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Supplier's selection of plate material using analytical hierarchy process and additive ratio assessment methods

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ABSTRACT

PT PAL Indonesia (PERSERO) is among the prominent shipyard companies in Indonesia that currently employs a simplistic supplier selection weighting system, prioritizing low prices and material specification conformity. This approach often leads to subjective assessments, making it challenging for the company to identify suitable suppliers from a large pool. Therefore, this study proposed a methodology to enhance supplier selection by incorporating additional criteria based on Dickson's criteria and company policies. The Analytical Hierarchy Process (AHP) and Additive Ratio Assessment (ARAS) methods were utilized for this purpose. The findings indicate that PT Krakatau Steel (A1) emerges as the top-ranked supplier with a Ki value of 0.19, followed by PT Diansakti Sejahtera (A5) in second place with a Ki value of 0.157, and PT Gunawan Dianjaya Steel (A3) in third place with a Ki value of 0.152. PT Jastindo Raya (A4) secures the fourth position with a Ki value of 0.151, while PT Gunung Raja Paksi (A2) takes the fifth and final spot with a Ki value of 0.15. This research helps the company effectively select the best suppliers, particularly in the procurement sector, by employing the AHP-ARAS method and considering Dickson's criteria, thereby addressing existing gaps the company encounters.

INTRODUCTION

A manufacturing company's success and growth depend on strategic choices, effective management, resource selection, and optimizing various aspects to achieve excellence [1]. Among these aspects, material procurement is crucial for supporting production processes and maintaining business goals. It falls under supply chain management, which involves managing relationships within the company and with external entities, including suppliers [2]. Supply chain management covers the company's logistics activities [3]. The procurement process encompasses identifying, sourcing, and managing materials to ensure high-quality supplies for the company's operations [4].

Suppliers play a pivotal role in providing essential goods to the company [5]. Even a highly efficient company becomes ineffective if its suppliers fail to deliver quality materials or meet agreed-upon delivery schedules [6]. Thus, selecting the best supplier is critical, and the selection criteria play a central role in this process [7]. Selection of supplier criteria is one of the efforts made by companies to cooperate with other companies by evaluating and then choosing the best supplier [8]. Dickson identified twenty supplier selection criteria, which companies tailor based on their raw material requirements and policies. An effective supply chain demands that suppliers meet all evaluation criteria, not excelling in just one aspect [9].

PT PAL Indonesia (PERSERO), a prominent shipbuilding company, relies heavily on plate materials for ship construction and maintenance. To ensure the procurement of high-quality materials and enhance performance, PT PAL Indonesia (PERSERO) seeks to improve its supplier selection process. Presently, the focus on low prices and material relevance has resulted in subjective assessments. With an increasing number of suppliers interested in supplying plates to the company, these criteria are becoming less practical. Thus, there is a need to adopt a supplier selection method that aligns with both Dickson's criteria and company policies [10], as a flawed selection process may lead to losses and customer dissatisfaction [11].

In this study, supplier evaluation employed the Multiple Criteria Decision Method (MCDM), a decision-making technique widely used in various industries [12]. The MCDM technique is widely used in the industrial world [13], [14]. MCDM can be applied in various fields, such as in the business and financial sector [15], environmental management [16], and supplier selection [17]. Many decision support methods can be implemented for selecting the best supplier [18], [19]. The specific methodology chosen for selecting plate material suppliers combines two techniques: AHP (Analytical Hierarchy Process) and ARAS (Additive Ratio Assessment). AHP is a decision support model that organizes complex multi-objective problems hierarchically [20]. On the other hand, ARAS is a method based on utility degree ratings, comparing total index values of alternatives to their optimal values [21]. This data-driven approach allows for quantitative ranking based on each criterion's weight [22]. By integrating AHP-ARAS methodology, PT PAL Indonesia (PERSERO) aims to enhance its supplier selection process, ensuring the acquisition of quality materials from reliable suppliers, and maintaining a competitive edge in the market.

Integration of AHP and Additive Ratio Assessment (ARAS) methods has been carried out by many previous researchers, for example, a research conducted by Yilmas *et al.* in selecting suppliers for water treatment facilities [23] and research by Fu on determining catering suppliers the best airline [24]. However, the focus of this study was solely on selecting the best supplier according to the criteria outlined in the company policy, with little consideration given to other influential factors that were not utilized by the company.

