = \begin{bmatrix} x_{01} & \cdots & x_{0n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} ;i=1\ldots m;j=1\ldots n \quad (4)$$

$$\bar{x}_{ij} = \frac{x_{ij}}{\sum_{i=0}^{m} x_{ij}} \quad (5)$$

$$x_{ij}^{*} = \frac{1}{x_{ij}};\bar{x}_{ij} = \frac{x_{ij}^{*}}{\sum_{i=0}^{m} x_{ij}} \quad (6)$$

$$\hat{x}_{ij} = \bar{x}_{ij}.w_j;i=1\ldots m;j=1\ldots \quad (7)$$

$$S_i = \sum_{j=1}^{n} \hat{x}_{ij};i=1\ldots m \quad (8)$$

3. RESULTS

Delphi is the initial phase. The objective of this stage is to collect crucial criteria for the business. Competent experts handled the submission of questionnaires at this point. designed. The specific criteria based on a 9-point Likert scale were used to rate the alternatives (suppliers) in the questionnaire. Table 1 and Table 2 provide the input and outcomes from the Delphi stages. Assessment of the criteria using convergence. The instrument is said to converge if the standard deviation is < 1.5 and the interquartile range is < 2.5. According to Table 2, supplier selection is based on seven factors: quality, delivery, price, communication, complaint procedure, service, and flexibility. There were three experts used in this research. They are the raw material procurement manager, production manager, and warehouse manager. All of these managers have worked in similar companies for more than 20 years. So the answers given by them are considered valid.

Getting expert preferences is the next phase, after which the average expert judgments are calculated. Sort the criteria from most important to least important. The decision-maker's preferences for the second most important criterion are given because the preference indicator for the first criterion is 0. Up until the least significant condition is reached, this process is repeated. These preferences are based on a pairwise comparison between this particular criterion and the first criterion, with the ratio of this comparison denoted by S_j, which is computed. Establish pairwise efficiency criteria K_j Using Eq. (1). Pairwise refers to the comparison of each element's relevance to the first and most significant factor. Create relative weights (q_j) based on the significance criterion ranking's sorted pairwise efficiency using equation (2), and then use equation (3) to create final weights (W_j). Table 3 displays the SWARA results.

In the stage is supplier evaluation using ARAS. In this method, the decision matrix to be formed by using Eq. (4) and then to be normalized using Eq. (5) for the criteria of benefits and Eq. (6) for the criteria of non-benefits. The weighting criterion matrix from SWARA is multiplied by normalized matrix using Eq. (7), and then calculate the optimality function (S_i) value using Eq. (8). The results for each step in the ARAS stage can be seen in Table 4, Table 5, Table 6, Table 7, Table 8, and Table 9.

Table 1 Assessment of criteria

No	**Criteria**	**Respondent**			**Mean**	**Deviation standard**
		1	**2**	**3**		
1	Quality	5	5	5	5	0
2	Delivery	5	5	5	5	0
3	Price	5	4	3	3.92	0.580
4	Communication	5	4	4	4.31	0.469
5	Complaint procedure	3	4	3	3.30	0.334
6	Service	4	5	4	4.31	0.334
7	Flexibility	4	3	5	3.96	0.580

Table 2 Assessment of criteria

No	**Criteria**	**Respondent**			**Mean**	**Deviation standard**
		1	**2**	**3**		
1	Quality	5	5	5	5	0
2	Delivery	5	5	5	5	0
3	Price	5	4	3	3.92	0.580
4	Communication	5	4	4	4.31	0.469
5	Complaint procedure	3	4	3	3.30	0.334
6	Service	4	5	4	4.31	0.334
7	Flexibility	4	3	5	3.96	0.580

Table 3 Results of the weighting criteria stage

No	Criteria	Mean	Rating	Relative value of interest level (S_j)	Coefisien of criteria (K_j)	Initial weighting (q_j)	Final weighting of criteria (W_j)
1	Quality	5.00	1.00		1.00	1.00	0.28
2	Delivery	5.00	1.00		1.00	1.00	0.28

No	Criteria	Mean	Rating	Relative value of interest level (S_j)	Coefisien of criteria (K_j)	Initial weighting (q_j)	Final weighting of criteria (W_j)
3	Price	4.31	2.00	0.88	1.88	0.53	0.15
4	Communication	4.31	2.00	0.88	1.88	0.53	0.15
5	Complaint procedure	3.92	3.00	1.31	2.31	0.23	0.06
6	Service	3.92	3.00	1.31	2.31	0.23	0.06
7	Flexibility	3.30	4.00	1.75	2.75	0.08	0.02