The primary contribution of this research is a novel approach which more efficient, and accurate methods for supplier selection, particularly in the procurement sector. This has been achieved through the application of the AHP-ARAS method, while also taking into account Dickson's criteria to address any existing gaps faced by companies. Moreover, these methods aim to aid suppliers in continually enhancing their quality standards, ensuring a consistent supply of materials to the company.

The main objective of this study is to identify the best plate material suppliers by incorporating additional criteria based on both Dickson's principles and company policies. By doing so, it endeavors to enhance the supplier selection process and optimize the procurement practices within the organization.

METHOD

The study was conducted at PT PAL Indonesia (PERSERO) located in the city of Surabaya. The research aims to identify and analyze the research variables, encompassing both dependent and independent variables. The dependent variable in this study is the best plate material supplier, whereas the independent variable is the set of supplier selection

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criteria. These criteria were derived from the combination of Dickson's principles and company policies and objectives. As a result, six criteria were established: Quality (C1), Past Performance (C2), Price (C3), Financial Condition (C4), Procedure Fulfillment (C5), and Reputation & Position in Industry (C6). For a visual representation of the research process, refer to Figure 1, which illustrates the research flowchart.

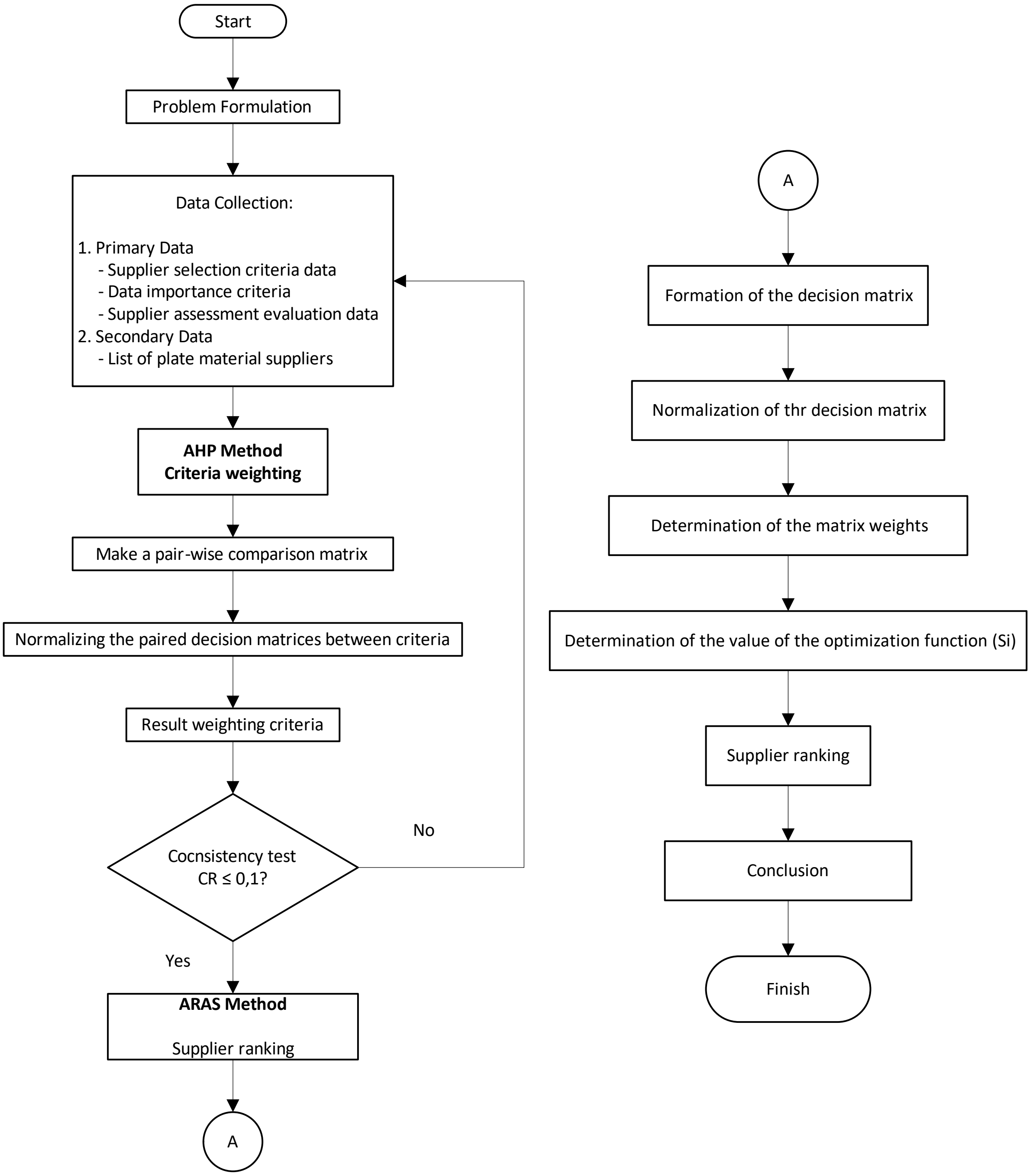

Figure 1. Research method flowchart

The research employs the AHP (Analytic Hierarchy Process) and ARAS (Additive Ratio Assessment) methodologies for the supplier selection process. AHP is utilized to determine the weight of each criterion, ensuring a systematic calculation of their relative importance. Once the criterion weights are obtained and data validity is confirmed, the ARAS method is applied to evaluate and rank supplier performance [25]. This ranking approach is particularly suitable as it involves comparing the utility degree of each alternative's optimal value against the total value of all alternatives, thus facilitating the selection of the best plate material suppliers based on their respective criterion weights [26]. These methodologies collectively support companies in making informed and objective decisions in supplier selection.

RESULTS AND DISCUSSION

1. Data Collection

Data collection was taken based on company documents, interview results, and distributing questionnaires at PT PAL Indonesia (PERSERO). The data used in this study are as follows:

a. Supplier's list of plate materials

At PT PAL Indonesia (PERSERO), five plate suppliers are alternatives in selecting the best supplier which is shown in Table 1.

Table 1. List of plate material suppliers

Plate Material Suppliers	Code
PT Krakatau Steel (A1)	A1
PT Gunung Raja Paksi (A2)	A2
PT Gunawan Dianjaya Steel (A3)	A3
PT Jastindo Raya (A4)	A4
PT Diansakti Sejahtera (A5)	A5

The current company policy selects the number of suppliers and maintains the best supplier. The results of ranking the best suppliers that have been obtained include all multi-criteria in terms of quality, past performance, price, financial condition, compliance with procedures, and supplier reputation.

b. Criteria Importance Level Data

This data was acquired through a questionnaire on the level of importance of the criteria, the results of which are numbers 1 to 9 based on the Analytical Hierarchy Process (AHP) method's pairwise comparison scale [27]. Respondents in this study were departments related to plate material procurement procedures. Table 2 presents the pairwise comparison scale.

Table 2. Paired comparison scale

Interest of Intensity	Information
1	Equal Importance
2	Weak or very little is more important
3	One element is slightly more critical (moderate importance)
4	A little more important
5	substantial importance (substantial importance)
6	Stronger
7	Extreme importance
8	Very strong
9	Absolute essential (extreme importance)

c. Supplier Assessment Evaluation Data

This data is derived from the supplier assessment questionnaire findings, which are presented as numbers ranging from 1 to 5 on a Likert scale of supplier assessment. Scale 1 represents the inferior performance of suppliers; scale 2 represents the poor performance of suppliers; scale 3 represents the moderately good performance of suppliers; scale 4

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represents the proper performance of suppliers; and scale 5 represents the extraordinary performance of suppliers [28].

2. Criterion Weighting

AHP method is employed to weight criteria. Hierarchy is defined as presenting a complex problem at a certain level. The first level is the target, the second is the criteria used, and the final is the alternative [29], [25]. The first level has a research objective: the best plate material supplier. The second level is the criteria used in supplier selection. Furthermore, the third or last level in the hierarchy is the alternative supplier that will be selected. Data processing begins with calculating the geometric mean of the results of the criteria interest questionnaire. This happens because AHP only requires one answer in the pairwise comparison matrix. Each number is multiplied to obtain the geometric mean, which is then raised to the power of 1/n. [30]. Then form a paired decision matrix between criteria based on geometric mean calculations according to Table 3.