Table 4 Decision matrix

No	Supplier	Quality	Delivery	Price	Commu nication	Complaint procedure	Service	Flexibility
1	Cianjur	90	85	80	70	80	80	95
2	Kediri	70	80	70	70	80	70	80
3	Lumajang	85	90	80	80	80	80	90
4	Cirebon	80	85	60	75	80	70	65
5	Jombang	60	70	70	70	80	60	55
6	Wonogiri	65	60	80	70	80	90	70
7	Sidoarjo	90	80	85	70	80	70	60
8	Rembang	60	70	75	65	80	60	55

Table 5 Decision matrix normlized

No	Supplier	Quality	Delivery	Price	Commu nication	Complaint procedure	Service	Flexibility
1	Cianjur	0.13	0.13	0.12	0.12	0.11	0.13	0.14
2	Kediri	0.13	0.12	0.12	0.11	0.11	0.12	0.14
3	Lumajang	0.10	0.11	0.10	0.11	0.11	0.10	0.12
4	Cirebon	0.12	0.13	0.12	0.12	0.11	0.12	0.14
5	Jombang	0.12	0.12	0.09	0.12	0.11	0.10	0.10
6	Wonogiri	0.09	0.10	0.10	0.11	0.11	0.09	0.08
7	Sidoarjo	0.09	0.08	0.12	0.11	0.11	0.13	0.11
8	Rembang	0.13	0.11	0.12	0.11	0.11	0.10	0.09

Table 6 Decision matrix weighted

No	Supplier	Quality	Delivery	Price	Commu nication	Complaint procedure	Service	Flexibility
1	Cianjur	0.04	0.04	0.02	0.02	0.01	0.01	0.00
2	Kediri	0.04	0.03	0.02	0.02	0.01	0.01	0.00
3	Lumajang	0.03	0.03	0.02	0.02	0.01	0.01	0.00
4	Cirebon	0.03	0.04	0.02	0.02	0.01	0.01	0.00
5	Jombang	0.03	0.03	0.01	0.02	0.01	0.01	0.00
6	Wonogiri	0.02	0.03	0.02	0.02	0.01	0.01	0.00
7	Sidoarjo	0.03	0.02	0.02	0.02	0.01	0.01	0.00
8	Rembang	0.04	0.03	0.02	0.02	0.01	0.01	0.00

Table 7 Overall Performance Index (S_i)

No	Cianjur	Kediri	Lumajang	Cirebon	Jombang	Wonogiri	Sidoarjo	Rembang
S_i	0.12	0.11	0.12	0.11	0.97	0.10	0.11	0.01

Table 8 Utility index (K_i)

No	Cianjur	Kediri	Lumajang	Cirebon	Jombang	Wonogiri	Sidoarjo	Rembang
K_i	0.95	0.84	0.97	0.88	0.77	0.80	0.93	0.77

Table 9 Ranking of suppliers (R_i)

No	Lumajang	Cianjur	Sidoarjo	Cirebon	Kediri	Wonogiri	Jombang	Rembang
R_i	1	2	3	4	5	6	7	8

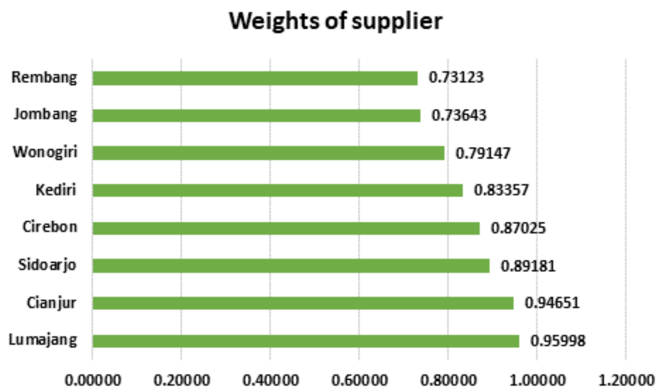

Figure 2 Ranking of supplier in the current scenario

4. DISCUSSION

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. Figure 3, Figure 4, Figure 5, and Figure 6 show the graph with the results. Nevertheless, Figure 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.