Table 3. Criteria pairwise comparison matrix

	C1	C2	C3	C4	C5	C6
C1	1	4	5	6	8	7
C2	1/4	1	1	1	1	1
C3	1/5	1	1	2	2	2
C4	1/6	1	1/2	1	1	2
C5	1/8	1	1/2	1	1	4
C6	1/7	1	1/2	1/2	1/4	1

Based on the matrix in Table 3, pairwise comparisons are obtained in assessing each criterion. These criteria have a scale value of 1 to 9 with different levels of importance, as described in Table 2. For the opposite criterion, comparing the second criterion is more important than the first criterion [31].

The next step is to normalize the decision matrix with the value of each matrix column divided by the number of each row matrix column value used [32]. The formula is shown in Equation (1). Then, the results of this calculation is presented in Table 4.

$$\bar{X}ij = \frac{xij}{\sum_{i=0} xij} \quad (1)$$

where
$\bar{X}ij$: Normalized matrix values
Xij : Matrix value row i column j
$\sum_{i=0} xij$: The number of column values in the matrix

Table 4. Normalized pairwise comparison matrices between criteria

	C1	C2	C3	C4	C5	C6
C1	0.531	0.444	0.588	0.522	0.604	0.412
C2	0.133	0.111	0.118	0.087	0.075	0.059
C3	0.106	0.111	0.118	0.174	0.151	0.118
C4	0.088	0.111	0.059	0.087	0.075	0.118
C5	0.066	0.111	0.059	0.087	0.075	0.235
C6	0.076	0.111	0.059	0.043	0.019	0.059

The average of each normalized matrix row is gotten by dividing the total number of the criteria (n = 6) by the total of all the criteria rows. This yields the weight of each criterion [33]. Then, the results of weights for each criterion are presented in Table 5.

$$C1 = \frac{C1 - C1 + C1 - C2 + C1 - C3 + C1 - C4 + C1 - C5 + C1 - C6}{6} \quad (2)$$

Table 5. Weight of each criterion

Criteria	Weight
C1	0.517
C2	0.097
C3	0.13
C4	0.09
C5	0.106
C6	0.061

Based on Table 5, it is found that the quality criterion (C1) has the highest weight, namely 0.517. The quality criterion (C1) significantly determines the best plate material supplier. The criteria that have a significant influence on both prices (C3), followed by criteria for compliance with procedures (C5), past performance (C2), financial condition (C4), and reputation and position in the industry (C6).

3. Consistency Test

The consistency test determines whether the comparison questionnaire data between the criteria processed is consistent and whether the calculation results can be declared correct if the consistency ratio value is ≤ 0.1. Collecting and re-calculating data is necessary if the consistency value exceeds 0.1 [34]. The first step of the consistency test is to determine the eigenvalues of the vectors. The eigenvector is calculated by multiplying the pairwise comparison matrix with the average value of the sum of each row in the matrix in Table 5.

$$\begin{bmatrix} 1 & 4 & 5 & 6 & 8 & 7 \\ 0.25 & 1 & 1 & 1 & 1 & 1 \\ 0.2 & 1 & 1 & 2 & 2 & 2 \\ 0.17 & 1 & 0.5 & 1 & 1 & 2 \\ 0.13 & 1 & 0.5 & 1 & 1 & 4 \\ 0.14 & 1 & 0.5 & 0.5 & 0.25 & 1 \end{bmatrix} \text{x} \begin{bmatrix} 0.517 \\ 0.097 \\ 0.13 \\ 0.09 \\ 0.106 \\ 0.061 \end{bmatrix} = \begin{bmatrix} 3,3649 \\ 0.6124 \\ 0.8431 \\ 0.5657 \\ 0.6665 \\ 0.3682 \end{bmatrix}$$

After getting the eigenvector values for each criterion, the next step is calculating the consistency ratio. The consistency ratio requires the consistency index (CI) and maximum eigenvalue (λ max). The eigenvalues are used to assess the consistency of the matrix itself. Thomas L. Saaty demonstrates how to calculate the maximum eigenvalue (λ max) and consistency index of an ordered matrix [35] using the formula as shown in Equation (3) and Equation (4).

$$\lambda \text{ max} = \frac{\Sigma(\frac{Wij}{\Sigma wj})}{n} \quad (3)$$

where:
λ max : Eigen value
Wij : Eigenvector column cell value (I, j = 1, …..,n)
Wj : Average the sum of each row of the matrix
n : The total number of matrices compared

$$\text{CI} = \frac{\lambda \text{ max} - \text{n}}{\text{n} - 1} \quad (4)$$

where:
CI : Consistency Index
λ max : Eigenvalue
n : The total number of matrices compared

Based on Equation (3) and Equation (4) obtained, the maximum value (λ max) that could be calculated was 6.3262, and the Consistency Index (CI) was 0.06524. The pairwise comparison matrix appears consistent if the consistency ratio is 0. According to Thomas L. Saaty, the consistency ratio (CR) determines the inconsistency limit. The consistency ratio compares random index values (RI) to consistency index values (CI). The random index value is affected by the order of the n matrix[36]. Thus, the Consistency Ratio can be formulated in Equation (5).