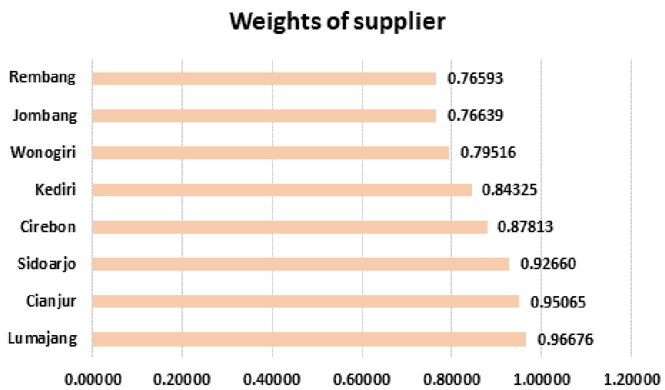

Figure 3 Ranking of supplier in scenario 1

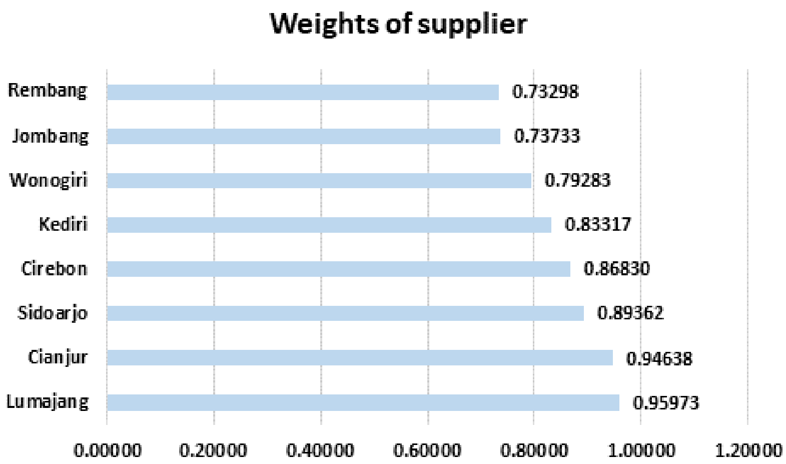

Figure 4 Ranking of supplier in scenario 2

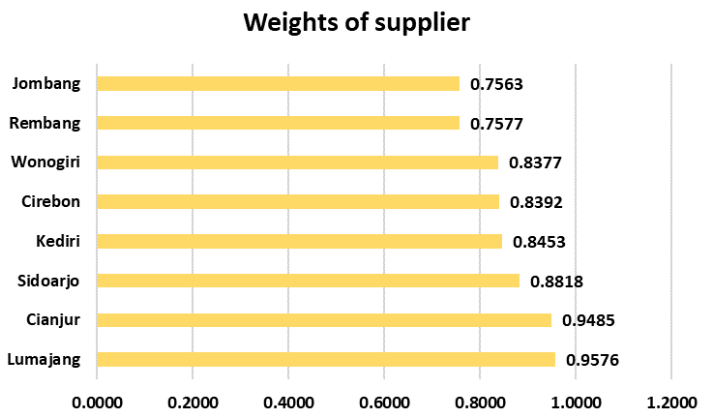

Figure 5 Ranking of supplier in scenario 3

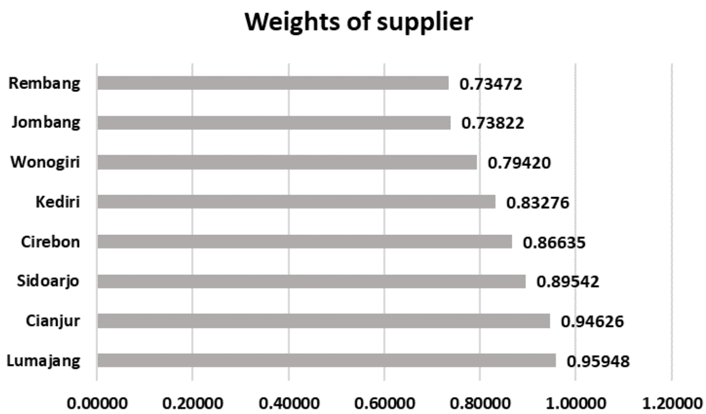

Figure 6 Ranking of supplier in scenario 4

5. CONCLUSION

Evaluation of raw material suppliers for PT. ASA uses Delphi, AHP, and ARAS integration to produce supplier rankings. The supplier rankings are Lumajang, Cianjur, Sidoarjo, Cirebon, Kediri, Wonogiri, Jombang, and Rembang. Based on sensitivity analysis, the results of the Delphi, AHP, and ARAS integration models are not sensitive to changes in criteria weights. So the proposed model is considered valid.

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