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$$CR = \frac{CI}{RI} \quad (5)$$

where:
CR : Consistency Ratio
CI : Consistency Index
RI : Random Index (n=6)

Based on the division of the random index (RI) value for n = 6 and the consistency index value. Consequently, the consistency ratio (CR) value is 0.05262. Because of the value of CR = 0.05262 ≤ 0.1. So, it can be said that the comparison data between criteria is consistent and meets the requirements.

4. Supplier Ranking

Supplier ranking employs ARAS method. This method uses the utility value (Ki) with the most significant value to get the best plate material supplier [37]. The first step in this process is creating a decision matrix based on the answers to the supplier evaluation questionnaire. The optimum number for each criterion is five at the top row of the decision matrix (A0) [25]. The matrix is then normalized by splitting the value of each column by the total number of rows, which is the column matrix's value [38]. The supplier evaluation decision matrix and the normalization of the supplier assessment matrix are shown in Table 6 and Table 7, respectively.

Table 6. Supplier evaluation decision matrix

	C1	C2	C3	C4	C5	C6
A0	5	5	5	5	5	5
A1	5	5	4	4	5	5
A2	4	4	3	3	4	4
A3	4	3	4	3	4	4
A4	4	4	3	4	4	3
A5	4	4	4	4	4	3

Table 7. Normalization of the supplier assessment matrix

	C1	C2	C3	C4	C5	C6
A0	0.192	0.200	0.217	0.217	0.192	0.208
A1	0.192	0.200	0.174	0.174	0.192	0.208
A2	0.154	0.160	0.130	0.130	0.154	0.167
A3	0.154	0.120	0.174	0.130	0.154	0.167
A4	0.154	0.160	0.130	0.174	0.154	0.125
A5	0.154	0.160	0.174	0.174	0.154	0.125

The normalized matrix weight values (as shown in Table 8) are then obtained by multiplying the normalized decision matrix components by the part of the criteria weights obtained using the AHP [39] in Equation 6.

$$D = [d_{ij}]_{mXn} = \bar{X}_{ij} . w_j \quad (6)$$

where:
D : Matrix weight values
$\bar{X}_{ij}$: Normalized Matrix Value
Wj : Criteria weight value

Table 8. Matrix weighting results

	C1	C2	C3	C4	C5	C6
A0	0.099	0.019	0.028	0.020	0.020	0.013
A1	0.099	0.019	0.023	0.016	0.020	0.013
A2	0.080	0.016	0.017	0.012	0.016	0.010
A3	0.080	0.012	0.023	0.012	0.016	0.010
A4	0.080	0.016	0.017	0.016	0.016	0.008
A5	0.080	0.016	0.023	0.016	0.016	0.008

The value of the optimization function (Si) in Table 9 below is generated by totaling the weighted normalized decision matrix elements for each available alternative and is then determined. The greater the value of the Si-optimized function, the more influential the alternative will be. The formula is shown in Equation 7.

$$Si = \sum_{j=1}^{n} dij : (I = 1, 2,.., m: j = 1, 2,\ldots,n) \quad (7)$$

where:
Si : Optimization function value
Dij : The weight in the ith row and the jth column

Table 9. Optimization function value results (Si)

Supplier	Si
A0	0.2
A1	0.19
A2	0.15
A3	0.152
A4	0.151
A5	0.157
TOTAL	**1**

Determination of supplier ranking (see Figure 2) is obtained based on the value of the utility degree. The Utility Degree is computed by splitting the optimized function's value for each ith alternative by the highest-performing option's overall index value [40]. The formula is presented in Equation 8.

$$Ki = \frac{Si}{So} \quad (8)$$

Information:
Ki : Utility Degree
Si : Optimization function value
So : The sum of the optimization function values

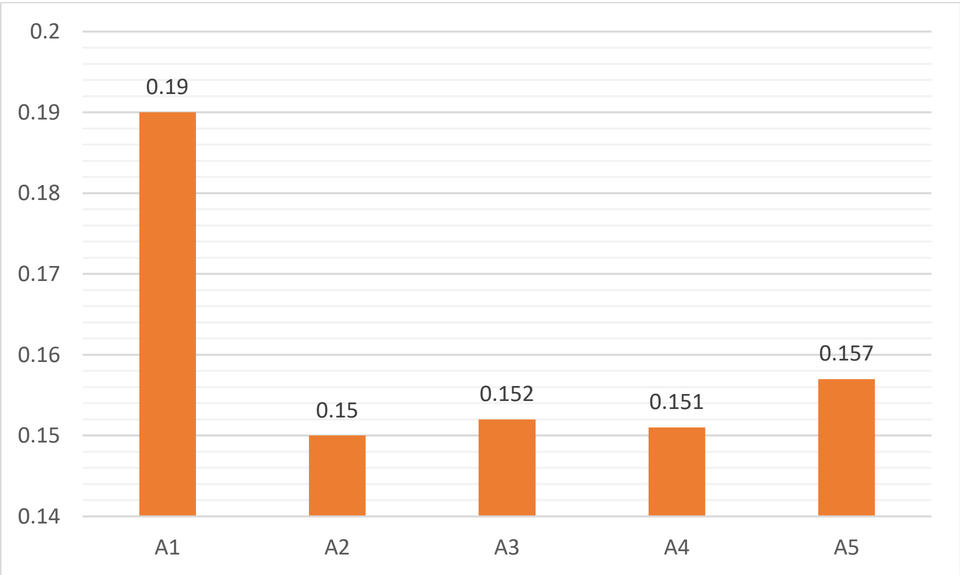

Figure 2. Calculation results of Ki

The ranking order of plate material suppliers was determined based on the calculated utility degree results mentioned earlier. The magnitude of the utility degree (Ki) value determines the supplier's position in the ranking. This approach draws inspiration from the research conducted by Ghram and Frikha [40], who used a hierarchical four-level system to rank websites of tourist destination brands.

Accordingly, the first rank was assigned to PT Krakatau Steel (A1), with a value of 0.19. PT Diansakti Sejahtera (A5) secured the second rank with a value of 0.157, followed by PT

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Gunawan Dianjaya Steel (A3) in the third rank with a value of 0.152, and PT Jastindo Raya (A4) in the fourth rank with a value of 0.151. PT Gunung Raja Paksi (A2) attained the fifth and final rank with a value of 0.15. Upon evaluating the plate material suppliers based on the data presented in Table 10, it was evident that PT Krakatau Steel emerged as the top supplier after incorporating the new criteria. Surprisingly, according to the company's previous data using the old criteria, PT Krakatau Steel ranked second. This shift in position can be attributed to the consistent evaluation of PT Krakatau Steel across all six criteria, resulting in the highest utility degree value and ultimately securing its position as the best supplier.

Furthermore, PT Krakatau Steel's exceptional performance in the quality criteria significantly contributed to its top ranking. This supplier outperformed its competitors, especially in terms of meeting quality standards. Notably, the weight assigned to the quality criteria was the highest among all the criteria, reinforcing PT Krakatau Steel's dominance in this aspect. The company's satisfaction with the quality of plates supplied by PT Krakatau Steel further substantiates its position as the top supplier. In conclusion, PT Krakatau Steel's outstanding overall performance and its ability to meet the newly added criteria have solidified its status as the best plate material supplier, surpassing other contenders in the ranking.

CONCLUSION

The supplier rankings were determined in descending order using the Analytical Hierarchy Process (AHP) and Additive Ratio Assessment (ARAS) for data analysis. PT Krakatau Steel (A1) secured the highest rank with a Ki value of 0.19, followed by PT Diansakti Sejahtera (A5) in second place with a Ki value of 0.157. PT Gunawan Dianjaya Steel (A3) attained the third rank with a Ki value of 0.152, while PT Jastindo Raya (A4) secured the fourth rank with a Ki value of 0.151. Finally, PT Gunung Raja Paksi (A2) claimed the fifth and final rank with a Ki value of 0.15. Implementing alternative decision-making methods in subsequent supplier assessments can further enhance the objectivity of selecting the best plate material supplier.

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